NIOSH Mining Program Briefing Book
Executive Summary

Mining provides a large part of the energy and raw materials that feed this nation's economy. Copper pipe, concrete, and window glass serve as well-known examples of the reliance on minerals in modern society. Less appreciated, but as important, are the hundreds of mined commodities that are an integral and necessary part of everyday products, ranging from medicines and computers to carpet and paper. Coal is a major portion of the country's energy mix today, as it will likely continue to be in a future hydrogen-based economy. The domestic mining industry also provides strategic minerals that are important for the nation's security.

The processes to recover these mineral commodities are among the most demanding and complex in an industrial society, and historically this inherently dangerous industry has had the highest risks of fatality and injury. Our vision is to deliver on the nation's promise of safety and health at work for all people through research and prevention, and our mission is to eliminate occupational diseases, injuries, and fatalities from the mining workplace through a focused program of research and prevention. Our progress towards achieving our vision and fulfilling our mission is a major component of this review being conducted by the National Academy of Science.

The information compiled in this book tells the story of how we assess the safety and health needs of the mining industry, operationalize these needs into a focused program of research, and translate the research outputs into practice. Substantial evidence of our progress towards the ultimate goal of eliminating occupational disease and injury from the mining workplace is presented to document the impact of the research.

The organization of this book reflects four key areas of background information on the Mining Program:

1. What is the Mining Program?
2. What does the Mining Program do?
3. What has the Mining Program Accomplished?
4. What will the Mining Program Accomplish?

The answers to these four questions are contained in the four chapters into which this briefing book is organized.

Chapter 1 - What is the Mining Program?

The first question addresses the type of research conducted in the mining program and the resources that can be brought to bear on the execution of this research. The basis for the research is presented in the section entitled "Research Needs." The mining research plan is the first step in moving from the safety and health needs of the mineworker to research projects to

address those needs. This plan is described in the section entitled "Mining Research Plan." The resources available include the research staff, funding, and the laboratories and major equipment, and these are characterized in the sections entitled "Human Resources," "Funding," and "Physical Infrastructure," respectively.

The Mining Program is the program of research that has been planned and executed with a top-level goal to reduce occupational fatalities, injuries, and illnesses in mine workers. The program has the following characteristics:

- there are seven strategic goals, each of which contributes to achievement of the top-level program goal;
- the major gaps or barriers associated with each strategic goal are identified and used to constitute intermediate goals;
- new projects are developed and approved, based on their contribution to the accomplishment of an intermediate goal;
- project decisions are guided by a "critical path approach," i.e. the most direct path between research projects, intermediate goals, and strategic goals;
- resource allocation is guided by the overall state of the top-level goal, and, to a lesser extent, by progress towards strategic and intermediate goals, in an effort to optimize the overall program rather than individual strategic areas of the program; and
- there are performance measures to provide meaningful targets for researchers and to assess progress toward intermediate and strategic goals.

Mining research within the Institute began transitioning into this program-based approach in 2000. The strategic goal areas were originally called program areas, and intermediate goals were called overarching goals of the program area. With the advent of PART in 2003, the terminology was changed to strategic and intermediate goals, and performance measures were formalized. It is important to note that this transition to sector- and outcome-based programs is ongoing within the Institute, and has not been fully completed for the mining program.

Research projects that will directly or indirectly benefit mineworkers can be found throughout NIOSH. Some of these projects are part of an integrated program of respiratory disease studies, while others are part of a program of research in personal protective technologies. The majority of the projects focuses on the development of safety and health interventions, and is concentrated at the Pittsburgh and Spokane Research Laboratories. These projects are the ones that have been fully integrated into the "program" format. Accordingly, the information presented in this book is not an inventory of all NIOSH projects that may ultimately impact the safety and health of mineworkers. Rather, it focuses on those projects that were planned as a program of research in mining. Notwithstanding, many of these other projects are highlighted at appropriate points in this review. However, the basis for those projects as well as evidence of their impact will be presented in their Program Reviews, rather than as part of this Mining Program. At the staff level, collaborations run throughout the Institute, even though the major facility assets for conducting much mining research exist only within the Pittsburgh and Spokane Laboratories.

The Mining Program Plan, presented in this first chapter, defines the scope of the mining program through the seven strategic goals. The choice of the strategic and intermediate goals was driven by the needs of the customers and stakeholders. The next section of this chapter describes the basis for the Program Plan.

Chapter 2 - What does the Mining Program do?

The second question addresses the processes of developing and executing projects. The process of building and maintaining the research portfolio is described in the "Project Planning and Evaluation" section. The "Customers and Stakeholders" section identifies many of the customer and stakeholder groups who have significant interactions with the program in one or more of the following roles: drivers for the type of research and prevention activities in which we engage, consumers of our products and services, and collaborators in the conduct of our research projects. Many of our research collaborations are listed in the "Partnerships" section. This chapter is concluded with a compendium of the "mining" research projects, which provides a one-page description of each project.

The Mining Program conducts a focused set of research and prevention activities that has been designed to meet the needs of mineworkers and related stakeholders. The previous chapter explained the basis for the Program Plan and presented the Plan. This chapter summarizes the processes used to develop the research portfolio, the projects currently in the portfolio, and the customers, stakeholders, and partners of the Program.

The overall process beginning with defining and conducting the research and ending with effecting improvements to mineworker safety and health is complex. A logic model has been prepared to illustrate the more important interrelationships.

Chapter 3 - What has the Mining Program Accomplished?

The third question addresses the conversion of resources into useful products and services that have improved mineworker safety and health. The third chapter contains the evidence to support the contribution of the Mining Program to improvements in mineworker safety and health. Specifically, this chapter establishes causal relationships from research projects, outputs of these projects, and intermediate impacts created by project outputs, to the safety or health outcome. These outcomes are organized by strategic research goals.

This chapter addresses the improvements to mineworker safety and health that have been realized over the past ten years, and that have resulted from the research and prevention activities of the NIOSH Mining Program. It is often difficult to establish causal relationships between research activities and tangible gains in safety or health measures, and the process is further complicated by the fact that multiple organizations or individuals have contributed to the sequence of events that has effected the desire health or safety outcome. We have organized the relationships between our research activities and the ultimate health or safety improvement into three categories of outputs, intermediate impacts, and strategic program outcomes. Each of these will be defined here, and then additional remarks on who can rightly take credit for safety and health advancements will be offered in this introduction. Finally, the layout of this chapter is defined.

The execution of our research projects leads to defined deliverables or **outputs**. Outputs include papers published in peer-reviewed journals, articles in trade magazines, reports, workshops, and patents, among others. Each of these outputs has intrinsic value, but only to the extent that it is translated into practice. For example, a specific technology to reduce dust entrainment may be developed and demonstrated as part of a project. Papers may be written on this technology and workshops may be conducted. These are important outputs of the research, but until they are put into practice, they cannot have much impact. The next step is therefore to identify outputs that have been applied with some measurable success.

The successful application of multiple research outputs leads to an **intermediate outcome**. Continuing with our example, suppose that as a result of the papers and workshops to promote the newly developed technology, the industry adopts it. The translation of these research outputs into practice is a necessary, but not sufficient condition, to define an intermediate outcome. The second necessary condition is that putting these into practice will contribute to the solution of a desired safety or health problem. In our example, if the adoption of the dust control technology throughout the industry also results in reduced dust exposure to workers, then a logical basis exists to believe that this will have an impact on reducing dust diseases among mineworkers. Thus, the intermediate outcome in this example would be reducing dust exposure. We have chosen to label these outcomes as intermediate to emphasize that they are, in themselves, not the final goal, but rather an intermediate step to the ultimate goal of positively impacting the safety and health measures.

The realization over time of one or more intermediate outcomes leads to a desired safety or health **strategic program outcome**. Strategic program outcomes for the Mining Program are reductions in the occupational illnesses, injuries, and fatalities that affect mineworkers. Thus, in our example, a reduction in dust exposure, in conjunction with other intermediate outcomes, would be expected to lead to the strategic program outcome of a reduction in a lung disease associated with that dust. Of course, this final extension of the logic is more difficult to prove when the strategic program outcome, e.g. reducing coal worker pneumoconiosis, has a long latency period. Nonetheless, most experts would agree that a long-term reduction in exposure would have the desired outcome. The safety-based strategic program outcomes tend to be easier in this regard because the time period between the intermediate outcomes and the measurable changes in the desired strategic program outcome is shorter.

Our Mining Program Plan defines a set of seven **strategic goals**. Six of these relate directly to safety or health outcomes, and the seventh is a surveillance goal. For the purposes of organizing this chapter, the strategic program outcomes are classified by strategic goal. Accordingly, the accomplishments of the Mining Program are presented hierarchically, as follows:

The electronic version of this briefing book has hyperlinks to facilitate browsing the logical relationship of outputs to intermediate outcomes to strategic program outcomes to strategic goals.

Finally, there is the issue of determining the underlying causes of improvements to observable safety and health measures. At the output level, despite the often significant synergies among researchers at universities, private-sector research groups, and government agencies, it is usually straightforward to link a specific research project to a specific output. At the intermediate impact level, however, this becomes more difficult. NIOSH outputs can be linked to measurable intermediate impacts. However, in many cases the activities of others directly or indirectly contributed to those intermediate impacts. In most cases, multiple intermediate impacts are required to effect a change in the strategic outcome, and it is likely that NIOSH had involvement in only some of those. We are certain that NIOSH research and prevention activities have contributed to the measured improvements in mineworker safety and health. At the same time, we are certain that the activities of other non-NIOSH researchers have also contributed, and without the combined efforts of NIOSH and non-NIOSH researchers, these improvements would not have occurred. Moreover, the efforts of labor unions, industry groups, and enforcement agencies are absolutely essential to the process, and without their actions, little good would ever come of the research. For the purposes of this review, we have established plausible relationships between our past research activities and presently measurable changes in mineworker safety and health, and we have summarized the evidence that we believe supports these relationships. The remainder of this chapter presents those relationships and the supporting evidence.

Chapter 4 - What will the Mining Program Accomplish?

Finally, the fourth question addresses the future impact of the mining program. This last chapter is structured similarly to the previous chapter, which addressed past achievements, except that it attempts to show a plausible connection between recent and near-future project outputs and future intermediate and strategic program outcomes. Changes in our research planning processes to better integrate health-outcomes-based research planning with sector-based research planning are discussed in the "Strategic Planning" section of this chapter.

This chapter addresses the improvements to mineworker safety and health that are predicted to occur over the next five years as a direct result of the research and prevention activities of the NIOSH Mining Program. Many of the same issues discussed in the introduction to Chapter III apply here as well. Here, the forecasted accomplishments are based on: the critical assumption that resources and processes similar to the ones used over the past five years will continue over the next five years; the outputs that have occurred in recent years and appear to be on their way to an intermediate impact; and on-going project outputs, which are expected to lead to intermediate impacts.

The organization of this information is similar to the format used in the previous chapter. The potential outcomes section lists the seven strategic goals and the outcomes expected to be produced as the research results are implemented. A number of potential intermediate outcomes are listed, which are generally the outcomes expected from the currently active research projects if these are concluded successfully, and the results implemented by the intended customers. There are 4 to 16 potential intermediate outcomess for each strategic goal. For each of these potential intermediate outcomes there is a brief description of the problem, research approach, and the impact expected from the research. The research past and planned outputs, which will contribute to the potential outcome, are also listed with these descriptions.

The planned outputs section is a database of outputs which are expected to result from the current research projects or planned follow-up projects. The outputs are research products which communicate the results of the research to the public and potential users of the results. Each item in this database includes a title, year produced, type of output, and the strategic goal toward which it is directed. Many of these planned outputs will contribute to the achievement of the future potential intermediate impacts and are also listed with those items. The planned outputs are based primarily on current active research projects, and the outputs from these projects are expected in the next 2 or 3 years as most of these projects reach their planned conclusion. As a result, the number of planned outputs diminishes each year. We expect that the actual number of outputs will be the same or larger, if available resources remain the same. However, it is difficult to be specific in planning outputs from possible future research projects, which have not yet been formally proposed, reviewed or approved.

This briefing book is also available as a web-based document. In addition to the information provided in this hardcopy, the electronic version contains dynamic links to related information.

Chapter 1
What is the Mining Program?

1.1 Overview of Chapter 1

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The Mining Research Plan, presented in this chapter, defines the scope of the mining program through the seven strategic goals. The choice of the strategic and intermediate goals was driven by the needs of the customers and stakeholders and surveillance data. The following sections describe the basis for the Mining Research Plan.

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[1] PART, the Program Assessment Rating Tool, was developed to assess and improve program performance so that the Federal government can achieve better results. A PART review helps identify a program´s strengths and weaknesses to inform funding and management decisions aimed at making the program more effective. The PART therefore looks at all factors that affect and reflect program performance including program purpose and design; performance measurement, evaluations, and strategic planning; program management; and program results. Because the PART includes a consistent series of analytical questions, it allows programs to show improvements over time, and allows comparisons between similar programs.

1.2 Vision and Mission

Our vision is to deliver on the nation's promise - safety and health at work for all people through research and prevention.

Our mission is to eliminate occupational diseases, injuries, and fatalities from the mining workplace through a focused program of research and prevention.

We are committed to the innovative development of practical solutions to the complex problems that cause occupational diseases, injuries, and fatalities in mining. We recognize that collaborative efforts in partnership with labor, industry, government, and other stakeholders are usually the best means of achieving successful outcomes. We will continue to strive for high quality, and we recognize that our reputation as the "honest broker" of science is earned on a continuing basis. Finally, we believe that our research only realizes its true value when reduced to practice, and towards this end, we will incorporate "r2p" into every aspect of our research programs.

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1.3 History

The Birth of the U.S. Bureau of Mines (1910)

For some years before 1910, there were calls from many quarters to create in the federal government a bureau that would collect, evaluate, and disseminate scientific, technologic, and economic data of value to the mineral industries. The American Mining Congress, for example, proposed the creation of a federal Department of Mines at its 1896 annual convention. The conservation movement also envisioned a federal role in helping the Nation use its mineral resources responsibly. Concern over the waste of both human and natural resources was reflected in President Theodore Roosevelt's recommendation in 1907 to establish a U.S. Bureau of Mines (USBM) in the Department of the Interior. Congress, however, did not act on this until a series of disasters in the Nation's coal mines had focused public attention on the loss of human life. These disasters took more than 3,000 lives in 1907 alone. There were 361 coal miners killed in Monongah, WV, on December 6, 1907; 239 killed 2 weeks later at Jacobs Creek, PA; 154 killed at Marianna, PA, on November 28, 1908; and 259 killed at Cherry, IL, on November 13, 1909.

The U.S. Geological Survey (USGS) of the Interior Department earlier had established a close relationship with the mining and mineral industries through the preparation and publication of its annual report on *Mineral Industries of the United States*. The USGS was also conducting studies in important mining areas. In 1899, the USGS Director recommended establishing a Division of Mines and Mining and, in 1904, Congress appropriated funds for analyzing and testing the coals of the United States. This led to the formation of the technologic branch, headed by Dr. Joseph A. Holmes, a former North Carolina State Geologist and university professor. On May 16, 1910, Congress passed the Organic Act (Public Law 61-179) establishing the USBM. The act authorized the Secretary of the Interior to transfer to the new bureau the types of investigations heretofore conducted by the technologic branch of the USGS together with the pertinent personnel, equipment, and property. The USBM became functional on July 1, 1910. Shortly thereafter, Dr. Holmes was appointed its Director and served until his death in July 1915.

The Early Years: Focus on Explosives and Disaster Research

The original mission of the USBM was to provide the mining industry with information on blasting materials and techniques that could be used safely in the presence of flammable mine gases and dust. This meant identifying the chemical and physical characteristics that allowed explosives to perform usefully without initiating disastrous fires and explosions. These considerations defined the two main objectives of the USBM's initial research and development - safer blasting materials for underground coal mines, and prevention of underground mine gas and dust explosions.

Although administratively headquartered in Washington, DC, the principal research activities were conducted by the Pittsburgh Mining Experiment Station under Dr. Holmes. According to the Organic Act, the USBM was, among other things, "to make diligent investigation of the methods of mining, especially in relation to the safety of miners, the use of explosives, the prevention of accidents." This reflects the origin of what eventually became known as the Pittsburgh Research Center.

In establishing the USBM, Congress undoubtedly was mindful of similar test stations established earlier in England, Germany, Belgium, Austria, and France, whose work had done much to reduce the frequency and severity of coal mine accidents. Recognizing this, the Secretary of the Interior had requested a delegation of foreign experts to visit U.S. mines to make recommendations to improve safety and efficiency. Thus, the groundwork for the birth of the USBM had been laid.

Dedication of the Experimental Mine, which opened in 1910

The USBM's Pittsburgh Mining Experiment Station, as it was then called, was located at the Government Arsenal in the Lawrenceville section of Pittsburgh, where the War Department had graciously allotted a portion of grounds and buildings to the U.S. Geological Survey. A 100-foot-long test passage, or gallery, that simulated an underground coal mine entry had been installed at the arsenal. It was similar to galleries already established in Courrières, France, and Altofts, England. Although mainly intended to test explosives, it also became the site of numerous coal dust explosion demonstrations, which were necessary to alert the public as to the severity of such explosions. However, many observers were not convinced that a rather short gallery could recreate actual mine conditions. Accordingly, in 1910, the newly created USBM leased a 38-acre tract of land from the Pittsburgh Coal Co. in Bruceton, about 13 miles south of Pittsburgh. Here, a new mine, known as the Experimental Mine, was opened. One of the early experiments in the Experimental Mine demonstrated that coal dust by itself was capable of propagating an explosion even in the absence of any methane gas. This demonstration was contrary to the old belief widely held at the time that coal dust could not explode without gas. This view had led to the very dangerous and widespread practice of using loose coal dust in mines to pack explosives in boreholes, which had cost many thousands of lives. These early experiments clearly proved that such a practice was too hazardous to continue.

One of the first objectives of the new Pittsburgh Mining Experiment Station was to test and approve explosives whose detonation products had temperatures low enough and flames short enough in duration to be considered safe in flammable mine atmospheres. Such explosives were then classified as permissible, or approved, for use in coal mines. At first, there were no safe, permissible types of explosives nor certified permissible equipment of any kind for use in U.S. coal mines. To be classified as permissible for use in underground coal mines, explosives now had to pass a series of scheduled safety and performance tests.

In 1910, the following USBM projects were underway in Pittsburgh:

- Installation of equipment for testing explosives similar to that used in European testing stations, and certification as permissible of a number of "short-flame" U.S. explosives that had been developed by manufacturers for use in gassy coal mines;
- Operation of an electrical section to develop permissibility requirements for electrical equipment, safety lamps, and electrical types of methane indicators;

- Investigation of the occurrence of methane gas in U.S. coal mines and the adequacy of ventilation to prevent the accumulation of dangerous concentrations of the gas; and
- Lab research on the flammability of coal dust and quenching of flame by the presence of rock dust.

Bureau of Mines mine safety railroad car equipped as a movable safety & rescue station

In addition to work on safer blasting materials and prevention of underground gas and dust explosions, mine postdisaster survival and rescue was another concern of the young USBM. Director Holmes initiated the scheme of equipping railroad cars, one of which was headquartered at Pittsburgh, as movable safety and rescue stations. These cars - purchased second-hand, and refitted and equipped at a total cost of $5,000 each - toured the Nation's coalfields, training miners in first aid, rescue work, and mine safety. In a mining emergency, the cars could be immediately dispatched to the accident scene. On October 30-31, 1911, the first national mine safety demonstrations were held at Pittsburgh "as an object lesson to those who had not adopted first-aid instruction or instruction in the use of artificial breathing devices and life-saving apparatus." Nearly 2,000 persons witnessed the demonstrations and exhibits of the USBM at the Arsenal grounds on the morning of October 30, 1911. About 1,200 persons visited the USBM's Experimental Mine at Bruceton to observe a demonstration of the explosion of coal dust. At a public demonstration of mine rescue work on October 31, 1911, which was attended by President William H. Taft, about 15,000 persons, chiefly miners, were present. The demonstration took place at the former Forbes Baseball Field. President Taft handed Red Cross medals and first aid packages to the rescue team captains, saying: "We must stamp out the spirit of carelessness and the happy-go-lucky idea that I am afraid is too common with Americans generally."

At the Experimental Mine, work focused on identifying the processes associated with initiation, growth, and eventual extinguishment of mine fires and explosions. There, under conditions similar to those of a working mine, it was learned how weak methane explosions can initiate violent coal dust explosions and how rock dust, water, and other quenching agents can be applied to arrest these explosions. Instruments were developed for the early detection of open flames and incipient fires due to spontaneous combustion.

The Central Experiment Station (1917)

In 1917, a major landmark in the USBM's history occurred when the Pittsburgh Mining Experiment Station was moved from Lawrenceville to the newly constructed Central Experiment Station at 4800 Forbes Avenue, adjacent to what is now Carnegie Mellon University, in the Oakland section of Pittsburgh. For reasons of safety, the explosives testing activities were moved to Bruceton, where additional buildings were erected to house the Explosives Experiment Station, later to be known as the Explosives Testing Station. All of the land occupied by the USBM at that time, including the Experimental Mine, was purchased in 1924.

Test in the Experimental Mine studying the initiation and growth of coal dust explosions

On June 4, 1925, President Calvin Coolidge issued an executive order creating the Department of Commerce and transferring the USBM and its employees, except those involved in oil-leasing work, into the new department effective July 1, 1925. The purpose of the transfer was to permit a closer coordination of USBM activities with related activities of the bureaus in Commerce. In 1934, the USBM was returned to the Department of the Interior by another executive order signed by President Franklin D. Roosevelt.

In 1928, Dr. Arno C. Fieldner, Chief Engineer, Experiment Stations Division, described the Pittsburgh Mining Experiment Station as consisting of -

- The health laboratory section charged with control of mine gases and dusts, disposal of mine waste waters, mine sealing against acid mine drainage, and catalytic treatment of automobile exhaust;
- The explosives section;
- The fuels section;
- The metallurgical section;
- The physical section;
- The Experimental Mine section;
- The mining research section; and
- The falls of roof and coal section.

Expansion of USBM Mission: Flames, Explosions, and Detonations (1936)

By 1936, research emphasis was placed on explosives, explosions, and combustion. Wilbert J. Huff was Chief of what was then known as the Explosives Division, followed by Dr. Bernard Lewis in 1946. Under Dr. Lewis' leadership, the division became the Explosives and Physical Sciences Division, and its function was substantially expanded to include fundamental research in the structure of flames, explosions, and detonations.

Gallery for testing explosives

Over the years, the USBM sought to reduce the use of unsuitable explosives, as well as the improper use of explosives, through research, training, and demonstrational programs. The introduction of permissible explosives to the coal mining industry had been a major step in increasing safety in gassy and dusty coal mines. Even though these early permissible explosives met with initial acceptance by the coal mining industry, it required about 30 years of unceasing effort in the form of education and developmental endeavors before mounting acceptance of permissibles eclipsed the use of black powder, the principal blasting explosive used in underground coal mines, to which many mine disasters were directly attributed. Additionally, in 1948, after extensive experimentation, an increase in the permissible charge limit from 1½ to 3 pounds, as requested by the industry, was authorized, which greatly improved productivity. Also paralleling these developments was the introduction of water-filled stemming bags, single- and multiple-shot blasting machines, and short-delay detonators.

Mining Research Begins in Spokane, Washington (1951)

In April 1951, the USBM moved its Northwest Region's Mining Division to Spokane, WA, opening the doors to what eventually became the Spokane Research Center. The division had been located in Albany, OR, but increased mining in Idaho and Montana during the late 1940s made it desirable to locate an office closer to the mining region. The Spokane location reduced travel time for USBM field engineers and made the USBM more accessible to miners in the area.

Early research at Spokane involved mainly regional problems, such as those of the deep lead and silver mines of the Coeur d'Alene mining district of northern Idaho and the underground phosphate mines of southern Idaho and Montana. By the 1960s, research focused on devising solutions to the problems of ground support, waste disposal, and rock bursts common to the deep mines of the region, problems that became even more intense as the mines reached deeper into the Earth to meet the Nation's need for lead, zinc, and silver.

Developing Safer Explosives (1950s and 1960s)

Further improvement in the safety of explosive formulations without the loss of necessary strength and reliability of ignition continued to be a longstanding objective for research at Pittsburgh. During 1955-1960, a major advance in this direction was achieved when it was established experimentally that the addition of sodium chloride to an explosive formulation significantly reduces the probability of a methane explosion. As a result of this research, by 1962 all active permissible explosives were modified by the manufacturer to include approximately 10% sodium chloride. A low-strength permissible explosive that included sodium chloride in its formulation was specially designed by the USBM for use in small coal mines as a substitute for black powder, which was ultimately outlawed in 1966. USBM research also led to the development of slurry and emulsion explosives, which are less subject to accidental initiation, thereby improving safety in explosives handling, transport, and storage.

Growing interest in field-mixed explosives raised problems as to the potential hazards of ammonium nitrate-fuel oil (ANFO) compositions used in open-pit mines and underground metal and nonmetal mines. These were resolved in various studies leading to recommendations for safe practices with these blasting agents. These studies also resulted in the development of a new table of safe distances, adopted internationally, for the bulk storage of ammonium nitrate and ammonium nitrate-fuel oil compositions.

Dr. Fieldner was able to report at an international conference that since the inauguration of the USBM's explosives testing program, there had not been a single coal mine explosion in the United States definitely chargeable to permissible explosives when used in a permissible manner. It is noteworthy that these results had been obtained without any appreciable loss in blasting efficiency. The permissible explosives initially developed by U.S. industry generally did not require large amounts of inert diluents or inert sheaths, as used in Europe, to pass the scheduled tests prescribed by the USBM at that time. The use of these relatively strong permissible explosives had materially aided in maintaining the coal production rate in the United States. Meanwhile, fundamental research, made possible by electronic instruments and ultra-high-speed and x-ray photography, provided much-needed insight into the high-temperature, high-pressure reactions associated with efficient detonation and the factors responsible for effective explosive performance. In 1967, Dr. Robert W. Van Dolah, the Pittsburgh Research Center's director from 1954 to 1978, had the singular honor of being awarded the Nitro-Nobel Gold Medal for the theory he developed to explain the accidental initiation of liquid explosives.

Significant USBM Contributions to Other Industries

Much USBM work had wider application that resulted in an important body of information on the flammability and explosibility of numerous other gases, liquids, and dusts, as well as on the toxicity of their combustion products. Early research at the Experimental Mine, in support of construction of the Holland Tunnel between New York and New Jersey, had established ventilation requirements for maintaining carbon monoxide from automobile exhaust at maximum allowable levels. This was accomplished through construction of an oval track in the Experimental Mine, whereby test cars were run around the track while observations were made of the effects of temperature, humidity, airflow rate, smoke, and exhaust gases on the drivers. A carbon monoxide detector installed in the Liberty Tunnels in Pittsburgh was the first of a long series of atmospheric monitors and detectors developed by the Pittsburgh Research Center. Another extensive investigation into the spark

ignition of anesthetic gases virtually eliminated the risk of explosions in hospital operating rooms. A later study for the American Gas Association resulted in burner designs capable of maintaining stable flames for a range of gas compositions, giving utilities greater flexibility in exchanging gases to meet peak commercial and private demands.

Technology initially developed for the coal mining industry was extended to a wide range of potentially explosive and flammable materials of interest to other industries and government agencies, including the Department of Defense, Air Force, Department of Transportation, Coast Guard, and the National Aeronautics and Space Administration (NASA). Preliminary work on the explosives trigger for the atomic bomb, specifically, the first experimental work on cylindrical implosions, was conducted at the USBM explosives lab in Bruceton. During World Wars I and II and thereafter, major contributions were made to the formulation of new military explosives and to the development and safe use of fuels and fluids for conventional aircraft, jet engines, and space vehicles. Projects for the military and NASA ranged from the destruction of earthen tunnels used by the Viet Cong to the effect of the extraterrestrial environment on Apollo attitude control engines. Investigations on the safe handling of hazardous materials ranged from routine loading of oil tankers, and the storage and transport of liquid natural gas, liquid hydrogen, and liquid chlorine to the safest method of ejecting burning fuel from a space capsule at an altitude of 100,000 feet. The effect of extraterrestrial atmospheres on the performance of explosives was also investigated. Dr. Van Dolah was one of an eight-member board that investigated the disastrous fire aboard Apollo 204 in 1967 in which three astronauts perished. Other USBM scientists developed methods for determining flammability hazards of combustible materials. Standard tests to determine autoignition temperatures, flammability limits, and minimum ignition energies, developed by USBM personnel, were adopted by the American Society for Testing and Materials. Fundamental and highly innovative research into the manner in which flames and explosions originate, propagate, and are quenched assured the USBM and the United States an authoritative place in the international scientific community.

The Federal Coal Mine Health and Safety Act of 1969: USBM Mission Extended to Other Mining Safety and Health Issues

Explosion at the No. 9 Mine in Farmington, WV

The death of 78 miners in an explosion at Consolidation Coal's No. 9 Mine in Farmington, WV, caused Congress to pass the Federal Coal Mine Health and Safety Act of 1969 (Public Law 91-173). This act put real teeth in federal safety enforcement, setting up procedures for developing mandatory standards, and called for expanded health and safety research. This legislation directed that the USBM conduct the research necessary to eliminate coal mining hazards and/or provide alternate means of mining that reduce the risks of health impairment, injury, or death. This marked a major reorientation and expansion of the Pittsburgh Research Center's mission and responsibilities. To the traditional work on fires, explosions, and explosives were added the health, safety, and productivity problems associated with the

increasing use of mechanized mining, the introduction of longwall mining, and the exploitation of deeper, less accessible resources. The aforementioned new concerns of the Pittsburgh Research Center were divided into two subprograms, health and safety, with respective activities listed below:

Health	Safety
- Respirable Dust	- Fire and explosion prevention
- Ventilation	- Methane control
- Noise	- Ground control
- Industrial hygiene	- Postdisaster survival and rescue
	- Explosives

The mission for Spokane expanded as well in the early 1970s to include coal, as well as metal and nonmetal mining research. Projects included research on ground control in coal mines, rapid development of mine openings, improved productivity, industrial hazards, and reclamation of coal waste piles. In addition to long-term research in ground control for metal and nonmetal mines, the Spokane Research Center also became involved in research on shaft sinking and hoisting, radiation control in uranium and other mines, safety of waste embankments, and general mining efficiency and safety.

Water sprays on a longwall shearer to reduce respirable dust

At Pittsburgh, in the area of respirable dust, the primary approach was at-source control. Deeper, slower cutting by specially designed bits in conjunction with water sprays reduced dust formation. Control of generated dust was achieved with machine-mounted water sprays and improved ventilation, cutting sequences that kept machine operators in clean air, and by improved dust collectors. Research into high-pressure water-jet-assisted cutting also achieved significant dust reductions. Personal protection was attempted by canopies that surrounded machine operators with clean air. In silica sand processing plants, new hardware greatly reduced worker dust exposure during bag filling and handling. New respirable dust monitors that continuously recorded the wearer's dust exposure attested to the significant reductions in respirable dust that had been achieved. However, more sophisticated analytical instruments revealed a high incidence of unsuspected quartz concentrations, necessitating research to comply with increasingly strict standards. The effect of somewhat coarser particles known as thoracic dust also became a matter of concern and research.

The respirable dust area received considerable support from the Pittsburgh Research Center's ventilation research, characterized by simple, low-cost procedures for maintaining sufficiently clean, cool air in mine workings. Typical developments were the use of a series of temporary cloth stoppings that are readily installed and easily repaired; a rapid brush-on method for sealing permanent masonry stoppings; and simple, reliable techniques for determining airflow patterns and detecting leakage using a tracer gas (sulfur hexafluoride) to follow airflows.

Ventilation air must be not only adequate in quantity, but also healthful. The Center's industrial hygiene research produced a number of small, lightweight samplers and analyzers that helped to ensure that potentially hazardous products from blasting, diesel engines, and other underground operations do not exceed safe levels. The Center also developed and/or tested fire sensors that are capable of detecting carbon monoxide and smoke particles at low levels, thus providing early warning of developing fires in underground mines.

In the critical area of roof control, roof bolting had become the accepted support practice. Introduced by the USBM as an adjunct to timbering, roof bolting proved its effectiveness in preventing roof fall fatalities. Advances in drilling and bolting techniques contributed greatly to the spread of roof bolting. The long-term objective of predicting and forestalling catastrophic roof and rock falls was being met through identification of the responsible geological factors. More immediate results were obtained with techniques that eliminated the need for working under unsupported roof, such as automated temporary roof support systems for use on roof bolting machines, now federally mandated for all coal mines, and machine-mounted cabs and canopies. The USBM also took an active part in the evolution of longwall mining, including developing one of the first shield faces in the United States, the first lemniscate-type shields, and the first shields in steeply pitching coalbeds, which contributed to a downward trend in ground control-related accidents.

Techniques were developed that allowed mining companies to determine the gassiness of coalbeds. Armed with this new technology, USBM researchers conducted a number of geological studies that identified the gassiness of most major coal basins. This information was used by most coal mining companies as a planning tool for methane control systems. New developments for methane control included advance surface drainage of coalbeds through vertical boreholes, with commercial recovery of the drained gas; underground drainage through long, horizontal boreholes, accurately controlled by wireless surveying of the hole trajectory; and cross-measure drainage of gob gas where surface drainage was not feasible. In addition, analytical techniques such as direct core analysis and computer modeling now made it possible to predict methane control needs.

The Pittsburgh Research Center's industrial hazards research used a double approach to a wide variety of safety problems. The first was aimed at preventing human errors through heightened awareness of safety problems, such as recognition of unstable ground and training in dealing with perceived hazards. The second approach was to provide a better working environment through safer equipment and electric power systems, better lighting, mine-wide monitoring and communication, and mechanization of materials handling. Self-paced computerized training programs and equipment models for hands-on experience became available for numerous tasks. Much was learned about organizational and personal factors that affect performance and safety, such as job satisfaction and absenteeism. As the number and size of mobile machines increased, so did the need for electrical power. Considerable progress was made toward intrinsic electrical safety, the elimination of spark ignitions and electrical shocks, and the development of explosion-proof electrical housing, intrinsically safe hardware, circuit breakers, cable-fault detectors, and warning devices. Problems of severely inadequate illumination in underground mines were resolved through the introduction of portable, stationary, and machine-mounted lighting systems and a lighter-weight nickel-cadmium battery for the miner's cap lamp. Safety and efficiency of mobile equipment operators were enhanced by the development of

human-engineered compartments and control panels. Stability indicators on surface equipment reduced rollover hazards. Inadequate materials handling practices in mines and plants, long recognized as a source of injuries, were relieved with the development of training and mechanical devices.

Although noise control research gave some attention to personal protection with earmuffs, the emphasis again was on at-source control. Cutting and drilling equipment, such as pneumatic drills and auger miner heads, were redesigned for lower noise levels. Dozers, loaders, and similar mobile equipment were provided with mufflers, sound barriers, and vibration absorbers. Workshops and handbooks on simple, "do-it-yourself" noise treatments were made available to industry.

Both routine and emergency operations were significantly improved by whole-mine monitoring and communication systems that provided continuous, two-way exchange of verbal and visual information between underground workings and the mine office, supported by extensive data display, storage, retrieval, and analysis. A vest with a built-in, two-way radio and portable phones and pagers kept roving miners in touch with all parts of the mine.

Rescue apparatus for application in mines continued to become more sophisticated. In earlier years, a USBM-approved self-rescuer made by Mine Safety Appliances Co. was available that could be carried in the pocket or worn on the belt. This protected the wearer against carbon monoxide for about one-half hour, but did not supply any oxygen. However, since passage of the 1969 Federal Coal Mine Health and Safety Act, considerable emphasis was placed on supplying the missing oxygen. To the filter self-rescuers that protected against toxic gases, postdisaster research added self-contained self-rescuers that supply the wearer with oxygen.

A second crucial, postdisaster action was to locate and communicate with miners trapped underground. Major advances in electromagnetic technology permitted two-way, through-the-earth communication. At the same time, television cameras and other instruments lowered down boreholes were able to assess the underground environment and the presence and condition of trapped survivors.

The Pittsburgh Research Center's long experience in mine fires and explosions was applied in generating new and more quantitative knowledge on the burning behavior of a wide variety of dusts, gases, fluids, and solids, and on the relative merits of flame inhibitors, quenching agents, and high-expansion foam. Large-scale research in the Experimental Mine produced much basic information on the origin, growth, and suppression of fires and explosions. Passive barriers designed to disperse a quenching agent under the action of an oncoming explosion were successfully demonstrated in a working mine. Improved cutting bits, directed water sprays, and machine-mounted ignition suppression systems were developed to combat the growing problem of frictional methane ignitions associated with modern, mechanized coal-cutting equipment.

Test studying the behavior of fires along a mine conveyor belt

The Center's explosives research continued along established lines, identifying factors that influence the safety and performance of explosives and other blasting agents, as well as developing innovative explosives and evaluating candidate permissible explosives. Proposed revisions in delay blasting regulations led to an extensive evaluation of commercial delay blasting relative to the hazards of explosive misfires.

Federal Mine Safety and Health Amendments Act of 1977

In 1977, Congress passed the Federal Mine Safety and Health Amendments Act (Public Law 95-164). This provided for the first time a single piece of comprehensive legislation for both coal and metal/nonmetal mining operations and extended the research mandates of prior legislation to all segments of the mining industry.

Transfer of USBM Functions to MESA and ERDA (1970s)

At different times in its history, large portions of the USBM were transferred to other agencies. The USBM's success in developing and introducing new safety technologies had always depended on a close cooperative relationship with industry. Industry officials attended USBM demonstrations and opened their mines to USBM scientists for testing new equipment and techniques. That close relationship seemed too close to some. Critics saw the USBM as an "industry-controlled agency" called upon to regulate its controller. A potential conflict of interest was perceived to exist. In 1973, because of such concerns, the Secretary of the Interior separated the mining regulatory function from the mining research function by creating the Mining Enforcement and Safety Administration (MESA). Almost 3,000 people, plus facilities, were transferred from the USBM to MESA. The responsibility for the mining research, development, and demonstration function continued to reside in the USBM. In 1978, MESA became the Mine Safety and Health Administration (MSHA) of the Department of Labor.

In 1960, the Office of Coal Research had been spun off from the USBM and established in the Interior Department to "develop new and more efficient methods of mining, preparing, and utilizing coal." In late 1974, this office was absorbed into the newly created Energy Research and Development Administration (ERDA), which was later to become part of the Department of Energy, created by President Jimmy Carter in 1977.

Acquisition of Lake Lynn Laboratory (1982)

The Lake Lynn Laboratory provides a realistic mine environment for full-scale health and safety experiments

Lake Lynn Laboratory, a 400-acre full-scale lab near Fairchance, Fayette County, PA, became operational in early 1982. It was developed in a limestone bed adjacent to an abandoned limestone mine. Lake Lynn is a highly sophisticated lab that provides an isolated surface facility and a full-scale underground mine for large-scale research in mine disaster prevention and response, as well as many other research areas of national interest that require the study of large-scale surface and underground safety and health problems. The ability of Lake Lynn to simulate virtually any underground coal mine geometry provides a practical, realistic lab for mining research under various controlled conditions of ventilation, humidity, pressure, and temperature. The surface facilities provide an isolated environment in which large-scale research and testing can be done in a realistic, yet environmentally controlled manner.

Closure of the USBM and Transfer to NIOSH (1995-1997)

From the 1970s to the 1990s, considerable progress had been made in improving the health and safety of U.S. miners. In 1970, for example, 260 coal miners lost their lives in the United States; 47 coal miners died in 1993. During this period, USBM research had played an important role, providing much of the breakthrough technology to reduce accidents, fatalities, and health-related problems in the U.S. coal mining industry. Since entering competition in 1978, the USBM had won an impressive total of 35 "R&D 100" Awards, given annually by Research and Development Magazine for the 100 most important research innovations of the year.

During the summer of 1995, however, as the Congressional budget process for fiscal year 1996 was proceeding, the U.S. Senate and House of Representatives held two distinctly different views of the destiny of the USBM. The Senate Interior Subcommittee supported the Administration's proposal for funding at $132 million. The House of Representatives Appropriation Subcommittee recommended the abolishment of the USBM. In September 1995, the Conference Committee composed of members from both houses of Congress recommended the closure of the USBM.

The end of the USBM came suddenly and surprisingly. Furthermore, closure of this statutory agency was to take place in an unprecedented 90 days. Congress also directed that some part of some USBM functions be transferred to other federal agencies. About 1,200 USBM employees were laid off. Another 600 were transferred to the Department of Energy (DOE), the U.S. Geological Survey, and the Bureau of Land Management.

The Health and Safety Research Program at the Pittsburgh and Spokane Research Centers was assigned on an interim basis to DOE (Public Law 104-99). In fiscal year 1997, it was permanently transferred to the National Institute for Occupational Safety and Health (NIOSH) (Public Law 104-134). NIOSH is part of the Centers for Disease Control and Prevention within the Department of Health and Human Services. A total of 413 full-time equivalent employees (FTEs) were transferred to NIOSH on October 11, 1996-336 in Pittsburgh and 77 in Spokane. A position of Associate Director for Mining in the NIOSH headquarters office was created. Under NIOSH, the Pittsburgh and Spokane Research "Centers" were renamed the Pittsburgh Research Laboratory (PRL) and Spokane Research Laboratory (SRL). PRL and SRL currently reside under NIOSH's Office of Mining and Construction Safety and Health Research.

The National Personal Protective Technology Laboratory (2001)

In 2001, NIOSH established the National Personal Protective Technology Laboratory (NPPTL). Its mission is to prevent and reduce occupational disease, injury, and death for workers who rely on personal protective technologies, including the Nation's miners; firefighters and emergency responders; and health care, agriculture, and industrial workers. PRL project work that focused on improving the design, reliability, and use of closed-circuit breathing apparatus such as the self-contained self-rescuer was transferred to NPPTL.

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1.4 Research Needs

Introduction

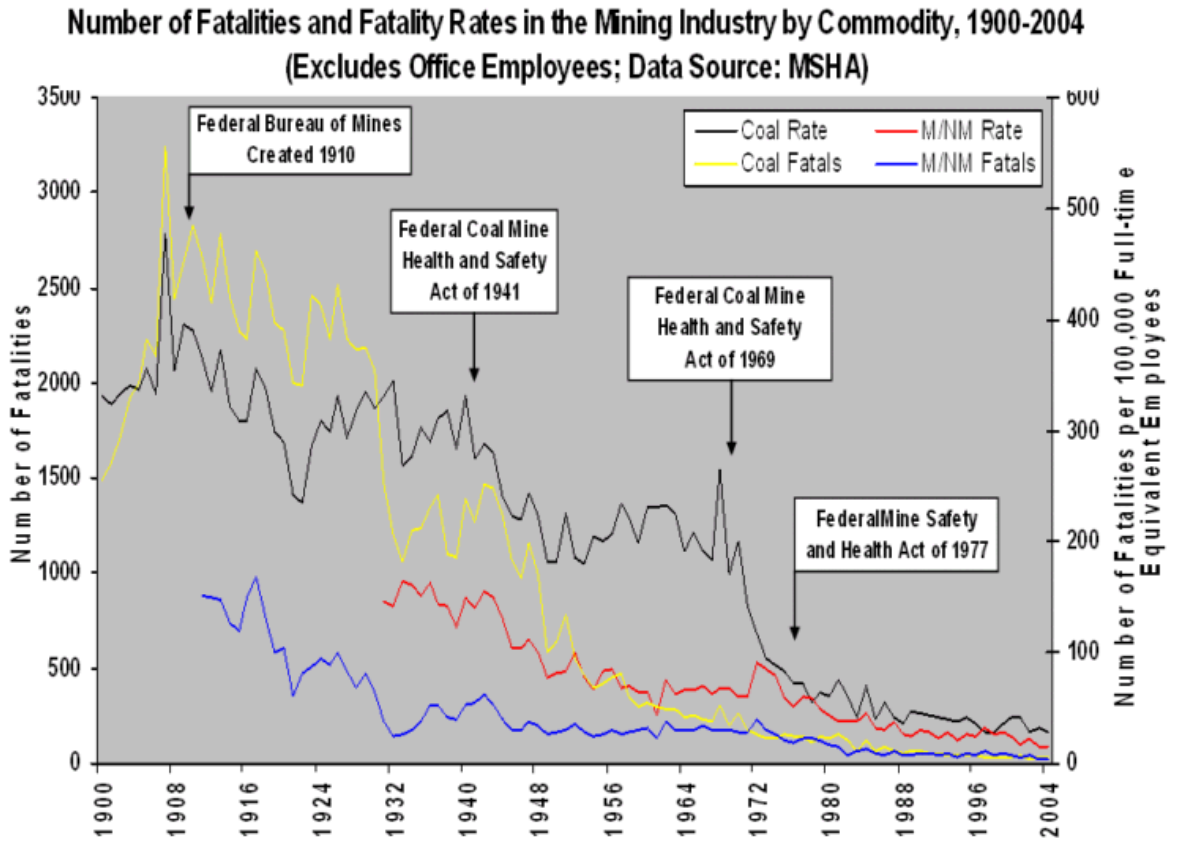
Surveillance data, stakeholder/customer requests, and risk/loss control requirements are used to define the research priorities, and these determine the overall goals. The causes of fatalities, lost-time injuries, and occupational illnesses obtainable from surveillance data drive our program decisions. Meetings with stakeholder and customer groups are used to generate lists of needs they feel are greatest. In general, there is remarkable agreement among the different groups. Finally, the risk/loss control component attempts to address low-probability but high-impact events like mine explosions or inundations. An extremely brief summary of each of these "portfolio drivers" is presented in the remainder of this section.

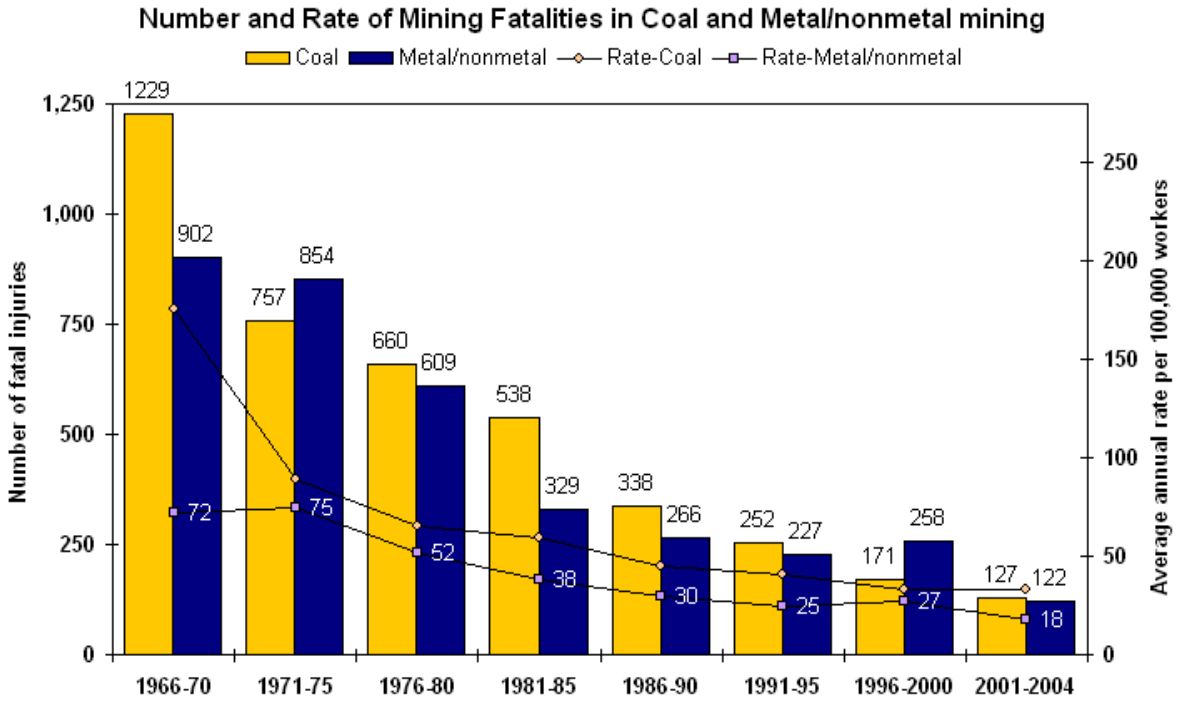
Surveillance Data

Surveillance data is obtained primarily from the MSHA and BLS databases, and then analyzed to establish research priorities or assess the effectiveness of past research. Here the surveillance data are highlighted within the three categories of fatalities, injuries, and illnesses. Although not shown here, the data are analyzed across many categories including the type of commodity, geographic location, and in-mine parameters, among others.

Fatalities

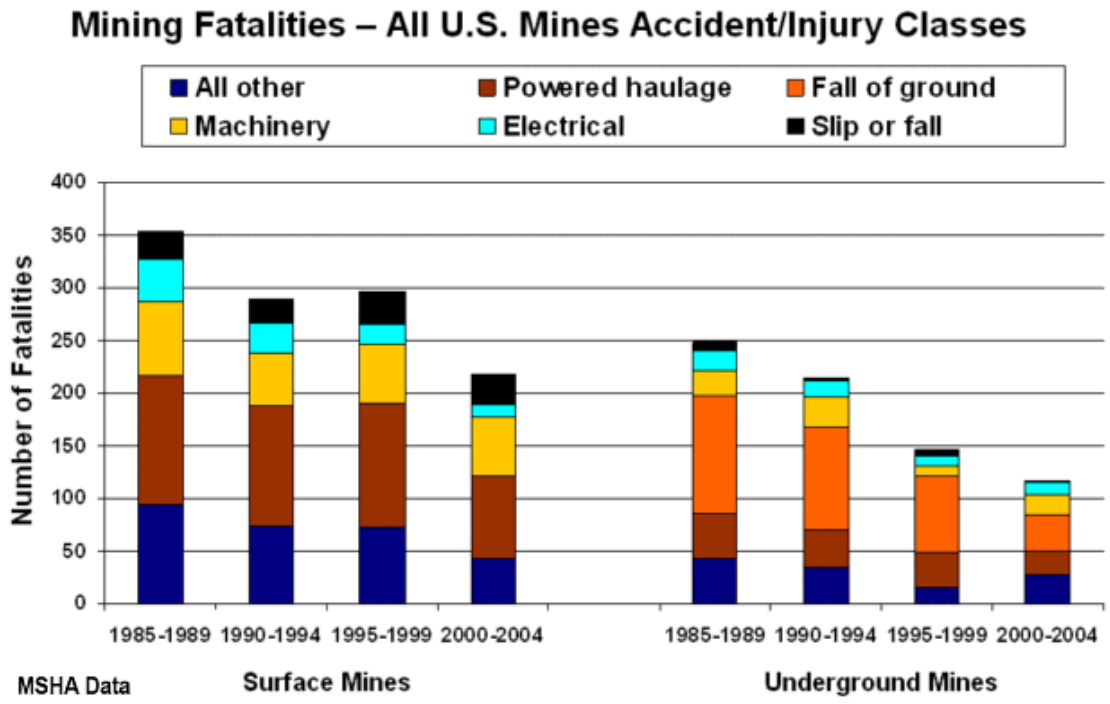
Over the last century, huge progress has been made in reducing the frequency of mining fatalities as shown in the figure below, which is the result of legislative, labor, corporate, research, and technological interventions.


Number of Fatalities and Fatality Rates in the Mining Industry by Commodity, 1900-2004
(Excludes Office Employees; Data Source: MSHA)
Federal Bureau of Mines Created 1910
Federal Coal Mine Health and Safety Act of 1941
Federal Coal Mine Health and Safety Act of 1969
FederalMine Safety and Health Act of 1977
Coal Rate
M/NM Rate
Coal Fatals
M/NM Fatals
Number of Fatalities
Number of Fatalities per 100,000 Full-time Equivalent Employees
0
500
1000
1500
2000
2500
3000
3500
0
100
200
300
400
500
600
1900
1908
1916
1924
1932
1940
1948
1956
1964
1972
1980
1988
1996
2004


Number and Rate of Mining Fatalities in Coal and Metal/nonmetal mining
Coal
Metal/nonmetal
Rate-Coal
Rate-Metal/nonmetal
Number of fatal injuries
Average annual rate per 100,000 workers
0
250
500
750
1,000
1,250
0
50
100
150
200
250
1229
902
757
854
660
609
538
329
338
266
252
227
171
258
127
122
72
75
52
38
30
25
27
18
1966-70
1971-75
1976-80
1981-85
1986-90
1991-95
1996-2000
2001-2004

The data for the previous 2 charts are from the MSHA public data files downloadable at http://www.msha.gov/STATS/PART50/p50y2k/p50y2k.HTM.

The frequency of these events varies by the commodity being mined (figure above) and whether the mine is on the surface or underground (figure below). For 2001-2004, the fatality rate for miners was 33 per 100,000 Full-time-equivalents (FTE) in coal mining and 18 in metal/nonmetal mining. These contrast to a rate of 4.1 for all industry (overall industry fatality rate: BLS Web site, http://www.bls.gov/iif/oshwc/cfoi/cfch0003.pdf



During the five-year period 2000 through 2004, the five leading major causes of underground mining fatalities were:

1. 28% fall of ground
2. 21% powered haulage
3. 17% machinery
4. 16% explosions
5. 10% electrical

These five causes account for 92% of the fatalities.

During the same period, the five leading causes of surface mining fatalities were:

1. 37% powered haulage
2. 25% machinery
3. 14% slip or fall of person
4. 8% fall of rock or highwall
5. 5% electrical

These five causes account for 89% of the fatalities in surface mining and processing operations. It bears mentioning that for the interval 1992-2002, overall employment in surface mining operations was estimated to be 217,000, while that in underground operations was 46,000 (NIOSH Chartbook, 2004), so the fatality rate was higher for underground miners.

Based on the leading causes of fatalities in underground and surface mining, our priorities are to address traumatic injury fatalities from powered haulage and machinery, fall of ground, explosions, slips and falls, and electrocutions.

Lost-time Injuries

For the period from 2000 through 2004, the nonfatal lost-time injury rate for mining is 4.5 injuries per 100 FTE in coal mining and 2.9 in metal/nonmetal mining. This contrasts to a rate of 2.6 (2003 rate) for all industry. The higher rate in coal mining leads us to place greater emphasis on research for injury reduction in this mining sector.

The five leading causes of nonfatal lost time injuries in underground mining are:

1. 33% handling materials
2. 18% machinery
3. 17% slips and fall of person
4. 12% powered haulage
5. 9% fall of ground

These five causes account for 89% of the nonfatal lost time injuries.

The five leading causes of nonfatal lost time injuries in surface mining are:

1. 36% handling materials
2. 28% slip or fall of person
3. 10% hand tools
4. 10% machinery
5. 9% powered haulage

These account for 95% of the nonfatal lost time injuries incurred by surface mine workers.

The frequency of nonfatal lost-time injuries provides insight into how many and what types of injuries are occurring. A second metric, severity, as defined by the median number of days lost, helps to further characterize the overall importance of the injury class. Note that this measure combines actual lost work days, statutory days lost, and days of restricted work activity through the following formula: Total days lost is calculated as the maximum of statutory days lost, or the sum of actual days lost plus days restricted, whichever is greater. The severity of nonfatal lost time injuries in underground mining for 2000-2004, ranked by severity, is shown below.

1. Slip or fall of person, 26 days
2. Powered Haulage, 23 days
3. Machinery, 21 days
4. Handling materials, 20 days

5. Fall of ground, 19 days

For surface mining for 2000-2004, the lost time injury classes, ranked by severity, are shown below.

1. Fall of ground, 20 days
2. Slip or fall of person, 16 days
3. Powered haulage, 13 days
4. Handling materials, 12 days
5. Machinery, 10 days

Illnesses

The following are the occupational illnesses and diseases newly reported to MSHA, by category (from MSHA public file for 2004):

1. Repetitive trauma, 43.1%
2. Hearing loss, 20.9%
3. Dust diseases of the lungs, 16.9%

These top three account for 81% of the newly reported cases. Uniquely, dust diseases can result in death, and for 1999, the most recent year for which data is available, 1003 people died from coal worker pneumoconiosis. During the 1990s, deaths from coal worker pneumoconiosis ranged from 1000 to 2000 per year. Silicosis death statistics in the mining industry are not as readily available, since many states do not report the associated industry with the silicosis-related death. For those states which do report the associated industry, the data shows that mining is responsible for approximately 25% of the deaths. Mining machine operators represent the occupation with the highest number of silicosis-related deaths, and account for about 16 % of the U.S. deaths due to silicosis. The provenance for the lung disease figure is DRDS's "WORLD" report, but the most recent one is quoted. http://www.cdc.gov/niosh/docs/2003-111/pdfs/2003-111.pdf, p28 has the table with the 1999 total of 1003 deaths.

Stakeholder/Customer Requests

Another major factor in setting research priorities is the input we receive from stakeholder groups, which have great knowledge and concern about the health and safety of miners. Some of the major customers/stakeholders who provide input are the following: Labor: United Mineworkers of America, United Steelworkers of America, and International Union of Operating Engineers; Industry: Bituminous Coal Operators Association, National Mining Association, National Stone, Sand, and Gravel Association, and Industrial Minerals Association of North America. In addition, several state organizations, universities, manufacturers, and government agencies participate in research partnerships and provide important input to the list of priorities. NIOSH also maintains a standing advisory committee: the Mine Safety and Health Research Advisory Committee.

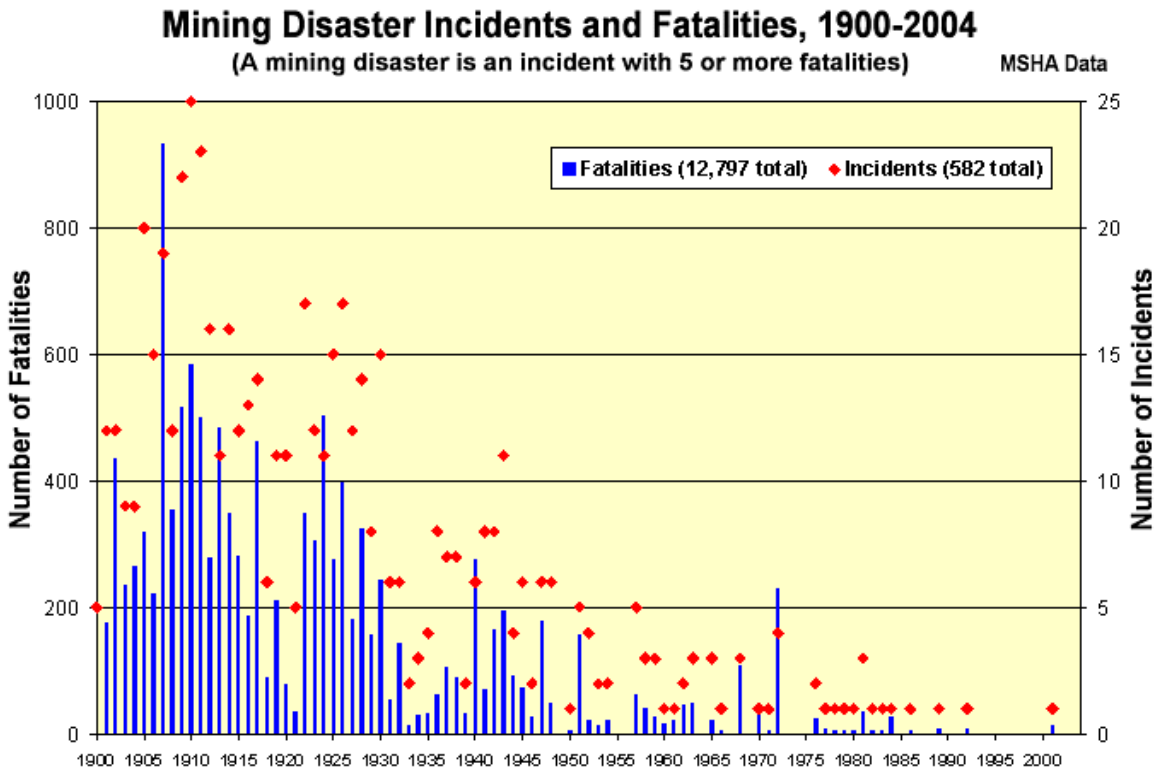
The areas of greatest need, as identified by the stakeholder groups are:

- Dust monitoring and control
- Noise control
- Diesel emissions control
- Disaster prevention and response

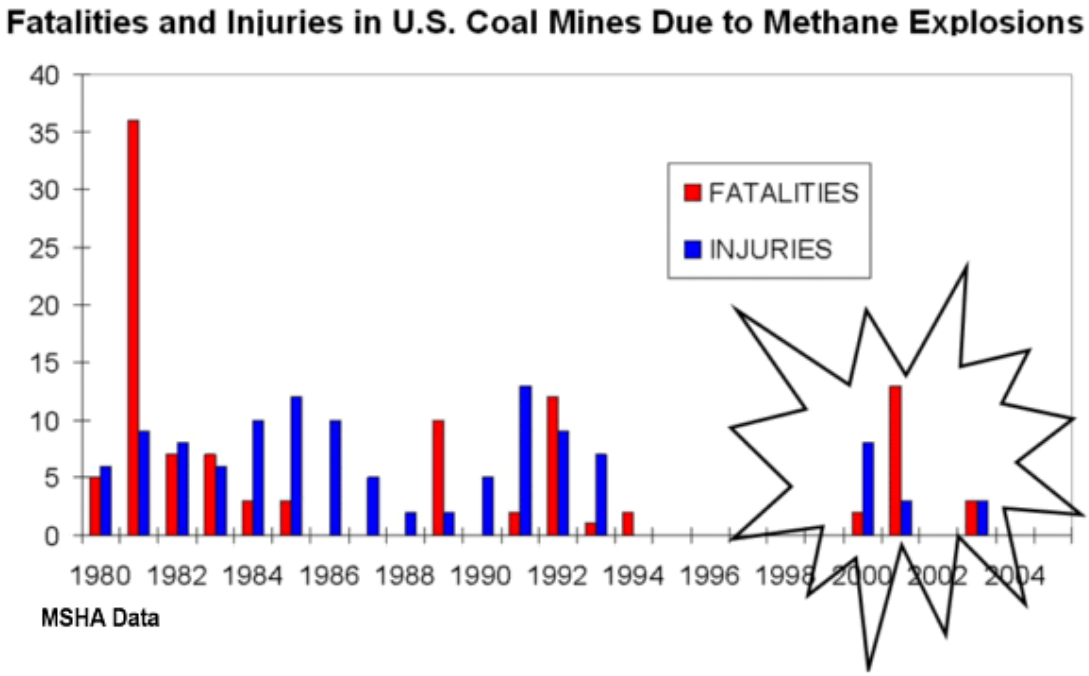
One major influence on these interests and perceived needs is any impending regulatory change. Other areas of strong stakeholder interest and stated need are ground control, training, machine and electrical safety, ergonomics practices, and blasting health and safety.

Loss Control

The third component of the "needs analysis" addresses the low-probability but high-impact events. These are mine explosions, mine fires, mine collapse, and mine inundations. While these events have become much less deadly over time, they still do occur, albeit sporadically as shown in the figure below. As part of the needs analysis, sentinel events and other indicators are tracked. All of the indicators point to increasing risk of disaster from explosions, fires, and inundations. In large part, this is due to the worsening conditions as mines progress into gassier deposits, go deeper, and work under generally more adverse geologic conditions. The greatest risks are in underground coal mining, although metal/nonmetal mining entails significant risks as well. In addition to preventing these disasters, a concurrent priority is to develop safer and more effective response methods and technologies.



While there has been significant progress on preventing underground mine disasters, there has been an increase in the occurrence of injuries and fatalities due to methane explosions in underground coal mines in the past five years. This indicates that we must always be vigilant to ensure mine workers are protected from catastrophic events. Research is continuing, and because of this recent trend in some cases expanding, to address the factors associated with coal mine methane explosions. The research encompasses methane drainage technology, frictional ignition prevention, seals and barrier designs, fire detection and suppression systems essentially a broad spectrum of investigations intended to expand the knowledge and technology for preventing underground mine fires and explosions.



NIOSH Role, Decision-Making, and Intervention

CDC and NIOSH often invoke the "surveillance cycle" as the theoretical framework for our method of operations. This provides a helpful model for public health practice based on surveillance data. For mining safety and health events, MSHA is the jurisdictional agency and, thus, the primary collector of data. NIOSH's important roles fall in the other three major areas of effort: consolidation and interpretation of data, dissemination, and recommending/planning for action to control and prevent the recurrence of these untoward events. The cycle repeats, with the roles remaining similar.

CDC and NIOSH often use a hierarchy in decision making to enable some comparison of disparate outcomes and events (in descending rank order):

1. Death (with multiple deaths set as highest priority for investigation and prevention)
2. Permanent disability and/or disfigurement
3. Severe/serious injury with long and/or painful rehabilitation

4. Lost time/wage events
5. Costly injuries not fitting prior stated categories
6. Potentially dangerous incidents not resulting in injuries
7. Hazards

Applying those criteria to the major categories of problems that the NIOSH Mining S&H program addresses, the surveillance data point toward 6 areas of greatest need (not ranked):

- Disaster Prevention
- Respiratory Diseases
- Traumatic Injuries (e.g. powered haulage, machinery, slips and falls, and electric shock)
- Hearing Loss
- Repetitive/Cumulative Musculoskeletal Injuries
- Fall of Ground

1.5 Mining Research Plan (Strategic Goals)

Introduction

The Mining Research Plan was developed to focus the research and prevention activities on the areas of greatest need, as articulated by our customers and stakeholders and illustrated by the surveillance data. In a time of diminishing resources and increasing customer expectations, it was seen as a prerequisite to improved resource allocation. The Plan represents a vehicle to communicate more clearly, both internally and externally, what it is we are doing, why we are doing it, and how we will know when we have done it.

Strategic Research Goals

A melding of the priorities, as established from the surveillance data, stakeholder/customer requests, and loss control, is performed to establish a set of strategic research priorities. While the top-level goal is to improve mining safety and health, this will only be achieved by eliminating the fatalities, injuries, and illnesses that were summarized previously. Accordingly, the first six strategic goals are defined. These are:

Strategic Goal 1: Reduce respiratory diseases in miners by reducing health hazards in the workplace associated with coal worker pneumoconiosis, silicosis, and diesel emissions.

Strategic Goal 2: Reduce noise-induced hearing loss (NIHL) in the mining industry.

Strategic Goal 3: Reduce repetitive/cumulative musculoskeletal injuries in mine workers.

Strategic Goal 4: Reduce traumatic injuries in the mining workplace.

Strategic Goal 5: Reduce the risk of mine disasters (fires, explosions, and inundations); and minimize the risk to, and enhance the safety and effectiveness of, emergency responders.

Strategic Goal 6: Reduce ground failure fatalities and injuries in the mining industry.

The above goals and their performance measures were established in the context of a 10 year planning horizon.

The seventh goal is aimed at preventing potentially adverse health or safety outcomes that may result from changes in the industry.

Strategic Goal 7: Determine the impact of changing mining conditions, new and emerging technologies, training, and the changing patterns of work on worker health and safety.

Researchers have identified many of the barriers, knowledge gaps, or technology gaps that must be addressed to affect a desired change at the strategic goal level. These are articulated as intermediate goals, which are presented for each strategic goal. The major steps that must be taken to achieve each intermediate goal are captured as annual goals. An average timeframe for

achievement of an intermediate goal is 5 years. Annual goals, however, are articulated for only 2 or 3 years at a time, to reflect both the uncertainty of the research process and variations in funding levels. Annual goals are not included in the Plan, as these are developed and used on a year-to-year basis by the researchers and first-level research supervisors.

It should also be noted that the set of intermediate goals defined in this Plan, for each strategic goal, represents the areas that NIOSH is committed to solving. It is likely that other intermediate goals will need to be achieved before it will be possible to fully achieve the strategic goal. The intermediate goals identified in this Plan were selected because they are on the critical path to achieve the strategic goal, and they are potentially achievable with the staff, facilities, and funds that are expected to be available. This Plan does not incorporate the essential research that will be conducted at universities or other agencies here and abroad.

The performance measures associated with the strategic goal reflect our ability to effect change with our resources. In most cases there are additional intermediate goals that are not being addressed by NIOSH, which must be achieved before the strategic goal can be fully realized. The performance measures are meant to provide meaningful targets to researchers, as well as to measure accomplishment. Existing evidence and expert judgment have guided our formulation of performance measures. Mine- and industry-level data, surveillance and intervention effectiveness data, customer and stakeholder inputs, and loss control assessments suggest that the measures are both reasonable and ambitious. On this basis, our measures represent approximate targets rather than precise projections of anticipated outcomes.

Strategic Goal 1: Reduce respiratory diseases in miners by reducing health hazards in the workplace associated with coal worker pneumoconiosis, silicosis, and diesel emissions

The primary focus of this goal is on reducing the respiratory diseases that result from exposure to coal dust, silica dust, and diesel particulate matter (DPM). Coal dust leads to coal worker pneumoconiosis (CWP), silica dust leads to silicosis, and DPM may be carcinogenic or cause other adverse health effects. All three are considered significant health hazards in mining. The ultimate goal is the elimination of new cases of CWP, silicosis, and the adverse health impacts of DPM. However, given the latency of the diseases in question, a period of 25-35 years will be required to achieve this goal. However, over a 10-year timeframe, significant progress toward this goal can be achieved by reducing worker exposure, and this can be effectively measured by looking at the reductions in dust, silica, and DPM concentrations to which workers are exposed.

The three major barriers to accomplishing this goal are the lack of a clear understanding of how miners receive their exposures to these health hazards, the current inability to obtain real-time exposure data, and the need for ever-improving mine-worthy engineering controls to protect miners from constantly increasing hazard concentrations.

Current sampling technology for dust, silica, and DPM provides an end of shift exposure measure and does not tell anything about how the worker received his exposure. By understanding the relationship between a worker's actions during a working shift and the sources of dust and DPM to which the worker is exposed, intelligent decisions can be made as to where administrative controls could be employed to reduce exposures and where engineering controls are needed. Real-time dust and DPM monitors would provide this much-needed information.

For years, mining stakeholders (both industry and labor) have expressed the need for real-time, person-wearable monitors for dust and DPM. Since 1980, the United Mine Workers of America have been asking for a real-time dust monitor to empower miners to do something about exposures before they occur. The Secretary of Labor's Advisory Committee on the Elimination of Pneumoconiosis Among Coal Mine Workers (1996) called for the development of continuous respirable dust monitors to help protect workers' health. Such a device would not only make it possible to observe what worker activities result in high exposures, but would also allow for actions to be taken to prevent overexposures before they occur. Presently, several days pass between the sampling of dust and the availability of results, making it impossible to take any timely corrective actions.

As mining production rates increase, there are accompanying increases in the production of coal dust, silica, and DPM. Thus, there is a continual need to develop and improve engineering control technologies to reduce the associated increased exposures. Since the introduction of longwall mining systems in the United States around 1970, longwall shearer advance rates have increased from 3 to 4 ft per minute to over 75 ft per minute, and average longwall shift production has increased from under 500 tons per shift to well over 5,000 tons per shift. This change has resulted in significant increases in dust production, making earlier control technologies inadequate. Increased usage of diesel equipment in mines has resulted in corresponding increases in DPM levels in mines, requiring additional control technologies. Furthermore, new or more rigid enforcement standards have made better control technologies a necessity.

Worker medical monitoring and surveillance findings can serve as a basis for prevention when primary methods (e.g., dust control and personal protection) fail. Failures of primary prevention occur because of imperfect standards (e.g., permissible exposure limits); suboptimal enforcement of, and compliance with standards; unrecognized hazards; and other factors that put workers at increased risk. For decades, worker medical monitoring using chest x-rays has been the method of choice for detecting the pneumoconiosis. Underground coal miners in the United States have been able to avail themselves of the benefits of radiographic monitoring for over 30 years through the NIOSH Coal Workers' X-ray Surveillance Program. Worker medical (as opposed to hazard/environmental) monitoring has the primary aim of preventing development of physical impairment and disability due to disease among individual workers found to exhibit early signs of disease. Case and case-cluster detection can also point to the need for adoption of more effective primary prevention approaches to protect other, as yet unaffected, workers from developing disease.

Performance Measure: This goal will be achieved by reducing the respirable coal dust overexposures of operators of longwall and continuous mining machines, roof bolters, and surface drills by 50% and the overall silica exposure of crusher operators and stone cutters by 50% within 10 years. The goal will also be achieved by reducing coal miner exposure to DPM by 80% and metal and nonmetal miner DPM overexposure rates by 50% within 10 years.

Intermediate Goal 1.1: Develop real-time, person-wearable monitoring technology for respirable coal dust. The availability of such a monitor(s) will empower both miners and management to take corrective action before overexposures can occur. Current reliable, real-time dust monitoring technology is large and not designed to withstand the rigors of the mine environment. This technology must be miniaturized and hardened before it can be successfully employed underground. This entails reducing the current 150-lb environmental

sampler down to a person-wearable, 2-lb unit. In addition, other scientific and engineering barriers must be overcome to realize a practical mine-worthy device. These include determining a sampling intake location that is representative of the miner's breathing zone, designing the instrument to correctly size and measure the respirable portion of mine coal dust, and insuring that the instrument is capable of microgram accuracy.

Performance Measure: This goal will be achieved if a real-time person-wearable dust monitor is commercially available and in use by 2009.

Intermediate Goal 1.2: Reduce exposure to coal dust for longwall miners. Historic and current compliance sampling results show that workers on longwall faces are the most frequently overexposed workers in underground coal mining. More effective control technologies are needed, especially since continuing gains in productivity are resulting in corresponding increases in respirable dust.

Performance Measure: This goal will be achieved if the frequency of overexposure is reduced by 50% over the next 6 years (baseline is 2003).

Intermediate Goal 1.3: Reduce coal miner exposure to silica and coal dust. Recent compliance sampling results show that 23% of continuous miner operators, 25% of roof bolter operators, and 31% of surface drill operators are overexposed to silica. Research will be directed at establishing how dust is generated and becomes airborne in these mining operations and then at developing control technologies to reduce these airborne dust concentrations. Reducing the exposure of these specific occupations, as well as other high exposure occupations, will have the additional benefit of reducing the exposure of other workers in the surrounding work area.

Performance Measure: This goal will be achieved if improved control technologies reduce the frequency of overexposure of continuous miner operators, roof bolter operators, and surface drill operators by 50% within 5 years (baseline is 2003).

Intermediate Goal 1.4: Reduce the silica dust exposure of workers in metal and nonmetal mines and mills. Personal sampling results indicate that many high-risk occupations, such as crusher operators, heavy equipment operators, and stone cutters in metal and nonmetal operations are experiencing overexposure to silica dust levels. For example, 35% of silica compliance samples for dimension stone cutters exceed the allowable level. NIOSH is developing improved control technologies to reduce the silica dust exposure in these, and other high risk occupations.

Performance Measure: This goal will be achieved if improved control technologies reduce silica exposures by 50% for crusher operators in mines and mills, workers in enclosed equipment cabs, and stone cutters in dimension stone plants within 4 years (baseline is 2003).

Intermediate Goal 1.5: Reduce miner exposure to diesel emissions in underground mines. Recent surveys have shown that individuals working in underground mines where diesel-powered equipment is used are exposed to DPM concentrations that exceed those of any other occupation. Technology gaps exist in the design, selection, and application of emissions control technologies as well as in laboratory and field measurement methods. The objective is to reduce miner exposure to DPM by facilitating the application of current and evolving diesel emission control technologies into underground mines.

Performance Measure: This goal will be achieved if (1) underground coal miners' exposure to DPM is reduced by 60% within 6 years and (2) the frequency of overexposure of metal and nonmetal miners to DPM is reduced by 40% (assuming the current 400-µg/m3 standard) (baseline is 2003).

Intermediate Goal 1.6: Reduce exposure to dust, silica, and diesel emissions in large-opening mines through the development of improved ventilation science. Ventilation can be a highly effective tool for diluting and removing respiratory hazards in mines. Large-opening mines are difficult to effectively ventilate. This is due to the size of the openings and the large volumes of airflow required for removing and diluting pollutants. NIOSH is developing improved ventilation designs for these large-opening mines.

Performance Measure: This goal will be achieved if 20% of large-opening mines incorporate these improved ventilation designs within 5 years.

Strategic Goal 2: Reduce noise-induced hearing loss (NIHL) in the mining industry

NIHL is the most common occupational illness in the United States. The use of heavy equipment, the inherently noisy aspect of ore winning processes, and the confined work environment are some of the factors that contribute to high levels of noise exposure to workers in the mining industry. Every day 80% of the Nation's miners go to work in an environment where the time-weighted average (TWA) exceeds 85 dB(A). Moreover, 25% of the miners are exposed to a TWA noise level that exceeds 90 dB(A) - the permissible exposure limit (PEL). Furthermore, a NIOSH analysis of a large sample of audiograms revealed that by age 50, approximately 90% of coal miners and 49% of metal/nonmetal miners have a material hearing impairment. By contrast, only 10% of the nonoccupational noise-exposed population has a hearing impairment at age 50. Simply stated, the majority of miners have a 25-dB or greater hearing loss by the time they retire. Although NIHL is the most common occupational disease in this country, the problem is especially acute among workers in the mining industry.

There are several barriers to reducing NIHL. These include gaps in knowledge of noise dose/source relationships, the unavailability of effective noise controls, and needs for worker education and worker empowerment. A related issue is the difficulty of communication in noisy workplaces by both hearing-impaired and normally hearing workers.

Noise dose/source relationships. - The mining industry has not dedicated the resources to determine where workers receive their noise exposures. Knowledge of the noise source/exposure relationship will allow for effective selection and implementation of noise controls, thus reducing NIHL within the mining population.

Availability of effective noise controls. - In many cases, attempts at reducing sound levels with noise controls are unsuccessful because of misapplication of technologies and/or treating a noise source that is insignificant in terms of a worker's exposure. In other cases, noise controls have not been developed because of the lack of understanding of the mechanisms of noise generation or the inability to develop controls that have suitable durability in the mining environment.

Worker education. - Workers typically receive inadequate education about what they can do to conserve their hearing. Common problems include training that is sporadic and uninteresting, little feedback on whether the training actually increased their knowledge or skills, and an overemphasis on hearing protection at the expense of the many other strategies workers can utilize to reduce their noise exposures.

Worker empowerment. - Workers report that they are rarely included or consulted in hearing conservation efforts. However, their involvement is crucial for the effective deployment of most exposure reduction strategies. Workers need to have better information about the noise hazards in their workplaces and how much actual exposure they are receiving from these sources. They also need to be empowered with techniques to reduce their exposure by playing a greater part in the overall hearing conservation effort.

Communication issues. - In mines and other noisy settings, workers report a significant problem with hearing warning signals, speech, and other sounds that are critical to working safely and efficiently. This problem is exacerbated by the masking nature of background noise, the high prevalence of hearing impairment, and the over reliance on simple hearing protection to reduce exposures.

Performance Measure: The shorter-term goal of this research will be achieved if the frequency of noise overexposure of miners is reduced by 25% in 5 years and 50% in 10 years. However, NIHL usually occurs gradually over a career. The ultimate long-term measure of success is the elimination of new cases of NIHL. The overall success of our hearing loss prevention research will only be seen in 20-30 years.

Intermediate Goal 2.1: Develop and maintain a noise source/mine worker exposure database for prioritizing noise control technology.

This database will identify and quantify the sources of noise in various mining environments and correlate these to workers' noise exposures. The source/exposure relationship will be developed from data collected during mine-site surveys of underground and surface coal mines, coal preparation plants, and underground and surface metal and nonmetal mining sites. The database of noise source/worker exposures will be used by NIOSH and key stakeholders to develop and prioritize control technology efforts.

Performance Measure: This goal will be achieved through development of a database of noise source/exposure relationships and equipment noise in all mining commodities and its use by the mining industry and the Mine Safety and Health Administration (MSHA) by 2008.

Intermediate Goal 2.2: Develop engineering noise control technologies applicable to surface and underground mining equipment.

Generalized procedures for the application and evaluation of suitable noise control technologies in mining environments will be developed for all mining commodities. The information will provide the industry with guidelines for applying and evaluating noise controls that will enable mine operators to reduce worker noise exposure. In addition, new or improved engineering noise controls will be developed, evaluated, and field tested to reduce sound levels produced by mining machinery used in the mining environment, thereby reducing noise exposure to mine workers.

Performance Measure: The goal for existing noise controls will be achieved by disseminating comprehensive procedures for the evaluation and application of suitable noise controls in underground and surface metal, nonmetal, and coal mines within 3, 4, and 5 years, respectively. The goal for noise control development will be achieved if the industry implements effective new noise controls that reduce the noise overexposures of miners by 25% (versus the baseline values) by 2009.

Intermediate Goal 2.3: Empower workers to acquire and pursue more effective hearing conservation actions.

Workers continue to be exposed to hazardous noise levels even in situations where noise controls and hearing protectors are available. The workers themselves need to be empowered with the motivation, knowledge, and skills to take more effective preventive actions. NIOSH will develop and test a range of more effective training, communication, and feedback techniques that will give workers the tools they need for conserving their own hearing.

Performance Measure: This goal will be achieved through measures of dissemination and usage of communication, training, and empowerment tools by 2006. A key measure will be the actual noise dose reduction attained through increased prevention behavior and usage of dose monitoring systems.

Intermediate Goal 2.4: Improve the reliability of communication in noisy workplaces.

Both hearing impaired and normally hearing workers face special communication challenges while wearing hearing protection devices in noisy workplaces. These include localization issues, problems communicating with other workers during actual work cycles, and not hearing safety cues, such as backup alarms. Guidelines will be developed that identify new communication issues, while remaining consistent with existing standard systems, using actual noise simulations, along with the testing of different types of hearing protectors for attenuation, localization, or other characteristics that affect intelligibility.

Performance Measure: This goal will be achieved to the extent that key stakeholders acquire, accept, and implement the guidelines on alleviating communications issues by 2006.

Strategic Goal 3: Reduce repetitive/cumulative musculoskeletal injuries in mine workers

Musculoskeletal injuries, primarily to the low back, neck, knees, shoulders, and arms, are a continuing concern within the mining industry. Over 45% of all MSHA reportable incidents during 1993-2002 were classified as musculoskeletal, which is a larger percentage than that of other industries. Many barriers to preventing these injuries exist in mining, including work in awkward or restricted postures, in muddy, wet, or icy conditions, and in hot or cold environments, as well as exposure to high levels of whole-body vibration, significant amounts of heavy manual work, and an aging workforce.

Reducing the incidence of musculoskeletal injuries in mining is dependent upon improved job design and work practices. These require an enhanced understanding of the physical capabilities and limitations of mineworkers, and the development of an effective process to institute job changes that reduce musculoskeletal risk at the mine.

Performance Measure: This goal will be achieved through successful delivery of the subsequent intermediate goals, which will result in a 30% reduction of the MSD 2003 baseline injury rate by 2014.

Intermediate Goal 3.1: Quantify job demands and physical capabilities of miners to develop improved recommendations for work design.

One effective method of reducing musculoskeletal injury risk is to ensure that the demands of a job are well within the worker's capabilities. Unfortunately, data on mining job demands and miner work capacity are scarce. Studies in our Laboratory and Ergonomics Research Mine (currently under construction) will provide data on job demands and worker capacity for improving the job design at the mine site. A current emphasis is to examine the effects of aging on the physical capabilities of miners, so that jobs can be designed to accommodate the aging mining workforce.

Performance Measure: This goal will be achieved by providing 10 improved designs and work practices for reducing musculoskeletal exposure in mining jobs by 2009.

Intermediate Goal 3.2: Develop and field test ergonomic interventions to reduce worker exposure to musculoskeletal risk factors.

Research has shown that an ergonomics process which identifies ergonomic risk factors, devises solutions to reduce injury, and evaluates the effectiveness of the solutions can effectively lower worker exposure to musculoskeletal risk factors and improve worker performance. Yet, few mining companies have an ergonomics process implemented in their operations. Despite the unique challenges present in the mining environment, the logical approach to building ergonomics awareness, field testing and adoption of the laboratory proven interventions in the work place, will pave the way for a significant reduction in repetitive injury rates.

Performance Measure: This goal will be achieved by reducing the repetitive injury rate by 25% at test mine sites by 2009, using the 2003 rate as baseline.

Strategic Goal 4: Reduce traumatic injuries in the mining workplace

The primary focus of the research is to prevent traumatic injuries related to electricity, machinery, powered haulage, and falls in mining. From a severity standpoint, accidents in these classes, according to MSHA, comprise over half of the total days lost in mining from all causes. Specifically, from 1993 through 2002, there were 1,859,368 lost workdays due to traumatic injuries in these areas. Of these days lost, 50% could be attributed to falls, 25% to powered haulage, 24% to machinery, and 1% to electrical causes. Electrical injuries, though small in number, comprised 10% of deaths from these causes during the 10-year period.

Traumatic injuries could be reduced through the development and application of technologies to prevent the burns and fatalities caused by contact with electricity, and through an improved understanding of the human-machine interface and the subsequent development of technologies to protect workers in close proximity to large equipment. Reduction of injuries from slips, trips, and

falls to the same level may be facilitated with enhancements to worker clothing or the integration of new wearable sensor technologies into the clothing. The small but persistent number of injuries and fatalities from blasting could be reduced through improved training and an improved understanding of the variations in explosive formulations that can contribute to unexpected results.

Performance Measure: This goal will be achieved through successful implementation of the subsequent intermediate goals, which will result in a 30% reduction in traumatic injury rates by 2014 from the 2003 baseline.

Intermediate Goal 4.1: Develop interventions for preventing electrocutions and burn injuries.

Electricity is the fourth leading cause of death reported in the mining industry by MSHA, with about 20% resulting from incidental contact with overhead power lines by high-reaching mobile equipment. Burns are the predominant nonfatal electrical injury. About half of mine electrical accidents are sustained during electrical maintenance, with meters, circuit breakers, and disconnects associated with many of the incidents. Further, lightning strikes on the surface may be communicated to underground mine workings and cause ignitions of methane-laden atmospheres. These hazards can be modeled in the Mine Electrical Laboratory, which features high-power, high-voltage, and high-current sources calibrated to NIST standards.

Performance Measure: This goal will be achieved through a 25% reduction in the 2003 baseline electrical injury rate by 2009.

Intermediate Goal 4.2: Develop interventions for preventing injuries related to machine safety and powered haulage.

MSHA data gathered from 1996 through 2000 showed that powered machinery incidents comprised almost 44% of incidents reported. During this same period, 77% of all fatalities were classified as related to powered machinery. The load-haul-dump, shuttle car, and mantrip are consistently the top three machine types cited for powered haulage-related injuries and accounted for 95% of the powered haulage incidents due to jarring and jolting. The potential for health and safety risks introduced by new technologies must be addressed proactively. Of particular importance is to understand the system requirements and specifications and to address human interface issues involving the design, operation, maintenance, computerized control, and repair of the equipment.

Performance Measure: This goal will be achieved by a 25% reduction in the 2003 baseline traumatic injury rate pertaining to machine safety and powered haulage-related injuries by 2009.

Intermediate Goal 4.3: Investigate wearable sensor technologies for empowering the miner to take proactive steps in decreasing his/her exposure to work-related injuries.

MSHA data gathered between 1998 through 2002 showed that lost-time injuries for mining operations totaled over 53,000, with a rate of 3.8 per 100 full-time employees. Underground coal's rate for the same period was more than double that number. Over 25% of the injuries were from falls (16%) and machinery (11%). Accessibility to sensory information poses problems, because workers might need to put themselves in unsafe areas or positions in order to obtain sensory information. Also, it may not be physically possible for a miner to obtain all the

appropriate sensory information to manage hazards as they perform their work tasks and activities. Real-time environmental and biometric information provided through wearable sensors enables the miner to take proactive safety steps to avoid impending and/or existing hazards.

Performance Measure: This goal will be achieved by a 25% reduction in the 2003 baseline injury rate related to machinery, slips, and falls by 2009.

Intermediate Goal 4.4: Reduce the incidence of injuries and fatalities resulting from the use of explosives in the mining industry. This will be accomplished through the development and distribution of training materials consisting of toolbox training sessions and one or more videos.

Blasting is a critical component of surface mining operations and the construction industry. Billions of pounds of explosives are used annually in the United States by these industries. Each and every blast is associated with the production of toxic fumes and the projection of rocks from the blast.

Performance Measure: This goal will be achieved if the flyrock training materials are transferred to 75% of the blasting specialists for the mining industry by 2006. The transfer will be achieved if MSHA incorporates the materials as part of its annual mining health and safety training.

Intermediate Goal 4.5: Develop interventions, best practices, and strategies for improving miners' training with respect to hazard recognition, risk factor awareness, and emergency response. These interventions are critical to ensuring that workers are well prepared to assess, prevent, and/or respond to hazardous situations. Mine safety and health professionals have long recognized training as a critical element of an effective safety and health program. Federal regulations (30 CFR 46 and 48) require mine operators to provide initial and refresher training each year. The time and money being spent to train U.S. miners is substantial. There is a strong and steady demand for new and better mine training materials and methods.

Performance Measure: This goal will be achieved to the extent that our published research findings and training interventions (1) become adopted by mine safety and health trainers and (2) are referenced and advocated by mine training and safety professionals.

Strategic Goal 5: Reduce the risk of mine disasters (fires, explosions, and inundations); and minimize the risk to, and enhance the effectiveness of, emergency responders

Historically, mine disasters (five or more fatalities per incident) have been the driving force behind enactment of mining laws and regulations and government entrance into mining health and safety research. These have occurred at irregular intervals over the last 80 years, resulting in nearly 10,000 worker deaths. Recent incidents over the past few years are stark reminders that these events can occur in the U.S. mining industry at any time and have not been eradicated. An explosion at the Jim Walter Resources No. 5 Mine in Alabama in September 2001 resulted in 13 fatalities. Another two miners were killed and eight injured in July 2000, in an explosion at the Willow Creek Mine in Utah. In another incident, the rapid inflow of millions of gallons of water into the Quecreek Mine in Pennsylvania on July 24, 2002, trapped nine miners, while nine others barely escaped in a widely publicized rescue. Emergency responders, such as mine rescue teams, are relied upon to save lives during a mine disaster. Because of the nature of these emergencies and the particularly hazardous and unique aspects of the mining environment, the responders need to be well-trained and equipped

and fully understand the hazards that they may face during exploration, rescue, and recovery operations. There are a number of issues facing the U.S. mining industry to reduce or eliminate disasters and to maintain the capability to adequately and safely respond to mine emergencies and potential mine disasters.

The major barriers to reducing or eliminating mine disasters and improving the safety and chances for successful rescue and response operations include the following:

1. An incomplete understanding of the root causes of mine fires, explosions, and inundations.
2. The lack of totally effective engineering controls to prevent, detect, and mitigate mine disasters.
3. The lack of education and training of the general mine workforce pertaining to methods to predict, prevent, and deal with mine emergencies.

Performance Measure: This goal will be achieved by reducing the number of injuries and deaths attributed to mine fires, explosions, inundations, and rescue and response activities between 2010 and 2014 by 25% compared to the average yearly totals from 1990 to 2001, as measured by MSHA accident statistics.

Intermediate Goal 5.1: Reduce the number of reportable (½ hour or longer) fires in U.S. mines by 25% in 5 years through the development of new or improved strategies and technologies in the areas of mine fire prevention, detection, control, and suppression.

Fire continues to be a serious hazard to the health and safety of our Nation's mining workforce. From 1990 through 2001, there were 1,060 fires, resulting in 560 injuries and 6 fatalities at U.S. mining operations. Fire in an underground mine is especially hazardous because of the confined space, problems with ventilation and mine gases, and, often, limited and long evacuation routes. Fire catastrophes such as the 1984 Wilburg Coal Mine fire in Utah, which clamed the lives of 27 miners, and the 1972 Sunshine Silver Mine fire in Idaho with 91 fatalities must continue to be prevented in the ever changing and technologically complex mining industry. PRL mine fire experts have examined the mining fire incidents and have developed a research program to address identified gaps in mine fire prevention, detection, control, and suppression, and are summarized by mining sector below.

The following gap areas were identified in the metal and nonmetal mining sector: potential use of inappropriate materials and materials whose combustibility have not been properly assessed, inadequate fire detection and suppression systems, lack of adequate fire safety standards, and a lack of knowledge of general fire safety principles.

In the coal sector, the following gap areas were identified: the preponderance of cutting and welding initiated fires, fires initiated by the spontaneous combustion (self-heating) of coal, and firefighting, containment, and response technologies. Analysis of fires in the coal mining sector showed that 20% were the result of either flame cutting or welding operations. The root causes of flame cutting and welding-related fires need to be determined and new and improved methodologies and technologies developed and evaluated to prevent these types of fires. Spontaneous combustion continues to be a problem for most Western mines, and the risk is being compounded by appreciable methane in these newer and future mines. Ventilation

schemes that can mitigate these two competing hazards need to be developed. Recent fires at coal mines have demonstrated an inadequate development and understanding of the technologies for remote application of extinguishing agents (foam, water, inert gas, etc.), deployment strategies for firefighting equipment (inert gas engines, foam generators, etc.), permanent and temporary fire containment sealing technology, and emergency ventilation control measures. Research must evaluate these devices and technologies under full-scale mine conditions to develop reliable deployment strategies that will help to ensure a safe and successful outcome during a mine fire. The dynamics of a coal mine fire initiation, growth and spread, smoke movement, and contaminant interaction with the ventilation are complex phenomena that are not well understood. Further research into these aspects can lead to an interactive mine fire simulator, which could then be more efficiently applied to emergency smoke management and fire suppression decisions, increasing miner safety.

Performance Measure: This goal will be achieved by reducing the number of fires in the coal and metal/nonmetal mining sectors between 2010 and 2014 by 25% compared to the average yearly totals from 1990 to 2001, as measured by MSHA mine fire statistics.

Intermediate Goal 5.2: Develop and facilitate the implementation of interventions to address currently identified shortcomings in the coal mining explosion prevention "safety net."

The recent reappearance of deadly coal mine explosions in the U.S. is alarming. Bracketed around the September 2001 sentinel event of the explosion at Jim Walter Resources (JWR) No. 5 Mine in Alabama (13 fatalities and 3 injuries) were the July 2000 explosion in at the Willow Creek Mine in Utah (2 fatalities and 8 injuries) and the McElroy Coal Mine explosion in West Virginia (3 fatalities and 3 injuries) in January 2003. These events signal that coal mine explosion incidents still take an unacceptable human toll and clearly demonstrate that some of the problems that can result in mine explosions have yet to be solved. Equally disconcerting is that certain changes affecting the underground coal industry indicate that the risk of mine explosions may increase in the near future. Among these events/changes are (1) an ongoing high level of frictional ignition incidents (62 per year over the last 5 years); (2) the impending exodus of large numbers of highly experienced miners, mining professionals, and mining enforcement personnel; (3) the depletion of "easy-to-mine" coal reserves and movement into "difficult," deeper reserves with increased amounts of methane; (4) technological and operational changes, such as higher mining productivity rates and longer and wider longwall panels that compound methane issues; and (5) the persistence of various potential ignition sources.

The recent mine explosions were studied extensively by labor, industry, and government experts. As a result, the following gaps in the explosion "safety net" were identified: (1) the lack of a full understanding of the critical parameters and their interrelationships governing the potential propagation of an ignition to a large mine explosion; (2) the lack of understanding of the mechanics and controlling parameters of explosions involving large volumes of nonuniformly mixed methane; (3) the lack of a full suite of explosion forensic investigation tools and information; (4) the need for a more complete understanding of the interaction of coal dust with the rock dust applied in mines as an explosion suppressant to insure adequately suppressed explosions; (5) the need for a more complete understanding of the process that leads to frictional ignitions; a need for a rapid, on-the-spot means to assess the explosion potential of specific mine areas; (6) the need for a means to assess that in-place mine seals are adequate to perform their function; and (7) the lack of, or

inadequate, explosion training and educational materials for the upcoming rapid influx of inexperienced miners, mine professionals, and regulators. These identified areas serve as the basis to develop research plans to address the shortcomings and form the basis for a systematic approach to explosion prevention.

Performance Measure: This goal will be achieved by reducing the number of injuries and deaths attributed to mine explosions between 2010 and 2014 by 25% compared to the average yearly totals from 1990 to 2001, as measured by MSHA accident statistics.

Intermediate Goal 5.3: Reduce or eliminate inundations in U.S. coal mines within 7 years through the development of bulkhead (structures to impound water in mines) design guidelines to be published by 2009. Also, to help reduce the safety hazard to miners from inundations, publish mine design guidelines that would mitigate or prevent inundations by 2009.

Underground mines routinely install solid structures called seals and bulkheads across mine openings for a variety of purposes. Seals are used to isolate abandoned coal mine workings that may contain a potentially explosive atmosphere from active areas of a mine. A bulkhead is used as a dam to contain water or liquidlike mine wastes (tailings or slurry) in abandoned mine workings. Bulkheads must withstand the expected hydraulic pressures exerted by water or slurry in the impoundment area behind the bulkhead. Failures of the bulkheads can result in rapid inundation of water, threatening miners' lives. Past bulkhead failures and a number of issues related to the use and design of these structures noted by experts in this area indicate the need for more robust guidelines regarding their use, deployment, and design to remove this hazard in the future.

Several gaps exist in the current knowledge base of the causes of mine inundations. These include the failure mechanisms of bulkheads constructed specifically to impound water and the inadvertent and sometimes undetected accumulation of water behind ventilation seals that fail because they are subjected to hydraulic pressures for which they were not designed. Currently, no specific engineering design criteria, construction guidelines, postconstruction inspection, or monitoring practices exist for bulkheads, nor does MSHA require that new bulkhead designs be subjected to a full-scale performance validation test. Developing sound engineering-based design criteria, construction guidelines, post construction inspection, and monitoring practices for bulkheads can significantly reduce the disaster potential associated with their failure. In addition, no mine design criteria exists to prevent or mitigate the occurrence of mine inundations in general and to increase the potential for the workers to escape.

Performance Measure: This goal will be achieved if (1) improved mine designs and comprehensive bulkhead design, inspection, and monitoring guidelines are developed and adopted by the industry (MSHA) within 5 years and (2) the number of mine inundations related to bulkhead failures are reduced by 50% within 7 years (baseline is 20 year period between 1983 and 2002). MSHA is a cooperator in this research.

Intermediate Goal 5.4: Assist the mining community to maintain and improve mine escape, rescue, and emergency response capabilities through realistic training exercises and the development and implementation of new or improved training aids and exploration, rescue, and escape technologies.

Approximately 780 underground coal mines and 240 underground metal and nonmetal mines operate in the United States, employing a workforce of 59,300. Currently, there are only 120 coal mine rescue teams and 116 metal and nonmetal mine rescue teams that can respond to an emergency at these mines. Because of the unique nature of these emergencies, rescue team members need to be well trained, physically fit, and equipped with the latest technology, and they must fully understand the hazards that will be encountered during exploration, rescue, and recovery operations. Mining is considered to be one of the most hazardous occupations, and it may be argued that mine rescue and response may be the most hazardous occupation in mining. Research is needed to develop improved tools for mine rescue and response in the mining industry. Hurdles that prohibit the use of aboveground technology in underground mines, such as permissibility issues, must be overcome. Because of the small market for this technology, partnerships with industry to bring this technology to the marketplace must be strengthened. The decrease in the number of mine rescue teams and team members is reaching a critical mass. Combined with the aging miner workforce and the economics of the coal industry, the numbers of mine rescue teams are not likely to increase and there will be an influx of highly inexperienced personnel on the existing teams. Innovative methods to recruit and train new members need to be developed and implemented.

Performance Measure: This goal will be achieved over the next 5 years through (1) the participation of 75 mine rescue teams and 2,500 miners in NIOSH-led training to improve their safety, skills, effectiveness, confidence, and teamwork for rescue and emergency operations; and (2) the incorporation of improved NIOSH-developed strategies and technologies for mine rescue and response into practice and deployment activities by at least 25% of U.S. mine rescue teams.

Strategic Goal 6: Reduce ground failure fatalities and injuries in the mining industry

Mining has the highest fatal injury rate of any U.S. industry, at more than five times the national average, and ground failures have historically accounted for up to 50% of the fatalities in underground mines. Nonfatal injuries from ground failures tend to be severe, resulting in a high percentage of lost time accidents for the mining industry. Even roof falls that do not cause an injury are significant hazards in underground mines. More than 1,400 noninjury, major, unplanned roof collapses were reported to MSHA in 2004. These roof collapses threaten miners, damage equipment, disrupt ventilation, and block critical emergency escape routes. Roof collapses also helped trigger recent mine disasters in Alabama and Utah, which together claimed 15 lives.

The structural integrity of the underground mine complex is essential to the mining operation and ensuring the ground stability of the mine complex is a significant undertaking and a specific operation for all mines. Fifteen to twenty percent of the operating costs of an underground mine complex are associated strictly with operations directly tied to preventing ground failures.

Barriers to preventing ground failure fatalities and injuries in underground mines include the need to develop models that incorporate an understanding of rock mass behavior given specific geological and geotechnical conditions (high stresses, interactions with surrounding mines), the development of technologies and strategies to prevent rock falls once the failure is understood and characterized, full-scale and accurate testing and structural characterization of newly developed support systems, and the lack of a monitoring system for identifying rock mass weakening prior to failure.

Rock bursts, coal bumps, massive pillar failures, and inundations have been identified as ground control problems that can have catastrophic consequences, often resulting in severe injuries or death, and potentially affecting an entire underground workforce. They are often characterized by large, violent rock collapses that occur without warning. Because of geologic and rock strength variability, these events continue to occur in areas that have seemingly acceptable safety factors.

The barrier to developing realistic ground failure models is actual measurements of rock mass characteristics under actual mining conditions and the formulation of specific relationships which cover the range of rock behaviors from stable to unstable conditions. Unplanned roof falls occur despite technology and specific engineering design criteria that are accurately followed. These unplanned falls can be eliminated, or at the very least have a minimal impact on the miners, if they can be characterized by the use of accurate models. Technologies and strategies for preventing unplanned roof falls under specific conditions, including high horizontal stress, weak roof rocks, skin-type rock falls, and multiple-seam mining interactions, need to be developed and experimentally tested in operating mines. The technologies would bridge the gap between the understanding of the failure mechanisms and the implementation of systems for preventing the failures.

The barrier to eliminating the injuries associated with support systems requires the full-scale performance testing of the systems under actual mining conditions. Standing roof support systems that maintain the opening between the mine roof and floor are routinely installed in all mines in an effort to prevent catastrophic roof falls from occurring, and the performance of these supports is critical to mine workers' safety. A database of support performance characteristics must be maintained and available to the entire mining community to ensure proper application of this support technology. The only laboratory for conducting the experimental full-scale tests is the Mine Roof Simulator.

The third barrier is the availability of technology to forecast or warn of impending roof falls. If an area appears to be unstable, current practice allows for the deployment of point-source monitors to evaluate the rate of entry convergence in the areas of concern. Typically, this approach is haphazard at best and has shown extremely limited success in identifying rock failures. There is currently no technology for monitoring an overall mine complex which provides accurate and timely information on the state of stability for the roof, floor, or surrounding rock layers. Recent research findings by NIOSH have identified an approach using multiple sensors (microseismic and deformations) that appears to have promise for solving the problems of rock failure forecasting. The principle barriers to deploying this technology lie in our lack of understanding of the microseismic precursor patterns associated with roof falls and the impact of local geologic and mining conditions on these same precursor patterns. There are also issues with enhancing the analysis and display of microseismic and convergence data in real-time.

Performance Measure: This goal will be achieved if (1) mine fatalities by ground failures are reduced by 50% within 8 years, (2) injuries by ground and roof support system failures are reduced by 25% within 5 years and by 50% within 8 years, and (3) unplanned roof falls are reduced by 20% within 5 years and by 40% within 8 years.

Intermediate Goal 6.1: Reduce the number of ground failures in underground mines by improved understanding of rock mass failure mechanics using in-mine experiments and numerical analysis models. Develop better methods for characterizing rock strength properties using novel techniques such as downhole electric logs and in-mine drilling analysis. This information will provide reliable input data that, when combined with a knowledge base of failure mechanisms for major failures observed in underground coal and metal/nonmetal mines, will allow the construction of accurate computer models. Using these models and the knowledge gained, develop strategies and interventions to eliminate the failures or reduce the hazard associated with the failures.

Performance Measure: This goal will be achieved if models are developed and successfully applied to explain the coal mine entry and coal mine caving/overburden response (3-year timeframe) and the failure modes caused by horizontal stresses in stone mines (4-year timeframe). The goal will also be achieved if the developed models and related knowledge, complete with appropriate design and intervention approaches, are transferred to the industry within 6 years.

Intermediate Goal 6.2: Reduce rock fall injuries in coal mines through enhanced application of roof surface control technology.

Each year more than 500 coal miners are injured and one or more are killed by relatively minor falls of rock in coal mines. These injuries are quite severe, resulting in an average of 50 lost workdays for each occurrence.

NIOSH is using a multipronged approach to reduce the number of rock fall injuries. Research is being done to determine the most effective of roof surface control technologies for different geologic environments. "Best practices" for installing surface controls using different types of roof bolting machines are also being documented. As gaps in the technology are identified, new roof surface control technologies are being developed. One example is the personal bolter screen that is currently being tested for use in thin seams and hard-to-reach roofs.

Performance Measure: This goal will be achieved by reducing the number of rock fall injuries in coal mines by 50% over the next 5 years.

Intermediate Goal 6.3: Reduce the ground control failures resulting from multiple-seam interactions through the development of design-based control technology.

More then 70% of the Nation's coal mines are located in areas where past mining has already been conducted, creating the possibility of multiple-seam interactions. Many of these mines are currently encountering ground stability problems because of concentrated ground stresses or fractured rock due to interactions from nearby mines. These interactions severely impact the stability of the mine structure, resulting in dramatic increases in roof, pillar, and floor failures. In extreme cases, dramatic collapses, possibly associated with inrushes of water, can occur. Multiple-seam instabilities have contributed to several fatalities in recent years.

NIOSH is now developing multiple-seam design guidelines that will help mine planners minimize the risk associated with multiple-seam interactions. The guidelines will integrate statistical back analysis of documented case histories with sophisticated numerical models.

Performance Measure: This goal will be achieved by (1) providing multiple-seam design guidelines to the mining industry within 3 years and (2) reducing instances of severe multiple-seam interactions by 80% within 8 years.

Intermediate Goal 6.4: Reduce the number of unplanned roof falls by developing new ground control technology for mines with low strength roofs. Develop improved mine layouts for stress control and prevention of time-dependent failure, and guidelines for effective roof support.

Coal miners working beneath a low-strength roof face significantly greater hazards from rock falls than most underground miners. MSHA statistics show that just 30 mines, accounting for about 5% of underground production, were responsible for nearly 25% of all unplanned roof falls during 1995-2002. These mines are located almost exclusively in the Illinois and northern Appalachian coal basins. Available ground control safety technologies developed for the broad range of U.S. mining conditions tend to be less useful when applied to mines with an extremely weak roof.

A low-strength roof is vulnerable to even low levels of horizontal stress. Fundamental studies are needed to explore the relationship between stress level and rock stiffness, and the relationship between depth and horizontal ground stress. Control technologies include improved mine layouts and better guidelines for rock strength characterization and support selection.

Performance Measure: This goal will be achieved when the newly developed ground control technologies are adopted by the target mine population. This is expected to result in a 50% reduction in the number of roof falls at these mines. The technologies will also be applicable to the estimated 25% of U.S. coal mines that occasionally encounter weak roof conditions.

Intermediate Goal 6.5: Development of more effective support-based ground control technology and decision logic for selecting the best support systems for specific geologic environments. Eliminate the trial-and-error application of these critical support systems.

Ground control is a fundamental aspect of all underground mining. Historically, between 30%-40% of the fatalities in underground mines are caused by inadequately supported roof rocks falling and striking the miner. Most unplanned roof falls can be attributed to incorrect application of support. Despite years of research, however, there are still many fundamental questions about issues like the role of tension in roof bolting and the interaction between primary and supplemental supports. Better guidelines for support design, based on improved ground control science, could be employed by mine planners and mine safety officials to significantly reduce the number of roof collapses.

New types of standing supports are being developed that offer improved ground control as well as better ergonomic and other advantages. Before they can be widely used with confidence, however, their characteristics must be thoroughly evaluated.

Performance Measure: This goal will be achieved if (1) 15 new standing supports are characterized over the next 5 years and if more efficient standing support systems are developed and successfully implemented in the mining industry, and (2) new decision logic for support selection and implementation is adopted by large segments of the mining industry.

Intermediate Goal 6.6: Develop a sensor-based risk-management system for roof falls in stone mines.

The fatality rate for underground nonmetal miners is 20 times higher than the average for all industrial sectors. Roof falls are responsible for a significant portion of the fatalities and injuries in underground nonmetal mines. Roof falls in these mines are rarely anticipated because significant mining heights (20-60 ft) make it difficult to recognize deteriorating conditions that might warn of impending roof failures. During 1983-2002, 936 unplanned roof falls occurred in U.S. underground nonmetal mines. About 77% of these roof falls injured miners, resulting in 15,974 lost workdays. The development of sensor-based roof fall warning technology will allow for early detection of the deteriorating conditions, removal of mineworkers, stabilization of the roof rock, and, ultimately, changes in mine plans, so that exposure of workers to these hazards can be eliminated.

The goal is to develop sensor-based technology and the accompanying fundamental knowledge that will allow us to provide some warning of roof falls over large areas of a mine. It is also important to establish where such warning technology is feasible. Currently, miners have little, if any, warning of roof falls.

Performance Measure: This goal will be achieved if a sensor-based risk-management system for roof falls is developed and used in 20% of underground stone mines within 4 years.

Intermediate Goal 6.7: Reduce rock bursts caused by high stress buildup by developing methods to asses the level of danger associated with potential rock bursts, eliminating the occurrence of rock bursts by safely reducing high rock stresses, and reducing the injuries caused by rock bursts by improving rock destressing techniques and hazard assessment technology.

Rock bursts and bumps are a small percentage of the total ground fall incidents, but because they occur in relatively few mines, they pose a higher risk to workers at those locations than industry-wide averages would suggest. For example, the rate of rock burst fatalities in the Coeur d'Alene Mining District in Idaho is eight times greater than the industry average for all causes of death.

Performance Measure: This goal will be achieved when the ground control technologies developed are adopted by 50% of the target mine population.

Strategic Goal 7: Determine the impact of changing mining conditions, new and emerging technologies, and the changing patterns of work on worker health and safety

The geologic conditions under which mining is conducted are generally becoming worse, exposing workers to increasing risks. Changing patterns of work, including workforce demographics and shift schedules, may adversely affect the safety and health of the workforce. Emerging technology may improve worker health and safety, or it may result in new hazards that compromise existing health or safety. Interventions developed by NIOSH may help mitigate health and safety hazards, but their effectiveness and extent of actual use will need to be determined.

It has been over 2 decades since the last demographics study of mine workers was performed. A new survey is needed to understand changes in the workforce and to provide accurate "denominator" data for surveillance analyses. The organization of work in the mining industry is undergoing significant changes globally, and some of these are occurring in the United States. The effect of these on worker safety and health is largely unknown, but the limited data available suggests that these changes may not all be positive. The effects need to be understood before consideration can be given to any interventions. As the mining industry has consolidated, the rate at which relevant new technologies are emerging has slowed. Nonetheless, the technologies must be studied in order to understand their potential impact on worker safety or health. Finally, changes in the industry are occurring, in part, from the introduction of NIOSH-developed interventions. The effectiveness of these interventions should be studied more formally, both to guide the research program and to promote widespread adoption of the most successful interventions.

Performance Measure: This goal will be achieved if the impacts of the changes have been identified and recommendations for mitigating adverse impacts are issued over the next 10 years. It should be noted that the intermediate goals identified here are, in most cases, looking at emerging or other issues in which the actual threat to mineworker safety and health is unclear. Accordingly, the performance measures are less quantitative than those of other strategic goals.

Intermediate Goal 7.1: Conduct a demographics survey of mine workers. Such a survey will be invaluable, not only for denominator data, but for guiding research and training activities that are necessary to prevent a sharp increase in occupational health and safety problems in the evolving workforce.

Performance Measure: This goal will be achieved by completing and publishing a comprehensive demographics survey of the mining industry by 2009.

Intermediate Goal 7.2: Document organization of work changes in the domestic and global mining industry and assess their impact on worker health and safety. Work organization refers to the way work processes are structured and managed, and it deals with subjects such as the scheduling of work, job design, interpersonal aspects of work, management style, and organizational characteristics, such as climate, culture, and communications. Work organization is influenced by factors such as economic conditions, technologic change, demographic trends (e.g., the rapid aging of the mining workforce), and changing corporate and employment practices. These trends may adversely affect work organization and may result, for example, in increased work load demands, and longer and more varied work shifts. However, the actual effects of these trends on the conditions of work and on the well-being of miners have received little study.

Performance Measure: This goal will be achieved if the impacts of organization of work changes have been identified and recommendations for mitigating adverse impacts are issued over the next 5 years.

Intermediate Goal 7.3: Examine emerging technologies for potential health and safety benefits/risks.

NIOSH sponsored two major recent studies of emerging technologies, which could have significant impact on health and safety of miners. These were published by RAND Corp. in 2001 and by the National Research Council in 2002. The identified emerging technologies will be monitored, and efforts will continue to track new developments and their impact on mining safety and health. This is a low-level effort given the relatively slow infusion of new technologies in mining, and will not require a separate project effort in the foreseeable future.

Intermediate Goal 7.4: Develop a more rigorous program to assess the effectiveness of NIOSH-developed interventions.

The effectiveness of certain safety interventions can be assessed over a relatively short period of years, whereas the effectiveness of many health interventions cannot be fully assessed in less than a worker's lifetime. Moreover, the tendency is to investigate new solutions, rather than do an assessment of past ones. This is no longer an acceptable practice; the impact of research and prevention expenditures must be better understood.

Tools must be developed or adapted to facilitate quantitative assessments of the economic impact of interventions, and models are needed to examine the efficacy of intervention alternatives in a mix of possible health and safety interventions. These tools and models should provide a modest forecasting capability, given the latency of many interventions.

Performance Measure: This goal will be achieved by (1) establishing intervention effectiveness measures for all program areas within 2 years; (2) undertaking intervention effectiveness studies within 3 years and publishing the effectiveness of interventions within 1 year of completion of each study; (3) studying mathematical tools that analyze the economic impact of interventions and, within 2 years, selecting and integrating one or more tools into the appropriate research projects; and (4) developing and evaluating a model for the aggregates industry within 4 years, distributing it publicly within 5 years, and if successful, undertaking similar efforts for other sectors of the mining industry.

Intermediate Goal 7.5: Reduce fatalities and injuries resulting from physiological stresses caused by extreme environmental combinations of climatic, geothermal, and ambient conditions in western metal and nonmetal mines.

U.S. mine workers face a work environment possessing health stressors that is unique among occupations. In addition to the whole-body vibration, chemical, particulate, noise, and gas exposures, miners endure environmental extremes, rotating and extended shifts, low light levels in underground mines, and physically demanding tasks. Many of these stressors are the subject of directed research programs in NIOSH. The combined effect of these and other stressors result in exposures which can cause acute health effects and accidents because of impaired judgment and reduced reaction times. A review of accident and illness data, as well as literature on the subject, has identified fatigue, heat strain, and cardiovascular disease-related death as problem areas where directed research has the greatest potential to reduce fatalities, illness, and injury. As such, this is an area that is being closely studied to determine an appropriate research response.

Cases of heat illness reported to MSHA are relatively rare, averaging 28 per year during 1999-2004. However, they have resulted in three deaths in the past 5 years. In order to be considered reportable to MSHA under 30 CFR 50, an incident must require medical treatment other than observation or preventative measures, have resulted in a loss of consciousness, or cause the employee to be unable to perform his/her normal job duties on subsequent days. Because of these reporting criteria, it is likely that only cases of severe hyperthermia are captured by the MSHA surveillance system. Half of all reported cases of heat illness result in lost or restricted duty, averaging 5 days per incident.

Performance Measure: This goal will be achieved through (1) development of appropriate recommendations for the mining industry to alleviate the health risks associated with physiological stress caused by extreme environmental conditions within 3 years and (2) adoption of the recommendations by 25% of the affected mines within 5 years.

Intermediate Goal 7.6: Reduce injuries and illnesses caused by chemical hazards found in mining by conducting epidemiological studies that track disease and illness.

Chemicals are essential for life processes. However, we know from other industries that toxic doses may lead to lung disease, cancer, burns, poisonings, sterility, heart and kidney disease, dermatitis, and numerous other health problems. Chemicals used in mines or produced from the mining process include fuels, lubricants, solvents, cyanide, silica, metals, and many others. Often such substances have a direct link to occupational diseases. Concerns have been raised about chemicals used in mineral processing such as acrylamide, manganese, arsenic and cyanide, as well as those used or present in mining operations, such as nickel, lead, cadmium, platinum, and mercury. The development of a database regarding the chemicals and disease and illnesses will be useful for health and safety researchers and will also further improve surveillance studies of the mining community.

MSHA recently enacted a Hazard Communication Standard in an effort to raise awareness of the hazardous chemicals in the workplace. MSHA has also acknowledged that "miners suffer numerous long-term health problems from chemicals as well. These illnesses, however, may occur years after an exposure when the relationship of illness to chemical can be difficult to see." There are important research and prevention activities based on our current knowledge, and there is an important need to assess the possible impact of chemicals that mineworkers are exposed to, in the course of their work. The former is addressed elsewhere in this Plan; the latter is the focus of this intermediate goal.

Performance Measure: This goal will be achieved if a disease and illness database for the mining industry is developed by 2008.

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1.6.1 Human Resources

Introduction

The success of the NIOSH Mining Program begins with the employees who generate the research concepts, conduct and support the research, and transfer the results to industry. Since the transfer of the Mining Program from the U.S. Bureau of Mines in 1997, the organization and the composition of the workforce has been changing in response to research priorities and funding limitations. This section provides comparative data for Fiscal Year 1998 (FY98), the first full year under NIOSH direction, and for Fiscal Year 2005 (FY05), the current organization.

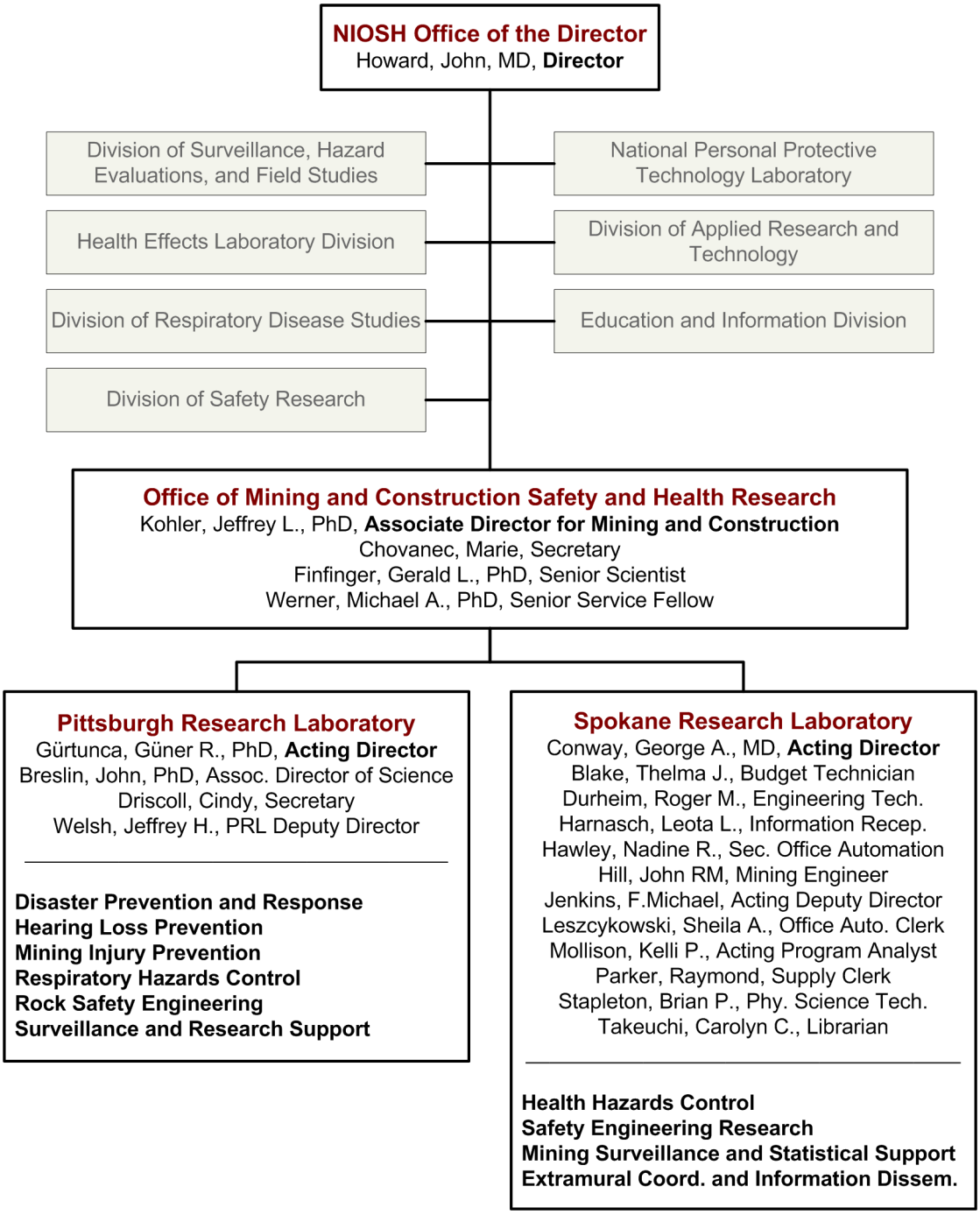
The Mining Program is under the direction of the NIOSH Associate Director for Mining and Construction, who reports to the Director of NIOSH. The research is primarily conducted by two NIOSH divisions: the Pittsburgh Research Laboratory and the Spokane Research Laboratory.

Through attrition and restructuring, the workforce has decreased by 21 employees during this time period. This decrease has allowed us to re-direct resources in response to changing programmatic needs. Despite the overall decrease in staff, we have continued with targeted hiring. We have begun using special hiring programs, such as Research Fellows, that provide opportunities for candidates with advanced degrees in scientific areas and open the hiring to include experts from around the world.

About 74% of the current 256 employees are engineers and scientists. An additional 15% are technicians. The training and experience of the scientific staff remains diverse. The engineers come from 15 different specialty areas, and the scientists are from 26 different disciplines.

We have been increasing the emphasis on the importance of advanced scientific education while still maintaining a practical, hands-on knowledge of the industry. In FY98, about 11% of the workforce had earned PhD´s. By FY05, that number had increased to 23%. We have achieved this through hiring and by committing resources to allow current, high potential employees to return to school.

Organizational Structure



Pittsburgh Research Laboratory

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DRISCOLL,C.,Secretary(Det)

WELSH,J.,DeputyDirector

BRESLIN,J.,AssocDirSci

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BAILEYS,R.,Secretary

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KOVALCHIK,P.,GenEng(ActingTL)
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McELHINNEY,P.,PhySciTech
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SPENCER,E.,MinEng
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RESPIRATORY HAZARDS CONTROL BRANCH

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PROKOP,A.,EngTech
REED,W.,MinEng
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TIMKO,R.,SupvResPhySci
TUCHMAN,D.,IndHyg
VANDERSLICES,S.,EngTech
VINSON,R.,Physicist
VOLKWEIN,J.,ResPhySci
ZIMMER,J.,PhySciTech

DIESEL

BUGARSKI,A.,MechEng
HUMMER,J.,EngTech
MISCHLER,S.,PhySci(ActingTL)
NOLL,J.,Chemist
PATTS,L.,PhySci
SCHNAKENBERG,G.,ResPhys

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MITCHELL,K.,ProgOperAsst

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BAJPAYEE,T.,MinEng
DOLINAR,D.,MinEng
DWYER,D.,EngTech
ELLENBERGER,J.,ResGeoPhys
ESTERHUIZEN,E.,SrServFellow
GEARHART,D.,ElecEng
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MORROW,G.,ElectronTech
PROSSER,L.,ResPhySci

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COMPTON,C.,EngTech
MARK,C.,SupvMinEng
MARSHALL,J.,ElectronTech
MOLINDA,G.,ResGeologist
OPFER,D.,OfcAutoAsst
OYLER,D.,MechEng
PAPPAS,D.,CivEng
ROBERTSON,S.,MinEng
ZIPF,K.,MinEng

EXPLOSIVES

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MINDA,C.,CorrClk
MYTRYSAK,C.,LogisMgmtSpec
ROWLAND,J.,ResPhys
SOBECK,R.,PhySciTech

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MYERS,K.,OAA(Det)
SAPKO,M.,SrResPhySci

VENTILATION AND EXPLOSION PREVENTION

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HOLLERICH,C.,PhySciTech
KARACAN,O.,SrServFellow
KROG,R.,AssocServFellow
MEIGHEN,M.,MinEng
SCHATZEL,S.,ResGeologist
THOMAS,R.,ElectronTech
ULERY,J.,ResGeologist
ZLOCHOWER,I.,ResChem

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EDWARDS,J.,ResPhys
FRANKS,R.,ElectronEng
FRIEL,G.,ChemEng
HWANG,C.,Expert
LITTON,C.,ResPhys
MONAGHAN,W.,ElecEng
SMITH,A.,SupvPhySci
TREVITS,M.,ResPhySci
YUAN,L.,AssocServFellow

LAKE LYNN LAB

GOFF,F.,ProgClk
HARTEIS,S.,MinEng
JACKSON,K.,ElectronTech
KARNACK,F.,PhySciTech
SELLERS,D.,PhySciTech
SLIVENSKY,W.,PhySciTech
WEISS,E.,SupvMinEng

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JANSKY,J.,PhySci
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HENNING,P.,ProgOperAsst

MSD

COOK,A.,EngTech
GALLAGHER,S.,ResPhysiol
LEWIS,P.,AssocServFellow
MATTY,T.,ElectronTech
MAYTON,A.,MinEng
McCLURE,L.,SCEP Eng
NELSON,M.,EngTech
PORTER,B.,SCEP Eng
ROSSI,E.,IndEngTech
SCHWERHA,D.,AssocServFellow
STEINER,L.,SupvGenEng
TORMA-KRAJEWSKI,J.,SrServFellow

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CAWLEY,J.,ElecEng
DUBANIEWICZ,T.,ElecEng
DUDA,F.,ElecEng
HOMCE,G.,ElecEng
MOWREY,G.,ElecEng
SCHIFFBAUER,W.,ElecTech
SHEPPARD,B.,OfcAutoAsst
YENCHEK,M.,SupvElecEng

MACHINE SAFETY

AMBROSE,D.,SafeEng
BARTELS,J.,MechEng
DuCARME,J.,MechEng
FRIES,E.,SupvGenEng
JOBES,C.,MechEng
LUTZ,T.,MechEng
MINOSKI,S.,OfcAutoAsst
SAMMARCO,J.,ElecEng
WANG,R.,MechEng

COMPUTATIONAL RESEARCH

CARILLI,A.,CompAsst(Det)
COLE,G.,CompEng
GLOWACKI,A.,CompSci
KWITOWSKI,A.,CivEng
UNGER,R.,SafeEng

HUMAN FACTORS

CALHOUN,R.,Saf&OccHlthSpec
MALLETT,L.,ResSociol
PETERS,R.,SupvSocSci
VAUGHT,C.,ResSociol
WIEHAGEN,W.,IndEng

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GRAMM,N.,Secretary(Det)

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McCONNELL,G.,PubHlthAdv
McHUGH-PEMU,K.,SCEP Epid
McWILLIAMS,L.,Statistician
PATEL,A.,SCEP Epid
PODLESNY,A.,StatAsst

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CARUSO,D.,HlthCommFellow
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TUCHMAN,R.,TechWriterEditor

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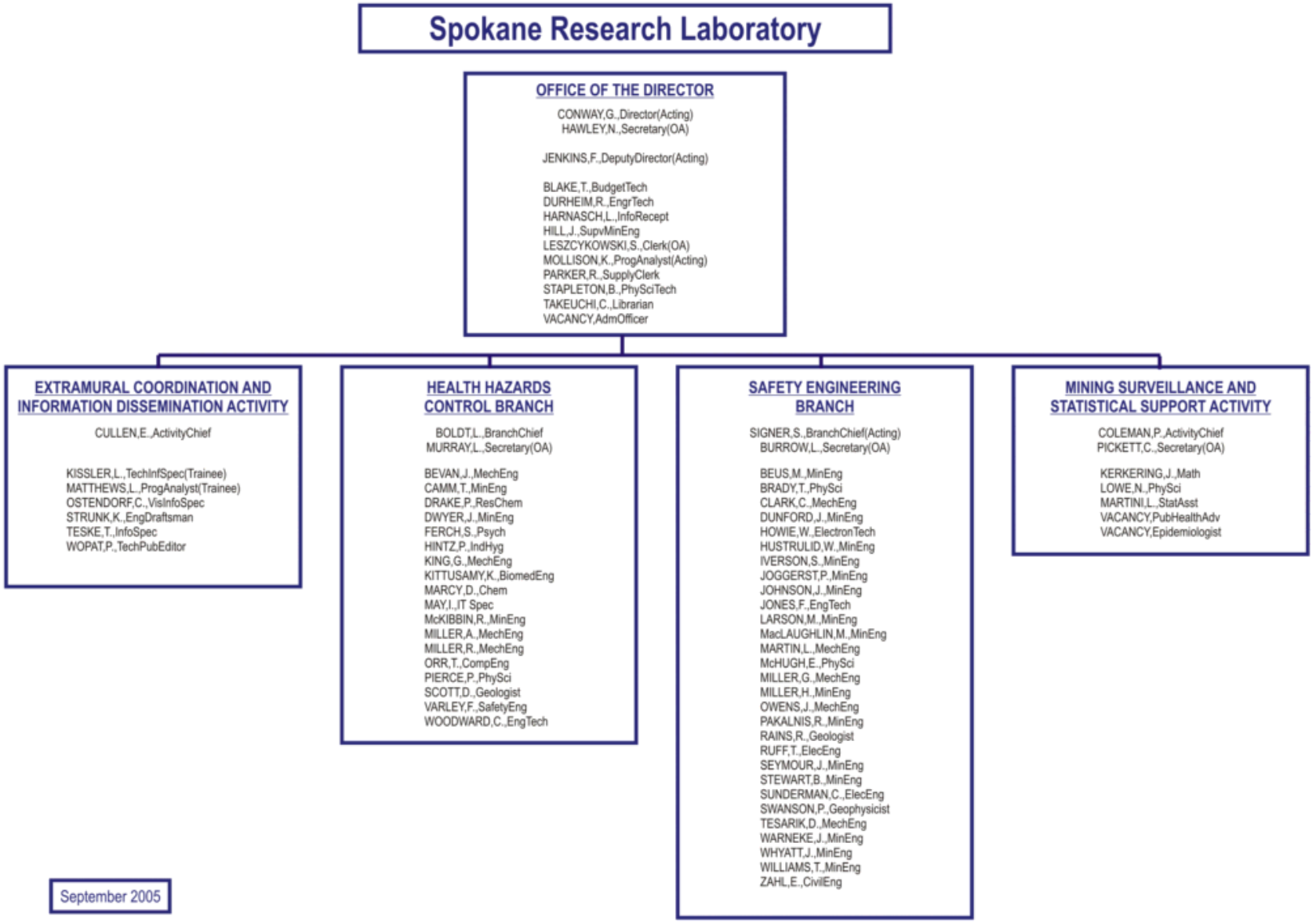
PASCOE-CONTEEN,A.,AdminOfcr

September 2005

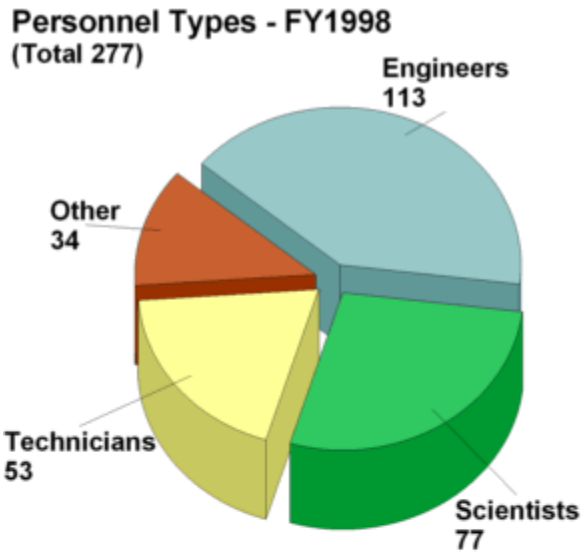
Spokane Research Laboratory

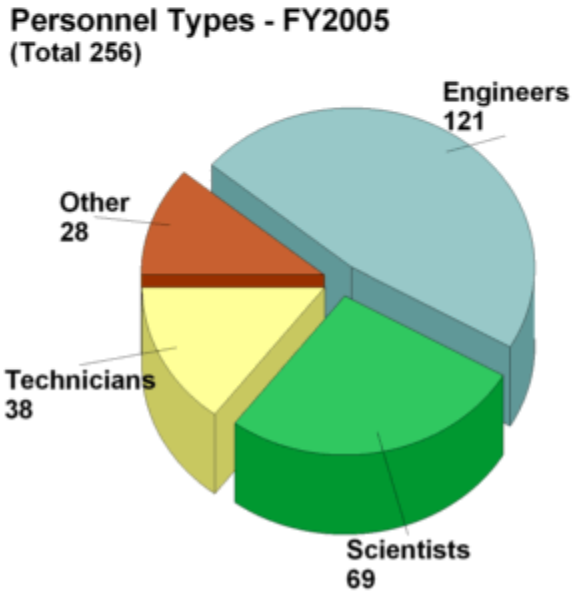


September 2005

Personnel Types

Type	FY1998	FY2005	Diff.	% Diff.
Engineers	113	121	8	7
Scientists	77	69	-8	-10
Technicians	53	38	-15	-28
Other	34	28	-6	-18
Total	**277**	**256**	**-21**	**-8**

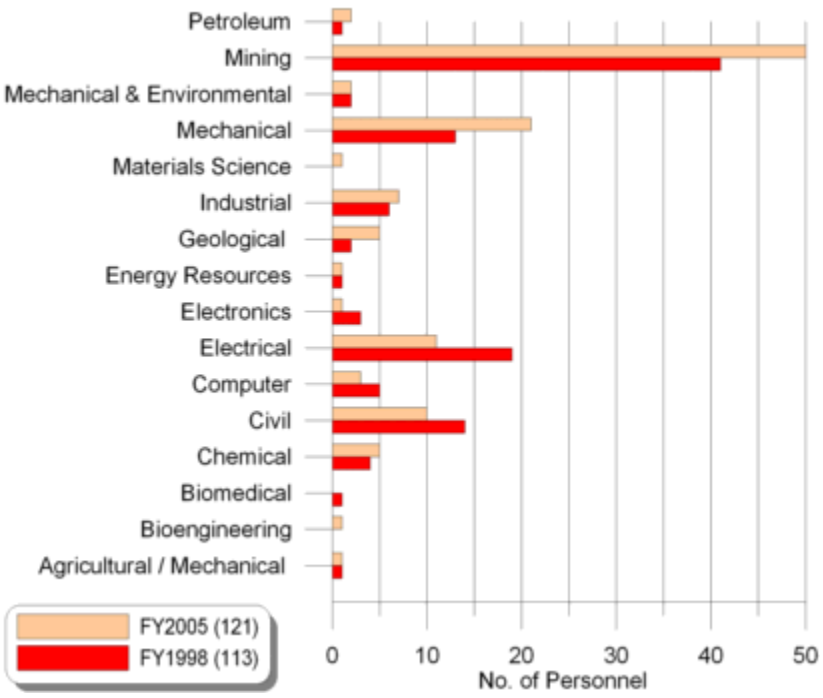




Engineering Speciality

Engineering Specialty	FY1998	FY2005
Agricultural/Mechanical	1	1
Bioengineering	0	1
Biomedical	1	0
Chemical	4	5
Civil	14	10
Computer	5	3
Electrical	19	11
Electronics	3	1
Energy Resources	1	1
Geological	2	5
Industrial	6	7
Materials Science	0	1
Mechanical	13	21
Mechanical and Environmental	2	2
Mining	41	50
Petroleum	1	2
Total	**113**	**121**

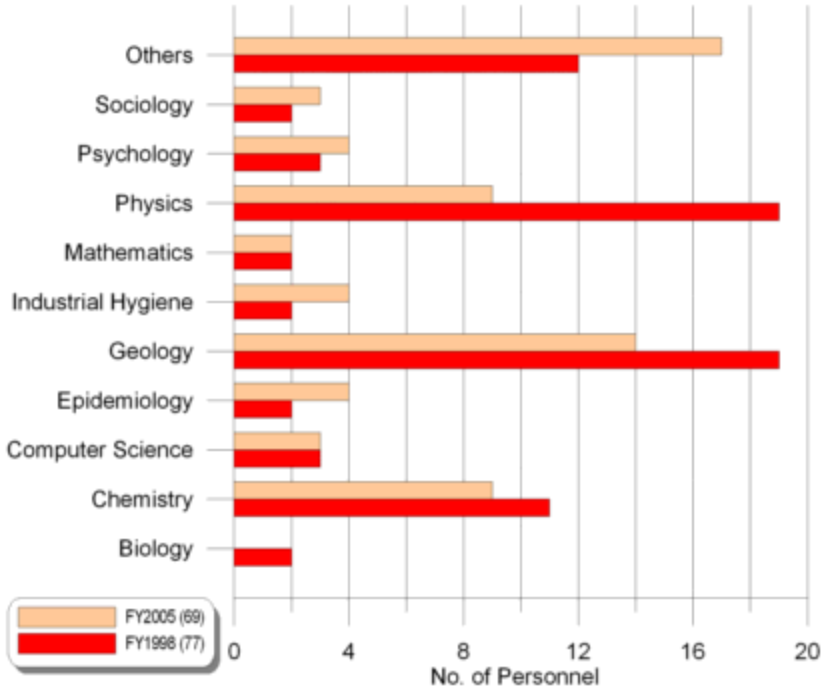
Personnel Breakdown by Engineering Specialty



Scientific Speciality

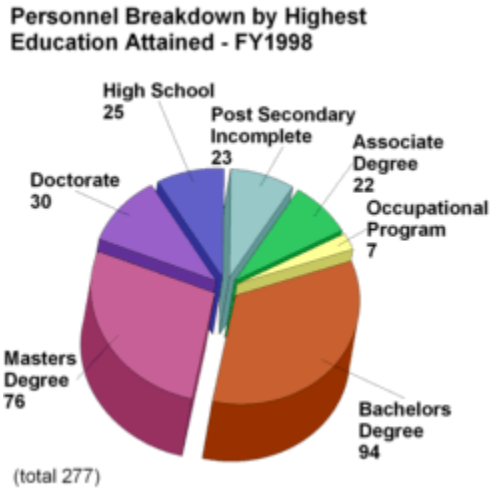
Scientific Specialty	FY1998	FY2005
Acoustics	0	1
Audiology	1	1
Biology	2	0
Chemistry	11	9
Computer Science	3	3
Earth Science	1	0
Education	1	1
Environmental Health	0	1
Epidemiology	2	4
Ergonomics	0	1
Geography	1	1
Geology	19	14
Geophysics	1	1
Health Services	1	1
Hydrology	1	0
Industrial Hygiene	2	4
Mathematics	2	2
MD, Occupational Health	0	1
Metallurgy	1	1
Microbiology	0	1
Physics	19	9
Physiology	0	1
Psychology	3	4
Public Health	0	1
Reading And Language Arts	1	1
Research Methodology	1	1
Safety Science	1	0
Sociology	2	3
Statistics	0	1
Symbolic Logic	1	1
Total	**77**	**69**

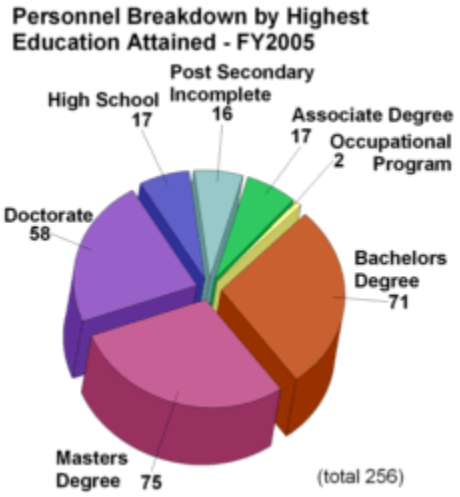
Personnel Breakdown by Scientific Specialty



Education Levels

Highest Education Attained	FY1998	FY2005	Net Diff.	% FY1998	% FY2005	% Net Diff.
Associate Degree	22	17	-5	8	7	-1
Bachelor Degree	94	71	-23	34	28	-6
Doctorate	30	58	28	11	23	12
High School	25	17	-8	9	7	-2
Masters Degree	76	75	-1	27	29	2
Occupational Program	7	2	-5	3	1	-2
Post Secondary Incomplete	23	16	-7	8	6	-2
Total	**277**	**256**	**-21**			





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1.6.2 Funding

Introduction

This section provides information on the financial resources available to the Mining Program. This section provides comparative data for Fiscal Year 1998 (FY98), the first full year under NIOSH direction, and for Fiscal Year 2005 (FY05), the current organization and some trend data for all years during this period.

The total budget for the Mining Program was relatively flat between FY98 and FY04. In FY05, Congress provided an additional appropriation that increased the Mining Program budget to $30.1 million, an increase of about 13% from the prior year.

The total budget can be divided into two major components: 1) personnel salaries and benefits (PS&B), and 2) discretionary budget. PS&&B is the largest fixed cost for the Mining Program. While PS&B can vary based on attrition and hiring decisions, it can not be quickly or easily changed. In addition, Congress provides an annual salary adjustment which can cause overall PS&B to increase even with limited hiring. Because of these forces, the discretionary budget available has decreased significantly. In FY98, 30% of the budget was discretionary, and there was about $26.6 thousand discretionary per Full-time Equivalent employee (FTE). By FY04, those numbers had fallen to 12% discretionary and only $12.9 thousand per FTE. The increased funding from Congress has brought the numbers back to 22% and $25.4 thousand. To deal with this increasing problem, we have limited hiring to a few key positions each year which has resulted in 21 less FTE. Discretionary spending decisions are closely monitored. We have limited conference participation, conducted field work at locations that will not involve travel, and prolonged the replacement of aging equipment and instruments.

The budget and FTE numbers are also shown by strategic goal. An extra category, 'Multiple Goals,' is shown to include projects that support more than one goal area. This includes projects responsible for technology transfer / health communications, support of the Lake Lynn Laboratory, and mining research planning and leadership.

Emphasis on strategic goals and changing research priorities has also led to a shift in how the discretionary funding and staffing is allocated. The most dramatic increase has been in the Hearing Loss Prevention area. Prior to FY98, we only had a very small program. We began building the laboratories and infrastructure in FY98. At that time, we only had 9 FTE working on this goal. By FY05, that number had increased to 25. The Respiratory Hazards area has also grown as we have increased staffing related to the personal dust monitor and diesel research. Since the total budget remained relatively flat, these increases had to be offset by decreases in Traumatic Injury and Disaster Prevention & Response.

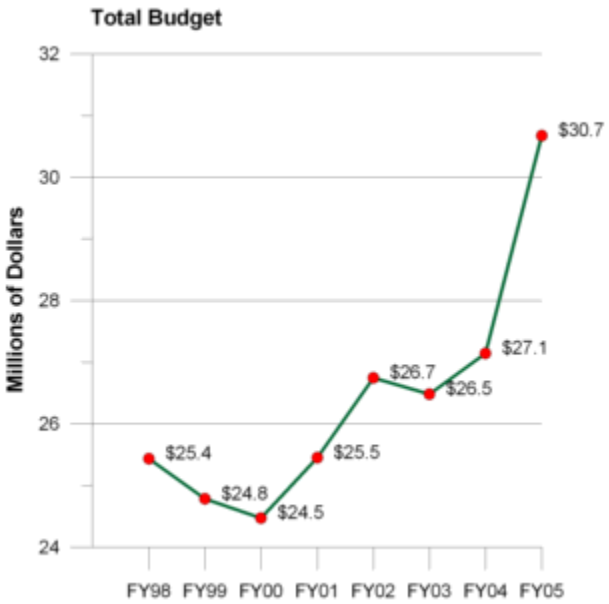
Financial History

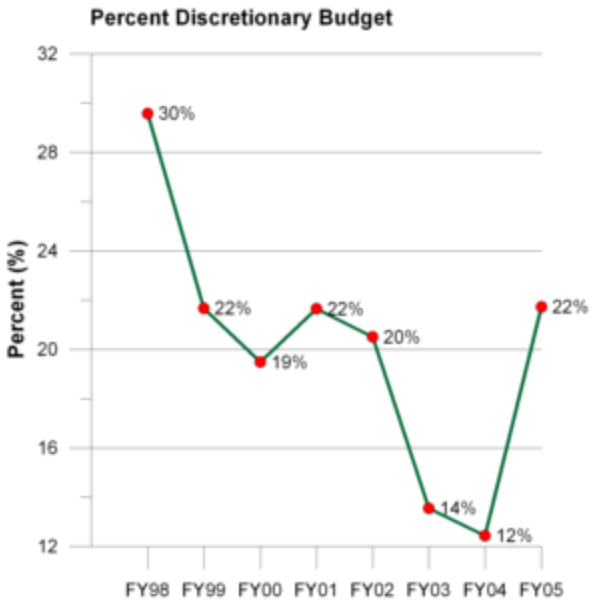
Millions of $

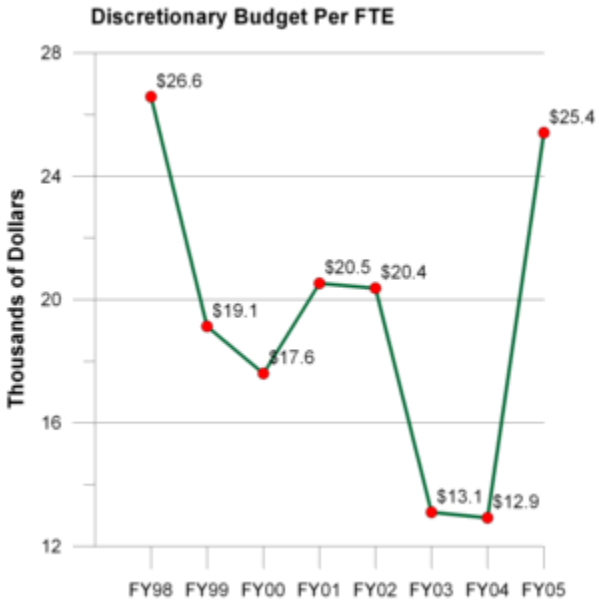
	FY1998	FY1999	FY2000	FY2001	FY2002	FY2003	FY2004	FY2005
Total Budget	$25.4	$24.8	$24.5	$25.5	$26.7	$26.5	$27.1	$30.7
Discret. Budget	$7.5	$5.4	$4.8	$5.5	$5.5	$3.6	$3.4	$6.7
% Discret.	30%	22%	19%	22%	20%	14%	12%	22%

Thousands of $

	FY1998	FY1999	FY2000	FY2001	FY2002	FY2003	FY2004	FY2005
FTEs	283	281	271	268	269	274	261	262
Discret. per FTE	$26.6	$19.1	$17.6	$20.5	$20.4	$13.1	$12.9	$25.4




Percent Discretionary Budget
Percent (%)
32
28
24
20
16
12
30%
22%
19%
22%
20%
14%
12%
22%
FY98 FY99 FY00 FY01 FY02 FY03 FY04 FY05


Discretionary Budget Per FTE
Thousands of Dollars
28
24
20
16
12
$26.6
$19.1
$17.6
$20.5
$20.4
$13.1
$12.9
$25.4
FY98 FY99 FY00 FY01 FY02 FY03 FY04 FY05

Total Budget by Goal

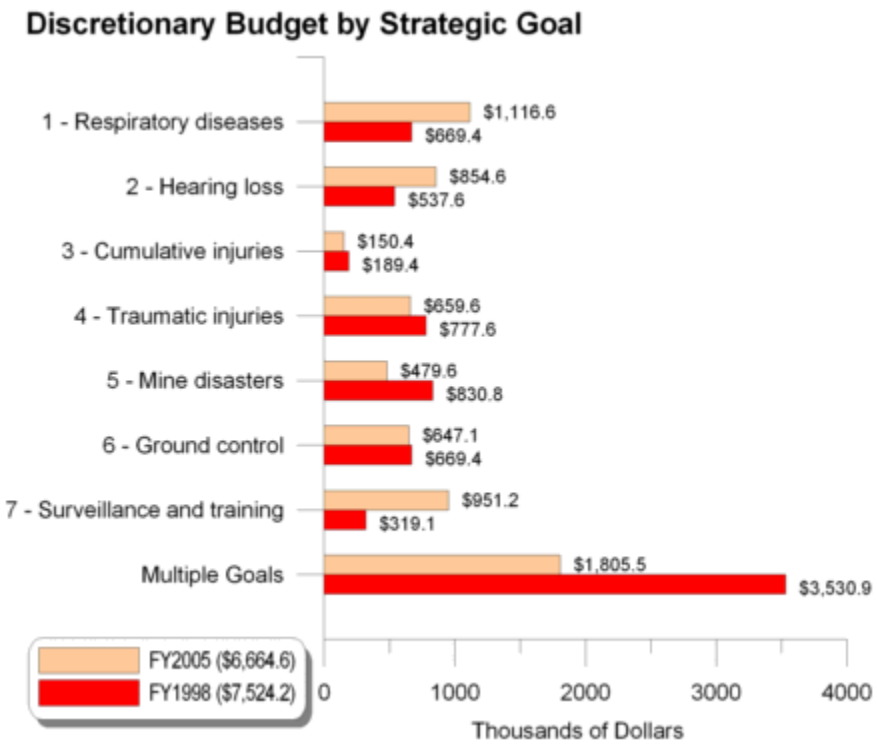
Thousands of $

Strategic Goal	FY1998	FY2005
1- Respiratory diseases	2518.2	4599.8
2 - Hearing loss	1096.8	3138.6
3- Cumulative injuries	1212.9	2023.9
4 -Traumatic injuries	5237.3	4125.9
5 - Mine disasters	4218.4	3862.2
6- Ground control	3761.9	4835.7
7- Surveillance and training	1581.2	3646.4
Multiple Goals	5810.4	4442.4
Total	**25437.1**	**30674.9**

Discretionary Budget by Strategic Goal

Thousands of $

Strategic Goal	FY1998	FY1999	FY2000	FY2001	FY2002	FY2003	FY2004	FY2005
1 - Respiratory diseases	669.4	870.6	793.9	1368.3	634.3	575.4	558.1	1116.6
2 - Hearing loss	537.6	336.5	515.1	554.5	693.1	314.8	345.6	854.6
3 - Cumulative injuries	189.4	204.2	192.7	263.8	205.1	153.5	229.6	150.4
4 - Traumatic injuries	777.6	448.6	502.5	672.1	549.5	349.5	452.9	659.6
5 - Mine disasters	830.8	693.3	605.9	531.7	612.3	409.1	251	479.6
6 - Ground control	669.4	672.8	714.6	634.4	551.9	489	336	647.1
7 - Surveillance and training	319.1	569.5	473.3	398.7	597.2	438.9	341.9	951.2
Multiple Goals	3530.9	1547.7	969.4	1085.9	1640	858.6	861.2	1805.5
Total	**7524.2**	**5343.2**	**4767.4**	**5509.4**	**5483.4**	**3588.8**	**3376.3**	**6664.6**



Full Time Employees (FTE) by Strategic Goal

Strategic Goal	FY1998	FY1999	FY2000	FY2001	FY2002	FY2003	FY2004	FY2005
1 - Respiratory diseases	30	32	33	33	40	37	37	38
2 - Hearing loss	9	14	18	30	26	23	27	25
3 - Cumulative injuries	16	17	19	20	19	19	20	20
4 - Traumatic injuries	70	46	36	37	40	38	42	37
5 - Mine disasters	56	56	60	46	44	44	40	38
6 - Ground control	48	44	42	39	39	42	41	46
7 - Surveillance and training	20	35	31	34	32	36	28	30
Multiple Goals	36	35	32	30	30	37	26	28
Total	**285**	**279**	**271**	**269**	**270**	**276**	**261**	**262**

1.6.3 Physical Infrastructure

Introduction

The National Institute for Occupational Safety and Health has many unique physical resources that provide researchers with the tools and environment to conduct world-class research in solving the health and safety problems affecting our nation's mine workers. These physical resources include state-of-the-art laboratories, one-of-a-kind facilities, and research mines. The research mines, and a number of the facilities and laboratories, allow researchers to conduct full-scale experiments before testing an intervention at a working mine site. NIOSH maintains and operates these facilities according to applicable standards and practices.

Pittsburgh Research Laboratory

Spokane Research Laboratory

This section lists the physical infrastructure resources of the NIOSH Mining Research Program. For the purposes of this information system, these resources are organized into the categories of Facilities, Laboratories, and Major Equipment:

- **Facilities** are locations which do not have a formal Standard Operating Procedure (SOP) or Protocol
- **Laboratories** are locations which have a formal SOP, or Protocol
- **Major Equipment** are the more important equipment associated with a laboratory or facility

Lake Lynn Laboratory

The site listed for each resource is its actual physical location, and is either PRL (Pittsburgh Research Laboratory), SRL (Spokane Research Laboratory), LLL (Lake Lynn Laboratory), or MIS (Missile Test Site).

Missile Test Site

The Pittsburgh Research Laboratory (PRL) site is 13 miles south of Pittsburgh. It consists of a 180-acre campus with a number of office and laboratory structures, along with an Experimental Mine and Safety Research Coal Mine. The Experimental Mine was developed in 1910 when the US Bureau of Mines was established, mainly to study coal mine fires and explosions. The Safety Research Coal Mine, which became operational in the early 1970s, is a room-an-pillar operation about the size of a working section in a commercial coal mine. Other unique facilities at PRL include the Mine Roof Simulator, the Acoustical Testing Laboratory, the Full-Scale Longwall Dust Gallery, and the Human Performance Research Mine.

The Spokane Research Laboratory (SRL) site is located just north of the downtown Spokane, Washington business area. It consists of a 2-story office and laboratory complex and associated buildings. One major equipment, the IMPAC 3636 Mark II free fall shock testing machine, is used to simulate impulsive forces experienced by heavy equipment operators that may contribute to sprains and strains and other lower back injuries.

The Lake Lynn Laboratory (LLL) is located 50 miles southeast of Pittsburgh. It consists of an underground limestone mine and surface quarry area. The underground mine portion is a sophisticated underground facility for conducting large-scale explosion trials and mine fire research. Entries are sized to match those of commercial mines, making them authentic, full-scale test galleries. Other facilities located at LLL are the Hydrostatic Testing Chambers for Mine Seals, the Fire Gallery, the Fire Suppression Facility, and the Explosives Testing Site.

The Missile Test Site (MIS) is an old Department of Defense missile launch location about 20 miles west of Spokane. This site consists of 20 acres of land and an underground and surface building complex. The site allows for various full-scale experiments to be conducted to support the mining research program. A unique laboratory is the Dynamic Materials Testing Laboratory, developed to characterize the response of rock to explosive loading.

Facilities

13 Facilities

Site	Facility	Purpose	Strategic Goals
PRL	Anechoic Chamber	Provides a reflection free environment for acoustic testing	Hearing loss
PRL	Bombproof 142	Assessing the quality and performance characteristics of explosive materials	Traumatic injuries
LLL	DC Trolley Railway System	A test bed for experiments involving DC trolley/track haulage equipment	Traumatic injuries
PRL	Explosives Testing Pond	Underwater testing of explosives	Traumatic injuries
LLL	Explosives Testing Site (Plateau)	Explosives testing	Traumatic injuries
LLL	Explosives Testing Site (Upper Quarry)	Explosives testing	Traumatic injuries
LLL	Fire Gallery	Evaluating the fire hazards of mine materials; fire fighting	Mine disasters
LLL	Fire Suppression Facility	A large-scale, state-of-the-art fire test facility	Mine disasters
PRL	Human Performance Research Mine	Simulating mining tasks and determining potential interventions for tasks with exposures to ergonomic risk factors	Cumulative injuries; Traumatic injuries
LLL	Lake Lynn Experimental Mine	Large-scale explosion trials and mine fire research	Ground control; Mine disasters; Respiratory diseases
LLL	Mine Fire Preparedness Facility	Evaluating technology and methods for fire suppression and conducting firefighting training	Mine disasters
PRL	Safety Research and Experimental Coal Mines	Testing new procedures and technologies in a mine setting	Cumulative injuries; Ground control; Hearing loss; Mine disasters; Respiratory diseases
LLL	Simulated Underground Mine Facility	A simulated borehole and underground coal mine entry for studying mining techniques and processes	Mine disasters

Laboratories

30 Laboratories

Site	Laboratory	Purpose	Strategic Goals
PRL	Acoustical Testing Laboratory	Sound power level testing of large mining and construction equipment	Hearing loss
PRL	Aerosol Physics Laboratory	Testing and development of new aerosol monitoring instruments	Respiratory diseases
PRL	Auditory Research Laboratory	Sound-treated room and hearing-protector test chamber for conducting hearing loss research	Hearing loss
SRL	Chemistry Laboratory	Provides a range of wet chemistry techniques to develop both lab-based and field- portable analytical methods	
PRL	Diesel/Aerosol Research Laboratory	Analysis of diesel samples collected in the laboratory and field for elemental and total carbon and creation of an aerosol atmosphere simulating that seen in an underground mine	Respiratory diseases
MIS	Dynamic Materials Testing Laboratory	Characterization of the response of rock to explosive loading	Ground control
PRL	Full Scale Continuous Miner Dust Gallery	Evaluation of technologies for control of respirable dust and face methane gas on continuous mining machines	Respiratory diseases
PRL	Full Scale Face Ventilation Gallery	Evaluation of the effectiveness of face ventilation systems for removing and diluting methane gas liberated at the face and sampling methodologies used to assess face methane levels	Mine disasters
PRL	Full Scale Longwall Dust Gallery	Development and testing of new dust control technologies for longwall mining operations in underground coal mines	Respiratory diseases
PRL	Gas Content Testing Laboratory	Measurement of the methane content of coal core samples	Mine disasters
PRL	Hearing Loss Prevention Unit	Mobile lab for taking hearing loss prevention research to workers and their families	Hearing loss
PRL	Hemi-Anechoic Laboratory	Noise source identification testing	Hearing loss
SRL	Human Factors Engineering Laboratory	Evaluating and reducing musculoskeletal injuries resulting from improper design of mobile mining equipment	Cumulative injuries
LLL	Hydrostatic Testing Chambers for Mine Seals	Full scale pressure loading of mine ventilation seals	Mine disasters
SRL	Industrial Hygiene Laboratory	Provides support for industrial hygiene field investigations and projects	
SRL	Instrumentation Laboratory	Designing and constructing prototype instruments in support of research	Ground control
LLL	Lake Lynn Cannon Gallery	Evaluating the hazards of explosives in a flammable gas and/or combustible dust atmosphere	Mine disasters
LLL	Lake Lynn Diesel Laboratory	Evaluation of diesel emissions control technologies and characterization of ultrafine and nanometer aerosols and gases emitted by diesel-powered vehicles	Respiratory diseases

Site	Laboratory	Purpose	Strategic Goals
PRL	Microbalance Laboratory	Gravimetric analysis of dust samples	Respiratory diseases
PRL	Mine Electrical Laboratory	A safe, secure, and properly equipped facility for conducting mine electrical safety research	Traumatic injuries
PRL	Motion Analysis Laboratory	Testing new work methods and equipment in an environment that minimize risk of injury and permits the collection of data with instrumentation not suitable for use in a mine environment	Cumulative injuries; Traumatic injuries
PRL	MTS Rock Mechanics Testing Laboratory	Small scale testing of materials	Ground control
PRL	Physical Strength Laboratory	Measuring the static and dynamic physical strength capabilities of mine workers	Cumulative injuries
PRL	Safety Structures Testing Laboratory	Large scale material and structural testing to prevent roof and rib falls	Ground control
SRL	Seismic Laboratory	Supports field measurement and analyses of seismic event activity produced by dynamic rock mass failures	Ground control
PRL	Sensors Laboratory	Testing wearable sensors and wireless networks for real-time protection of miners from work related hazards	Traumatic injuries
SRL	Soil/Rock Properties Laboratory	Provides the capability to wash, screen, dry, and mix unconsolidated materials such as soils prior to testing by various test frames	Ground control
PRL	Toxic Fumes Laboratory (Surface)	Determining the toxic fumes produced by high explosives	Traumatic injuries
PRL	Toxic Fumes Laboratory (Underground)	Detonation of large, confined charges in a controlled volume and sampling of the resulting fumes	Traumatic injuries
PRL	Whole Body Vibration Laboratory	Measuring whole body vibration exposure and testing seating and suspension systems that isolate equipment operators from vehicle vibrations	Cumulative injuries; Traumatic injuries

Major Equipment

35 Major Equipment Resources

Site	Equipment	Purpose	Facility	Laboratory	Building	Strategic Goals
PRL	20-Liter Explosion Chamber	Measuring the explosion characteristics of dusts, gases, and hybrid mixtures			143	Mine disasters
MIS	60 mm Split Hopkinson Pressure Bar	Measuring the dynamic strength attenuation of materials used in close proximity to blasting		Dynamic Materials Testing Laboratory		Ground control
SRL	AMTI Biomechanics Platform	Study of landing forces (as operator exits from the cab) and postural stability and their relationship to musculoskeletal injuries		Human Factors Engineering Laboratory		Cumulative injuries
PRL	Bruel & Kjaer Investigator 2260 Hand-Held Analyzer	A hand-held, 2-channel analyzer capable of making broadband and real-time octave band measurements			154	Hearing loss
PRL	Bruel & Kjaer Investigator 2260 with Sound Intensity Probe	Measuring the sound intensity radiating off of an object or machine; locating noise sources on complex pieces of machinery			155	Hearing loss
PRL	Bruel & Kjaer PULSE Multi-Analyzer System	A multi-channel data acquisition system that provides real time acoustical data collection and analysis		Acoustical Testing Laboratory	154	Hearing loss
SRL	Direct Shear Test Frame	Biaxial testing on rock, concrete, and soil samples from 1 inch square to 14 inch blocks		Soil/Rock Properties Laboratory		Ground control
MIS	Drilling Equipment	Provides the ability to obtain core samples and to install test equipment both on the surface and underground				Ground control

Site	Equipment	Purpose	Facility	Laboratory	Building	Strategic Goals
PRL	Earthen Bermed Magazines	Magazines for safe storage of explosives				Traumatic injuries
SRL	Fiber Panel Testing Device	Portable field testing device for gathering information on initial breaking strengths of shotcrete		Soil/Rock Properties Laboratory		Ground control
PRL	Fletcher HDDR-13-C-F Roof Bolting Machine	Testing noise controls for roof bolting machines to determine effectiveness of the controls in a laboratory environment prior to testing in operating mines			152	Cumulative injuries; Ground control; Hearing loss
PRL	Frictional Ignition Apparatus	Studying frictional ignitions and methods to prevent their occurrence			152	Mine disasters
PRL	Hipotronics 100-KV AC and DC High Voltage Sources	Provides electrical power for experiments where high voltages must be applied to electrical power system components such as mine electrical cables		Mine Electrical Laboratory	151	Traumatic injuries
PRL	Hipotronics 750-KVA Three-Phase and DC Power Source	Provides electrical power for experiments involving power system components such as electrical cables, motors, and circuit protection devices		Mine Electrical Laboratory	151	Traumatic injuries
SRL	ICP Plasma Spectrometers	??		Chemistry Laboratory		
SRL	IMPAC 3636 Mark II Free Fall Shock Testing Machine	A free-fall testing machine that can perform a wide range of shock tests		Human Factors Engineering Laboratory		Cumulative injuries
PRL	Joy 14CM9 Continuous Mining Machine	To study mining tasks and machine interventions related to continuous mining operations			152	Hearing loss; Traumatic injuries

Site	Equipment	Purpose	Facility	Laboratory	Building	Strategic Goals
PRL	Joy 3FCT-4 Flexible Conveyor Train	A continuous haulage system used to study mining tasks and machine safety			152	Traumatic injuries
PRL	Large Fumes Chamber	Determining toxic fumes produced by explosives		Toxic Fumes Laboratory (Surface)	117	Mine disasters
PRL	Large Spherical Explosion Chamber	Measuring the explosion characteristics of gases and the toxic fumes produced from the detonation of high explosives		Toxic Fumes Laboratory (Surface)	117	Mine disasters
PRL	LMS Pimento Portable Noise and Vibration Analyzer	A portable device for measuring sound pressure levels, vibration, and frequency response functions of a structure in the field			154	Hearing loss
PRL	MB Dynamics 110 Electromechanical Shakers	Pinpointing areas on structures that have the highest vibrations			153	Hearing loss
SRL	Million Pound Compression Test Frame	Testing specimens up to 6 inches in diameter for determining unconfined compressive strength and rock modulus		Soil/Rock Properties Laboratory		Ground control
PRL	Mine Roof Simulator	Evaluating the integrity, stability, and load performance of large structures and equipment		Safety Structures Testing Laboratory	155	Ground control
LLL	Mobile Diesel Powered Propeller Fan	A mobile, self-sufficient source of ventilation airflow for performing on-site research in specific areas of large-opening underground mines, independent of the operator´s infrastructure	Lake Lynn Experimental Mine			Mine disasters; Respiratory diseases

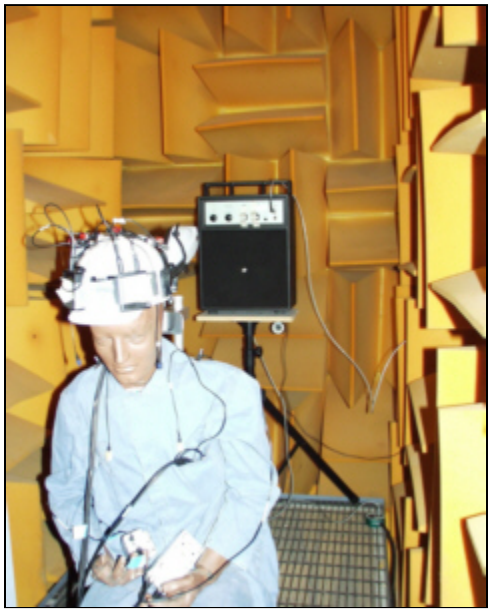
Site	Equipment	Purpose	Facility	Laboratory	Building	Strategic Goals
PRL	Motion Analysis Eagle i Motion Analysis Capture System	Quantitative assessment of a subject´s task by providing comparative or absolute measurement of various motions involved in the task		Motion Analysis Laboratory	152	Cumulative injuries; Traumatic injuries
PRL	OROS OR38 Multi-Analyzer/Recorder	A portable, 8-channel device for measuring sound and vibration level in 1/3-octave bands			154	Hearing loss
SRL	Programmable Controlled Tension-Compression Test Frame	Cyclic loading for earthquake simulation and fatigue evaluations		Soil/Rock Properties Laboratory		Ground control
PRL	Robotron 50-KA High Current Source	Provides electrical current for testing power system components such as fuses, circuit breakers, and conductors		Mine Electrical Laboratory	151	Traumatic injuries
PRL	Scanning Electron Microscope And X-Ray Elemental Analysis System	High-resolution imaging and x-ray elemental analyses of particles and other solids related to mine explosion research and forensic studies			143	Mine disasters
PRL	Servo Controlled MTS Load Frame	Materials testing		MTS Rock Mechanics Testing Laboratory	156	Ground control
LLL	Small Scale Burn Tunnels	Evaluating combustible materials and ventilation impact in mine atmospheres				Mine disasters
PRL	Temporary Magazine	Magazine for explosives received after hours				Traumatic injuries
SRL	Tension-Compression Test Frames	Measuring the physical properties of materials		Soil/Rock Properties Laboratory		Ground control
PRL	Vibration Table	Studying whole body vibration		Whole Body Vibration Laboratory	153	Cumulative injuries; Traumatic injuries

NIOSH Mining Facility

Anechoic Chamber

The Anechoic Chamber provides a reflection free (free-field) environment for acoustic testing. It is 1.3m wide by 2.6m long by 2.3m high interior wedge tip to wedge tip. The wedges are .71m long which yields a low frequency cut-off of 120 Hz. The chamber was recently used in an experiment to determine the effects of sound source position on measured noise exposure. For the experiment, it was necessary to insure that measurements were made in an environment that was free of acoustic reflections down to 150 Hz. The anechoic chamber provided the ideal location for these tests. The chamber can also be used for measuring the sound power of small devices.

Strategic Goals: Hearing loss
Site: Pittsburgh Research Laboratory
Building: 154



Interior of anechoic chamber

NIOSH Mining Facility

Bombproof 142

This bombproof facility is used to conduct experiments that examine both quality and performance characteristics of explosive materials. The facility can totally contain the detonation of 5 lb of explosives and has provisions for electronic instrumentation.

Strategic Goals: Traumatic injuries
Site: Pittsburgh Research Laboratory
Building: 142

The Bombproof facility

NIOSH Mining Facility

DC Trolley Railway System

The DC Trolley Railway System provides a test bed for experiments involving DC trolley/track haulage equipment. A 300-kW, 300-V DC rectifier supplies power to the system which features 4/0 AWG, figure-eight trolley wire and 42 in gauge track. A 316 ft straightaway is installed on a 4% grade. A 10-ton locomotive and several 10 ton rotary dump cars, stored on a 130 ft spur, are available for use.

Strategic Goals: Traumatic injuries
Site: Lake Lynn Laboratory

A mine locomotive is operated up the sloped track at the Lake Lynn Railway

NIOSH Mining Facility

Explosives Testing Pond

The Pittsburgh Research Laboratory possesses a 177-ft diameter, 25-ft deep pond in which underwater shots of explosives may be conducted. The pond was constructed specifically for explosives research. Underwater testing of explosives is a standard technique for determining the strength of an explosive. Typically, a 10-lb explosive charge is lowered into the pond, with pressure transducers suspended in the water nearby to record the pressure pulses produced by the detonation.

Strategic Goals: Traumatic injuries
Site: Pittsburgh Research Laboratory

Explosives Testing Pond

NIOSH Mining Facility

Explosives Testing Site (Plateau)

The plateau Explosives Testing Site is located off of the road leading to the fan house at the Lake Lynn Laboratory. This area was originally constructed to provide increased environmental controls for several of the explosive burn tests. The site consists of a 125-ft by 125-ft concrete pad. The pad has been constructed so that all drainage off the concrete pad can empty into a 500 gallon concrete tank; this provides for environmental containment in the event of a spill. A 16-ft high woven wire fence with gates surrounds the concrete pad; this fence assists in containing debris that may be ejected during a burn test and secures the area between tests. An instrument shed is located a safe distance away from this test site to serve as the control center. Power is provided to the site through underground lines. This site can be used for many other types of research where a large, secured area is needed.

Strategic Goals: Traumatic injuries
Site: Lake Lynn Laboratory

Researcher assessing the condition of a detonator transport container following a burn at the Explosives Testing Plateau

NIOSH Mining Facility

Explosives Testing Site (Upper Quarry)

The Explosives Testing Site located in the upper quarry section of the Lake Lynn Laboratory occupies approximately 50,000 ft^2 of gently sloping quarry bottom and is separated from the Mine Fire Preparedness Facility by a 50-ft high earthen berm which provides protection during the testing of explosives. This explosives area contains a 1,000 ft^3 horizontal gallery and two vertical galleries, several specially constructed bunkers, a 25-ft-high, 15-ft-wide steel retaining wall, a 12-m drop tower with electric winch and lift magnet, and concrete burn pads. Natural gas, power, and instrument lines are installed to several of these test facilities. Video cable is also installed to this area to permit viewing of the explosive tests from a safe vantage point or from within the Main Office building. An instrumentation control shed is located on the other side of the earthen berm. A secured explosive magazine site is also available to facilitate the explosive studies.

Strategic Goals: Traumatic injuries
Site: Lake Lynn Laboratory
Laboratories: Lake Lynn Cannon Gallery

Dust explosion venting from the large vertical gallery; 12-m drop tower can be seen in the background

NIOSH Mining Facility

Fire Gallery

The Fire Gallery consists of a 90 ft long arched roof tunnel that is coupled to a 6 ft diameter axivane fan by a 20 ft transition section. The cross-sectional area of the tunnel is 84 square feet. The tunnel is equipped with temperature sensors and gas sampling lines. Associated structures include a control room/shop trailer and instrumentation shed.

The Fire Gallery is used to evaluate the fire hazards of mine materials, such as conveyor belting, at various air velocities. Conveyor belt samples up to 50 ft in length are mounted on a typical belt structure and ignited at one end by a gas torch or liquid fuel fire. Flame spread rates and downstream gas compositions and temperatures are measured. The Gallery is also used to train fire brigades and mine rescue teams on the proper procedures to fight conveyor belt fires and liquid fuel fires with water lines and high expansion foam in a confined space.

Strategic Goals: Mine disasters
Site: Lake Lynn Laboratory

Firefighter training at the Lake Lynn Fire Gallery

NIOSH Mining Facility

Fire Suppression Facility

The Fire Suppression Facility (FSF) was constructed to evaluate the effectiveness of fire suppression systems for the extinguishment of diesel fuel fires. The fire tunnel is tee-shaped to simulate a crosscut off a main entry. The main entry is 153 ft long and the crosscut is 40 ft long. Each entry is 18 ft wide and 7 ft tall to simulate modern mine entry dimensions. The crosscut area and 75 ft of the main entry are fireproofed and instrumented with thermocouples, gas monitoring instrumentation, and video equipment to monitor fire tests in progress. The FSF has a 2000 gal closed water system, in which all water is collected, filtered, and stored for re-use, to comply with all environmental regulations. In addition, a 100 h.p., pneumatically controlled, variable speed mine fan was installed in the main entry for experiments under ventilated conditions.

The FSF has also been used to study the flammability of mine combustibles under realistic, full-scale conditions. Among the materials evaluated are hydraulic fluids, diesel fuel, noise materials, and conveyor belting. A burn pad was added to the facility in order to conduct full-scale equipment cab fire detection and suppression experiments.

Strategic Goals: Mine disasters
Site: Lake Lynn Laboratory

The Fire Suppression Facility at the Lake Lynn Laboratory

NIOSH Mining Facility

Human Performance Research Mine

Due to the dynamic nature of the mining environment, an actual operating mine is not suitable for most worker task studies. The Human Performance Research Mine allows researchers to study task specific risk factors and ergonomic intervention possibilities in a simulated underground mine setting with actual mining equipment. Studying these tasks and interventions before introducing them to the field helps to ensure useable and effective designs. Each study can be performed with varying seam heights and entry widths. The simulated mine accommodates portable EMG and Motion Analysis systems, making possible detailed research on the physical requirements of mining tasks and the capabilities of mine workers. The research mine is also available to support studies in other NIOSH focus areas.

Strategic Goals: Cumulative injuries; Traumatic injuries
Site: Pittsburgh Research Laboratory
Building: 152

Testing physical requirements and intervention alternatives for roof screening tasks

NIOSH Mining Facility

Lake Lynn Experimental Mine

The Lake Lynn Experimental Mine is a sophisticated underground facility for conducting large-scale explosion trials and mine fire research. The workings are located in a massive limestone deposit. Entries are sized to match those of commercial mines, making them authentic, full-scale test galleries. Movable bulkheads permit the setup of single-entry, triple-entry, and longwall face configurations for experiments. The underground test areas are amply instrumented and coupled to a remote control center at the surface. Research conducted at this facility includes large-scale gas and coal dust explosion studies, conveyor belt flammability trials, and evaluations of explosive materials and mine stoppings. In addition, diesel, ground control, and emergency response and rescue research is conducted here.

Strategic Goals: Ground control; Mine disasters; Respiratory diseases
Site: Lake Lynn Laboratory
Laboratories: Lake Lynn Diesel Laboratory; Hydrostatic Testing Chambers for Mine Seals
Equipment: Mobile Diesel Powered Propeller Fan

Lake Lynn Experimental Mine

NIOSH Mining Facility

Mine Fire Preparedness Facility

The Mine Fire Preparedness Site is in the upper quarry of the Lake Lynn Laboratory. It consists of concrete pads on which various size liquid and/or solid fuel fires can be initiated; a 10,000 gallon water tank, diesel powered water pump, and hydrant; and storage sheds to house fire extinguishers, water hose, nozzles, dry chemical powder, high expansion foam generators, and associated firefighting equipment.

The facility is used to train miners, fire brigades, and mine rescue teams on the extinguishment of liquid and solid fuel fires with portable fire extinguishes, water lines, and high expansion foam. It is also used to conduct experiments on the efficacy of fire suppression agents and firefighting equipment and to evaluate firefighting tactics.

Strategic Goals: Mine disasters
Site: Lake Lynn Laboratory

Firefighting training at the Mine Fire Preparedness Facility

NIOSH Mining Facility

Safety Research and Experimental Coal Mines

Portal of the Safety Research Coal Mine

The Safety Research Coal Mine and Experimental Mine complex is a multi-purpose underground coal mine research facility used to support research for the development and evaluation of new health and safety interventions for mine workers. Its 4 miles of underground workings have been utilized extensively from the pioneer stages of coal mine health and safety research until the present day. The Experimental Coal Mine consists of 2 drift entries driven into the Pittsburgh coal seam developed to support full-scale mine explosion tests. The Safety Research Coal Mine is a room-and-pillar operation approximately the size of a working section of a coal mine and is utilized for mine health and safety research in areas such as ground control, ventilation, fires, explosives use, materials handling, and environmental monitoring. A full-time staff of miners provides technical and physical assistance to in-house and contract researchers.

Strategic Goals: Cumulative injuries; Ground control; Hearing loss; Mine disasters; Respiratory diseases
Site: Pittsburgh Research Laboratory
Laboratories: Toxic Fumes Laboratory (Underground)

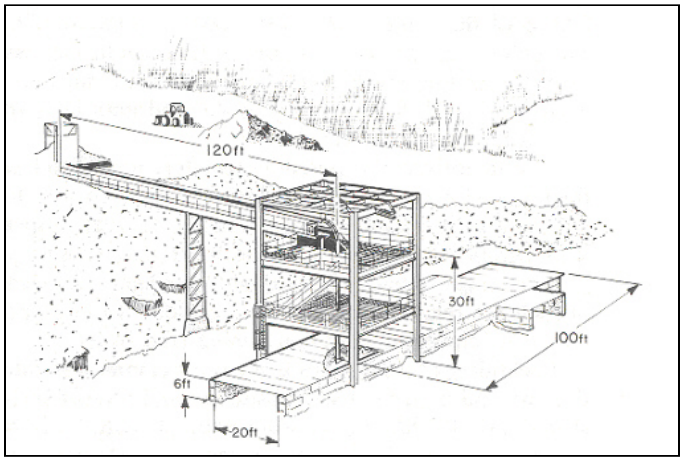
NIOSH Mining Facility

Simulated Underground Mine Facility

The Simulated Underground Mine Facility is a surface structure that simulates an underground coal mine entry. It's used to evaluate remote material injection methods for seal, bulkhead, or roof support construction. It's also used to evaluate suppression foams and other inert gas techniques for fire fighting. The structure can also be used as a test site for other underground mining research projects before full-scale testing in the experimental mine or a commercial mining operation.

This flexible structure simulates up to 10-in diameter borehole drilled into a mine void. The structure consists of a 3-story, 30-ft by 30-ft steel tower with two elevated working platforms and a simulated underground mine below. Access to the working platforms is by a catwalk on the elevated conveyor bridge. The conveyor bridge provides the supporting structure for a 24-in conveyor belt, a 6-in conveying pipeline and utility conduits. The simulated borehole can be configured to extend from either the upper or lower platform to the mine roof. A 1½-ton hoist located above the borehole is used to lower casing or other tools into the borehole. The simulated mine is constructed as needed from interlocking concrete block with removable steel bridge planks serving as the mine roof.

Strategic Goals: Mine disasters
Site: Lake Lynn Laboratory



A schematic of the Simulated Underground Mine Facility

NIOSH Mining Laboratory

Acoustical Testing Laboratory

Determining sound power level in a reverberant field is one of several methods available to calculate the noise emission of equipment. Per ISO acoustics standards for determining sound power in reverberant fields (ISO 3741 - precision grade measurements or 3743-2 - engineering grade measurements), the device under test should be a small percentage of the volume of the test chamber. This reverberation chamber has a volume of roughly 1,300 cubic meters, four times the size of what is considered to be a large chamber. Thus, the chamber is ideal for sound power level testing of the large equipment typically found in mining and construction environments. Further, a state of the art data collection, analysis, and reporting system allows for a significant amount of testing in a short period of time. Currently, NIOSH is actively pursuing NVLAP accreditation of the facility per the ISO 3741 standard.

Strategic Goals: Hearing loss
Site: Pittsburgh Research Laboratory
Building: 154
Equipment: Bruel & Kjaer PULSE Multi-Analyzer System

Sound power measurements on a Fletcher HDDR roof bolter in the Acoustical Testing Laboratory

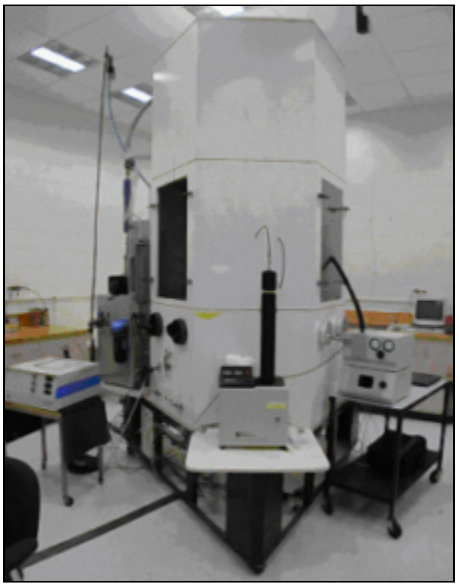
NIOSH Mining Laboratory

Aerosol Physics Laboratory

The Aerosol Physics Laboratory is a 600 sq ft humidity and temperature controlled laboratory. The lab contains a Marple Aerosol Chamber, which is a specially designed apparatus used to create a very uniform distribution of various sized aerosols. The chamber is capable of producing a highly stable aerosol concentration that is essential when attempting to compare the aerosol sampling performance of various instruments. Uniformity of aerosol exposure is enhanced by a rotational platform in the chamber that slowly moves all instruments through equivalent areas of the chamber.

Ancillary equipment to support the chamber includes: Two TSI Inc. model 3400 Fluidized Bed Aerosol Generators, TSI Inc. model 3012 Radioactive Charge Neutralizer, TSI Inc. model 3321Aerodynamic Particle Sizer (APS), TSI Inc. model 3302A Aerosol Diluter, TSI Inc. model 3080 Electrostatic Classifier, Miller Nelson Research Inc. model HCS-401 Flow Temperature and Humidity Control System, R&P Co. Inc. model 1400A Ambient Particulate Monitor, MSP Corp. model M-03 Multi Orifice Ultra Low Pressure Impactor (MOUDI), Air flow controllers and calibration equipment. The laboratory also contains other aerosol generation and sampling equipment. It is used for the staging area for assembly and calibration of personal sampling equipment used for field evaluations.

Strategic Goals: Respiratory diseases
Site: Pittsburgh Research Laboratory
Building: 144



Marple chamber with a tapered element oscillating microbalance (TEOM) in the foreground, aerosol particle sizer (APS) to the right, and Flow Temperature Humidity Control System to the left

NIOSH Mining Laboratory

Auditory Research Laboratory

The Auditory Research Laboratory houses a double-wall sound-treated room and a hearing-protector test chamber for conducting hearing loss research. The quieted room is used for screening and/or evaluating human research subjects and conducting experiments where background sound levels must be kept at a minimum. The hearing protector test chamber is used to test the attenuation of hearing protectors and to research issues related to hearing protector usage and performance.

Strategic Goals: Hearing loss
Site: Pittsburgh Research Laboratory
Building: 154

Subject testing for evaluation of ESP microphones/hearing protectors

NIOSH Mining Laboratory

Chemistry Laboratory

The Chemistry Laboratory is capable of conducting a range of wet chemistry techniques that have been recently used to develop both lab-based and field-portable analytical methods. Additionally, the laboratory is equipped with an inductively-coupled plasma-atomic emission spectrometer (ICP-AES) and an inductively-coupled plasma-mass spectrometer (ICP-MS) capable of determining the chemical composition of any material.

Site: Spokane Research Laboratory
Equipment: ICP Plasma Spectrometers

The Chemistry Laboratory allows a range of analytical tests

NIOSH Mining Laboratory

Diesel/Aerosol Research Laboratory

The Diesel/Aerosol Research Laboratory is capable of generating diesel particulate matter (dpm) or other aerosols within an isolated Marple chamber. Particulate emissions within this chamber closely simulate dpm and dusts found in an operating underground mine. This laboratory is equipped with a tapered element oscillating microbalance for determining dust mass and other instruments that permit measurement of particle size distribution and concentration. It also contains carbon analyzers to perform NIOSH 5040 on field and laboratory samples. The laboratory supports the investigation of dpm sampling and measurement concerns, the development and production of size selective samplers, and other projects concerning exposure to diesel emissions.

Strategic Goals: Respiratory diseases
Site: Pittsburgh Research Laboratory
Building: 150

A marple chamber is used to simulate an aerosol atmosphere found in underground mines

NIOSH Mining Laboratory

Dynamic Materials Testing Laboratory

The Dynamic Materials Testing Laboratory was developed to characterize the response of rock to explosive loading. Here, researchers measure properties under dynamic loads ranging from low-energy acoustic waves to intense stress pulses created by a gas gun to tests driven by full-scale explosive charges. Sophisticated electronics are available for monitoring dynamic response at sampling frequencies up to 10 MHz. The laboratory building, established in a structure originally used as a Nike missile silo, is a revetment with thick concrete walls and floor and is situated in a remote area east of Spokane. Exterior locations are suitable for explosive charge tests and full-scale diamond drilling of samples. Overall, the laboratory is ideally situated for conducting a wide range of very dynamic tests with little risk of disturbing the neighborhood.

Strategic Goals: Ground control
Site: Missile Site
Equipment: 60 mm Split Hopkinson Pressure Bar

Researcher conducting experiment in the Dynamic Materials Testing Laboratory

NIOSH Mining Laboratory

Full Scale Continuous Miner Dust Gallery

Evaluating technologies to control respirable dust and face gas levels can be difficult in an underground mine environment. Such assessments can be easily confounded when variations in dust control and ventilation factors such as curtain airflow and water pressure mask the true effectiveness of the technology being tested. Testing in the full scale continuous miner facility provides tight control of these factors so that any variations in dust and gas concentrations can be attributed more to the specific use of one or more control technologies. Having been evaluated under controlled test conditions and shown to reduce dust and gas levels, these technologies can be employed in an underground mine environment with more certainty that improved control will result.

Strategic Goals: Respiratory diseases
Site: Pittsburgh Research Laboratory
Building: 151

Mining machine in the Full Scale Continuous Miner Dust Gallery

NIOSH Mining Laboratory

Full Scale Face Ventilation Gallery

The full-scale gallery is designed to simulate face ventilation in mining entries having a 7-ft mining height and widths up to 16½ ft. An exhaust fan draws air into the gallery and curtains or tubing are used to direct air to the face of the entry. A full-scale model mining machine, equipped with water sprays and dust scrubber, and a roof bolting machine are used to determine the effects of face equipment on ventilation.

To evaluate how selected face ventilation systems affect gas distributions near the face, methane is released from a pipe manifold located at the entry face and measured at 16 locations with methanometers. The measurements are recorded with a computer-based data acquisition system. The speed and direction of airflow near the face is determined with ultrasonic anemometers. A computer program, written specifically for research in the ventilation gallery, is used for airflow data collection.

Strategic Goals: Mine disasters
Site: Pittsburgh Research Laboratory
Building: 175, 165

Full Scale Face Ventilation Gallery

NIOSH Mining Laboratory

Full Scale Longwall Dust Gallery

The Full Scale Longwall Dust Gallery is used to conduct tests of engineering control technologies in a controlled environment where the complexity or length of the testing would prohibit evaluation in an operating mine. After controls are optimized in the gallery, implementation and testing is then conducted in underground mines.

The gallery is 125 feet in length and represents a segment of a longwall mining face. Full-scale wooden models of a shearer, 25 shields and a panline are used to simulate longwall mining equipment. Coal dust is injected into the face near both cutting drums on the shearer and in the panline to simulate dust liberated during the cutting and transport of coal from the mining face. Various operating parameters can be changed to evaluate their impact on dust liberation and control. Mining height, spray system design, face air flow, water quantity and pressure to sprays, and cutting direction can be varied to study the impact on dust levels. A number of operating parameters, including air velocity, water pressure, and dust levels, are monitored real-time during testing from the control room to ensure valid test conditions are maintained. Gravimetric and instantaneous dust sampling is utilized to quantify changes in airborne respirable dust.

Strategic Goals: Respiratory diseases
Site: Pittsburgh Research Laboratory
Building: 151

Adjusting water pressure on a shearer at the Full Scale Longwall Dust Gallery

NIOSH Mining Laboratory

Gas Content Testing Laboratory

The Gas Content Testing Laboratory is designed to conduct in-house gas content testing of coal cores in accordance with NIOSH´s Modified Direct Method (MDM) testing procedure. The portable modified direct method testing apparatus is designed for both laboratory and field use. The Laboratory meets or exceeds the minimum testing requirements of the NIOSH patented MDM testing apparatus and procedure. After coal samples are collected in the field, they are returned to the gas content testing laboratory where sample containers are stored in a stable, temperature controlled environment for the duration of the test. The laboratory includes test benches and storage space for the MDM apparatus and associated equipment and supplies needed to conduct the gas content tests. Two activities related to gas desorption volume monitoring are also performed in the gas content testing laboratory. Coal core sample containers are leak tested in the lab using pressurized gas prior to the sample container going into the field. Pressurized gas is also used in the canister free space determination procedure that is a component of the total gas content calculation method. After the gas desorption volume monitoring of the samples is completed, the coal core samples are crushed in a Siebtechnik puck and ring mill to determine the residual gas content left in the sample. The Siebtechnik puck and ring mill is housed in a separate room within the Gas Content Testing Laboratory.

Strategic Goals: Mine disasters
Site: Pittsburgh Research Laboratory
Building: 118

NIOSH researcher conducting gas content test using the Modified Direct Method apparatus

NIOSH Mining Laboratory

Hearing Loss Prevention Unit

The Hearing Loss Prevention Unit (HLPU) is a mobile lab for taking NIOSH Mining hearing loss prevention research to workers and their families. On the outside, it is a 32-foot trailer towed by a heavy-duty pickup truck. Inside the sound-insulated trailer is a full hearing research clinic consisting of a four-person testing booth and a training/counseling area. It contains instruments to perform extensive hearing valuations, a one-of-a-kind system that fit-tests hearing protectors for four people at once, and computers to control all of the instruments. The laboratory also contains an audiovisual training system.

The HLPU can be configured to perform a wide range of research tasks. It has been used to perform experiments on a new earplug insertion technique, evaluate a training program using hearing test feedback, and support a study on more effective hearing loss prevention programs.

Strategic Goals: Hearing loss
Site: Pittsburgh Research Laboratory

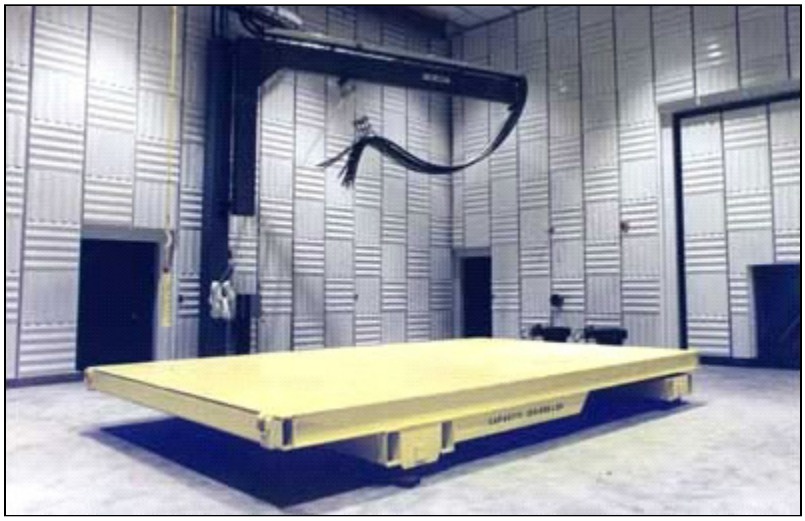
The Hearing Loss Prevention Unit mobile laboratory

NIOSH Mining Laboratory

Hemi-Anechoic Laboratory

This new laboratory will utilize Supersoft Panels on the walls and ceiling to yield a free-field over a reflecting plane. The interior dimensions of the room will be approximately 17.7 meters long by 10.4 meters wide by 7.0 meters high, approximately 1.300 cubic meters. The chamber should meet the requirements of the ISO 3744 standard down to approximately 100 Hz. Initially, the hemi-anechoic chamber will be equipped with a Bruel & Kjaer Pulse data acquisition system with 40 inputs and 2 output channels. This chamber will be utilized primarily for noise source identification testing. In addition, the hemi-anechoic chamber may be used to measure sound power levels according to ISO 3744. This chamber is expected to be completed in April, 2006.

Strategic Goals: Hearing loss
Site: Pittsburgh Research Laboratory
Building: 153



Representation of the Hemi-Anechoic Laboratory

NIOSH Mining Laboratory

Human Factors Engineering Laboratory

The Human Factors Engineering Laboratory at the Spokane Research Laboratory provides unique capabilities to evaluate and reduce musculoskeletal injuries resulting from improper design of mobile equipment used in mining, construction and agriculture industries. A large shock testing machine, accelerometers and data loggers (from Lansmont and NexGen Ergonomics) enable researchers to characterize vibration and shock exposures in the field and laboratory settings. The laboratory also has an AMTI force platform that is capable of studying landing forces (as operator exits from the cab) and postural stability (which can be compromised after exposure to whole-body vibration). Ergonomic software is available to perform occupational ergonomics and biomechanics evaluation.

Strategic Goals: Cumulative injuries
Site: Spokane Research Laboratory
Equipment: IMPAC 3636 Mark II Free Fall Shock Testing Machine ; AMTI Biomechanics Platform

Human Factors Engineering Laboratory at SRL

NIOSH Mining Laboratory

Hydrostatic Testing Chambers for Mine Seals

Two large-scale underground chambers in the Lake Lynn Experimental Mine are used to conduct pneumatic, hydrostatic, or explosion pressure loading of candidate seals for Mine Safety and Health Administration (MSHA) approval. Besides serving as a NIOSH research laboratory, the hydrostatic test chambers were designed to demonstrate a less costly alternative to full scale explosion tests and to provide the industry with a test procedure that can be used at individual mine sites for site-specific testing of candidate seals.

The largest chamber is 29.9 ft wide by 15.1 ft high by 10.2 ft deep with a maximum cross-sectional area of 452 ft^2. The smaller chamber is 20 ft wide by 7.9 ft high by 10.2 ft deep and can accommodate a seal design with a cross-sectional area up to 158 ft^2. Each chamber is connected to a diesel driven air compressor which is used to conduct the pre- and post-explosion leakage measurements and to pressure load seal designs up to 20 psi. An electric water pump capable of 100 gpm at 100 psi at the chamber inlet is fed from an underground 130,000 gal reservoir for the hydrostatic tests, and a methane and oxygen injection system is available for conducting methane-air explosion studies. The two chambers are equipped with internal 0-200 psi strain gauge pressure transducers (1000 Hz) for measuring the internal explosion pressure history and an array of spring-loaded linear variable displacement transducers (LVDT) to measure the displacement of the candidate seal. Data are recorded at 2000 samples per second per channel with a WINDAQ PC-based data acquisition system.

Strategic Goals: Mine disasters
Site: Lake Lynn Laboratory
Facility: Lake Lynn Experimental Mine

Failure of a 4 foot thick cementitious type pumpable seal

NIOSH Mining Laboratory

Industrial Hygiene Laboratory

The purpose of this laboratory is to sustain industrial hygiene field investigations and projects. When evaluating health hazards in the workplace, the researcher will observe with his or her senses and collect data by obtaining samples of material in the work environment and measure the work conditions. Obtaining samples and taking measurements requires the proper equipment, supplies, and other tools to carry out the exposure assessment. Oftentimes, these items will require periodic maintenance, repairs, and calibration in order to function properly and provide reproducible, dependable, and legally defensible data.

The Industrial Hygiene Laboratory includes a variety of equipment designed to provide data on industrial contaminants or environmental conditions that may be harmful to workers. Specific equipment includes: air pumps, size selective particle samplers, particle analyzers, ventilation monitors, heat stress and heat strain monitors, noise monitors, monitors for a variety of gasses, and calibration standards.

Site: Spokane Research Laboratory

Equipment in Industrial Hygiene Lab used to monitor workplace environments

NIOSH Mining Laboratory

Instrumentation Laboratory

The Instrumentation Laboratory is used for the application of strain gauge technology to a variety of surfaces in order to determine the amount of force being exerted on that material during field testing and experimentation. This is essential for determining both static and dynamic loads being applied to rock structures and prototype equipment. The laboratory has the capability to apply strain gauges, either by spot welding or by gluing, to a variety of surfaces to include steel, aluminum, rock samples, etc. The laboratory also has the capability to wire the gauges to electronic connectors that are compatible with various data-loggers that capture strain data over extended periods of time. The equipment in the laboratory includes various types of soldering tools, small tweezers and probes to apply and wire strain gauges and ovens to cure the special epoxy cement used in applying the strain gauges.

Strategic Goals: Ground control
Site: Spokane Research Laboratory

Data gathering instruments being designed and constructed

NIOSH Mining Laboratory

Lake Lynn Cannon Gallery

The Lake Lynn Cannon Gallery (LLCG) is a 22 ft long by 8 ft diameter horizontal steel cylinder open at both ends. Mounted inside the LLCG near one end is a 5 ft long by 2 ft diameter steel cannon with a 2.25 in diameter by 4 ft long bore. The steel cannon can be easily removed from the gallery to facilitate other types of dust and/or gas ignition studies or demonstrations. The gallery has 15 pair shielded instrumentation cable and 120 vac power lines available which extend to a control shed located approximately 300 ft away and protected behind an earth berm. Natural gas is also plumbed to the gallery with a metering system located at the control shed. Gas sampling and video lines extend from the gallery back to the control shed. In a standard LLCG experiment, the flame and combustion products from a detonating explosive charge exit the cannon toward the geometric center of the gallery, where combustible dust has been pre-dispersed and/or an atmosphere of flammable methane-air is present.

Strategic Goals: Mine disasters
Site: Lake Lynn Laboratory
Facility: Explosives Testing Site (Upper Quarry)

Coal dust ignited by unstemmed ammonium nitrate - fuel oil (ANFO) at the Lake Lynn Cannon Gallery

NIOSH Mining Laboratory

Lake Lynn Diesel Laboratory

The Lake Lynn Diesel Laboratory is an in-mine setting which allows for controlled laboratory quality studies in an actual mine environment. The core of the lab is the NIOSH Mobile Engine Emissions Laboratory (MEEL), which is developed around two dynamometer/engine systems. The smaller dynamometer is coupled to a naturally aspirated, mechanically controlled Isuzu C240 diesel engine. The larger dynamometer is coupled to a modern, electronically controlled, turbocharged Mercedes Benz OM904 engine. Each of the dynamometer/engine systems and all accompanying equipment are mounted on the base plate and on a custom built trailer that provides needed mobility. The MEEL is currently integrated into D drift of LLL that serves as a full-flow constant volume sampling (CVS) dilution tunnel. The state-of-the-art equipment and instrumentation are used for characterization of aerosols and gases emitted by tested engines in mine air.

The NIOSH MEEL offer a unique environment for field-evaluation of diesel emissions control technologies and their effects on quality of the air and workers exposure to diesel particulate matter and gases. This facility is currently used to conduct research on physical and chemical characterization of ultrafine and nanometer aerosols emitted by diesel engines in actual occupational settings and establishing role of nano-particles in COPD and other occupational diseases.

Strategic Goals: Respiratory diseases
Site: Lake Lynn Laboratory
Facility: Lake Lynn Experimental Mine

Mobile Engine Emissions Laboratory installed at the Lake Lynn Diesel Laboratory

NIOSH Mining Laboratory

Microbalance Laboratory

Stable ambient air is an essential requirement for accurate weighing. In response to this need, NIOSH staff designed and constructed this insulated 20′x20′x10′ facility which is equipped with a recirculating Liebert computer room HVAC system and HEPA filtration. The weigh room is divided into 2 chambers of 2:1 ratio. The smaller chamber serves as an airlock for entering as well as a buffer for the conditioned air. The buffered air is dispersed into the larger chamber through a perforated grill ceiling for even dispersion. The chamber houses two Cahn & four Mettler microbalances. Control filters are maintained to track balance performance and the long-term balance precision is approximately 5 micrograms.

Strategic Goals: Respiratory diseases
Site: Pittsburgh Research Laboratory
Building: 144

Microbalance Laboratory

NIOSH Mining Laboratory

Mine Electrical Laboratory

The Mine Electrical Laboratory supports full-scale testing of mine (and other industrial) electrical power system components, such as cables, motors, circuit breakers, and fuses, as well as experiments involving electrical safety equipment. It is equipped with electrical power supplies capable of delivering high voltage (up to 100 kV ac or dc) and high current (up to 50 kA ac), instrumentation that is regularly calibrated to NIST traceable standards, and a secure control room from which tests and experiments can be controlled and observed safely. It has been used for projects examining mining safety issues such as fuse performance, electric motor failure, trolley system faults, electric motor circuit protection, electrical cable performance, and overhead power line hazards. The Mine Electrical Laboratory can also be utilized when responding to requests for technical assistance by the Mine Safety and Health Administration, private industry, and other NIOSH divisions.

Strategic Goals: Traumatic injuries
Site: Pittsburgh Research Laboratory
Building: 151
Equipment: Hipotronics 750-KVA Three-Phase and DC Power Source ; Robotron 50-KA High Current Source ; Hipotronics 100-KV AC and DC High Voltage Sources

A mine electrical cable overload experiment in the Mine Electrical Laboratory

NIOSH Mining Laboratory

Motion Analysis Laboratory

Data on human movement is useful for simulation modeling (using virtual humans) and for biomechanical studies. Force plates measure forces at the feet which, when combined with motion data from the motion analysis capture system, provide information regarding the loads experienced by the joints of the body during work activities. EMG equipment measures muscle activity, which is used to estimate muscular fatigue and the force needed to perform a task. This laboratory allows researchers to test new methods of performing work under controlled conditions, so that physical stresses can be minimized and injury risk can be reduced. Specific equipment located in this laboratory includes: Motion AnalysisCorporation 12 camera Eagle System, Noraxon TeleMyo 2400R 16 Channel Base System, Biometrics Portable 4 Channel EMG System SX2300 (4), Biometrics Dual Axis Goniometers, and K100 Amplifier Base Unit.

Strategic Goals: Cumulative injuries; Traumatic injuries
Site: Pittsburgh Research Laboratory
Building: 152
Equipment: Motion Analysis Eagle i Motion Analysis Capture System

Researchers calibrating the motion analysis system

NIOSH Mining Laboratory

MTS Rock Mechanics Testing Laboratory

Small scale material tests are performed in accordance to the ASTM Testing Methods in the state-of-the-art MTS Rock Mechanics Testing Laboratory. This laboratory includes a servo-controlled MTS load frame and the equipment to perform uniaxial and triaxial tests on samples that range in size from 1 to 20-inches in diameter. Small scale material tests are performed to support large scale field programs and provide input parameters for numerical modeling efforts.

Strategic Goals: Ground control
Site: Pittsburgh Research Laboratory
Building: 156
Equipment: Servo Controlled MTS Load Frame

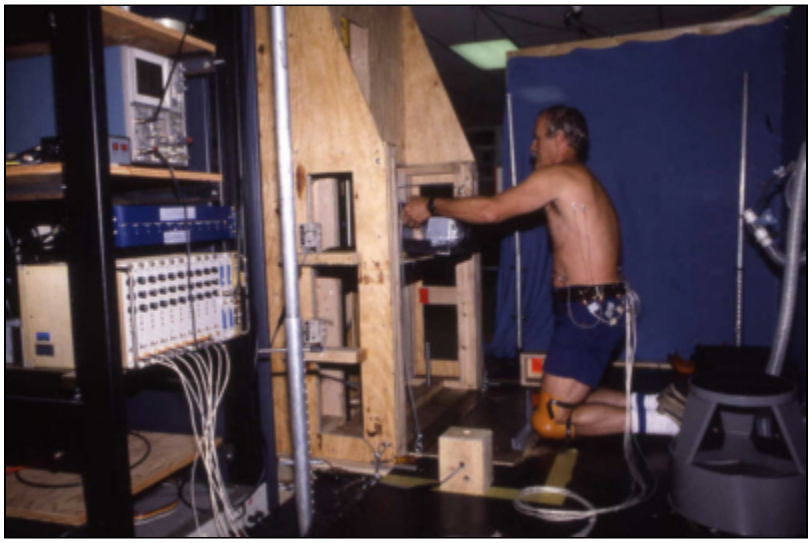
MTS Rock Mechanics Testing Laboratory

NIOSH Mining Laboratory

Physical Strength Laboratory

Tests of physical strength are an important assessment tool for ergonomists studying the effort required of workers performing manual materials handling tasks. In some cases, the task demands may approach or even exceed the strength that an individual is voluntarily willing to exert in a test of strength. In such cases, the likelihood of injury is significantly greater than when the task demands lie well within an individual's strength capacity. Because the relationship between strength capabilities, job demands and musculoskeletal injury has been established, tests of muscular strength may be of benefit in redesigning jobs so they are within the capability limits of mine workers. The lab has machines to test a wide range of static strengths (measured with a joint set at a specific angle) and dynamic strength (measured throughout the range of motion of a joint). Specific equipment located in this laboratory includes: BIODEX System, AMTI OR6-5 Force Plate, Lumbar Motion Monitor II, Chatillon CSD 300 Series Digital Dynamometer, Chatillon DFA-R-ND Digital Force Gauge (50 and 500 lb attachments), Static Lift Platform, Polar HR Monitor S810i, The Human Solution ErgoKit, and GPM Anthropometric Calipers.

Strategic Goals: Cumulative injuries
Site: Pittsburgh Research Laboratory
Building: 152



A subject performs a psychophysical test of strength in the Physical Strength Laboratory

NIOSH Mining Laboratory

Safety Structures Testing Laboratory

The Safety Structures Testing Laboratory is dedicated to large scale material and structural testing relating to the prevention of roof and rib falls. The focal point of the SST laboratory is the Mine Roof Simulator (MRS) load frame that is designed to simulate the extreme weight and movement of the overburden rock that must be supported when coal or other minerals are extracted from the earth. It is the largest load frame of its kind in the world and is the only load frame that can simulate the complex behavior of rock masses at great depths below the surface.

Strategic Goals: Ground control
Site: Pittsburgh Research Laboratory
Building: 155
Equipment: Mine Roof Simulator

Safety Structures Testing Laboratory

NIOSH Mining Laboratory

Seismic Laboratory

The Seismic Laboratory supports field measurements and analyses of seismic event activity produced by dynamic rock mass failures in the mining workplace. Seismic data acquisition, analysis, and display systems are configured using modular PC hardware and software components distributed over wired or wireless networks. Novel methods for remote detection of ground fall instabilities using laser techniques are also investigated.

Strategic Goals: Ground control
Site: Spokane Research Laboratory

Equipment used to measure and analyze seismic events

NIOSH Mining Laboratory

Sensors Laboratory

The Sensors Laboratory is well equipped to test emerging smart-wearable sensors technology for use in hazardous environments. A wide range of wireless sensors for physiologic, environmental, and personnel tracking applications and the associated ad-hoc/mesh networks can be tested. Research focuses on 1) developing new knowledge for correlating the sensor data to assessed risk, 2) adapting the sensors and networks to the mining environment, and 3) using biometric data such as posture, trunk and knee flexion, joint angles, and moments to identify hazards and quantify risk. Wearable sensor solutions will empower miners to take necessary steps to eliminate/reduce their risk to hazards produced by an ever-changing and unpredictable hazardous work environment in real-time.

Strategic Goals: Traumatic injuries
Site: Pittsburgh Research Laboratory
Building: 152

Researcher testing wireless network. Inset shows typical wearable sensor

NIOSH Mining Laboratory

Soil/Rock Properties Laboratory

The Soil/Rock Properties Laboratory is contained in the soils bay, a 4,700 sq ft facility that provides space and equipment for preparing, characterizing, and testing consolidated and unconsolidated materials. The laboratory provides the capability to wash, screen, dry, and mix unconsolidated materials such as soils prior to testing. Consolidated or cemented materials and rock are tested for various engineering properties using a suite of test frames in the laboratory.

The laboratory contains a 70 sq ft wet cure room equipped to fog-cure cementicious samples prior to testing. Depending on the samples' components or the required curing timeframe, the room provides space for large-sized samples as well as a large number of samples. The laboratory is also equipped with a million pound compression test frame, direct shear test frame, programmable controlled tension-compression test frame, three tension-compression test frames, and a fiber panel testing device.

Strategic Goals: Ground control
Site: Spokane Research Laboratory
Equipment: Million Pound Compression Test Frame ; Direct Shear Test Frame ; Programmable Controlled Tension-Compression Test Frame ; Tension-Compression Test Frames ; Fiber Panel Testing Device

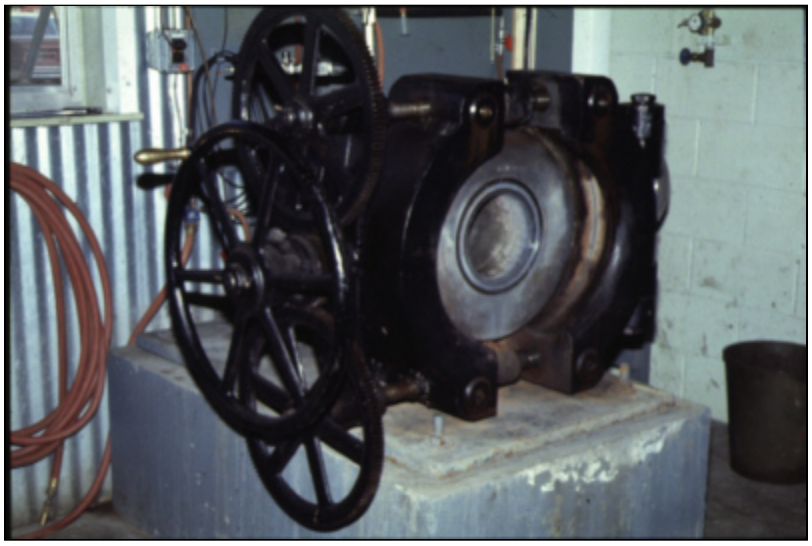
Wet cure room at the Soil/Rock Properties Laboratory

NIOSH Mining Laboratory

Toxic Fumes Laboratory (Surface)

The surface Toxic Fumes Laboratory houses facilities for determining the toxic fumes produced by high explosives. The laboratory contains a variety of equipment for measuring the fumes produced by new candidate permissible explosives pursurant to approval by the Mine Safety and Health Administration, for measuring the fumes produced by other high explosives pursuant to determination of their IME fumes class, and for studying the effect of explosives composition and other factors on toxic fumes production.

Strategic Goals: Traumatic injuries
Site: Pittsburgh Research Laboratory
Building: 117
Equipment: Large Fumes Chamber ; Large Spherical Explosion Chamber



The Bichel Gauge is used to determine the IME fumes class of high explosives

NIOSH Mining Laboratory

Toxic Fumes Laboratory (Underground)

To accommodate fume testing of blasting agents, the underground Toxic Fumes Laboratory was constructed in the PRL Experimental Mine for detonating large, confined charges in a controlled volume. It consists of a portion of mine entry (once used for full scale mine explosion research and demonstrations) enclosed between two explosion proof bulkheads. Total volume of the chamber is 9,666 ft^3 (274 m^3). The chamber is equipped with an air circulating system and is vented using the mine's airflow. Up to 10 pound (4.5 kg) charges can be detonated in the chamber using a variety of confinements. Twenty-four 2-inch thick steel plates are suspended around the explosive charge to stop shrapnel that would otherwise seriously damage the chamber. Fumes from the explosive are confined in the chamber and samples are taken for lab analysis.

Strategic Goals: Traumatic injuries
Site: Pittsburgh Research Laboratory
Facility: Safety Research and Experimental Coal Mines

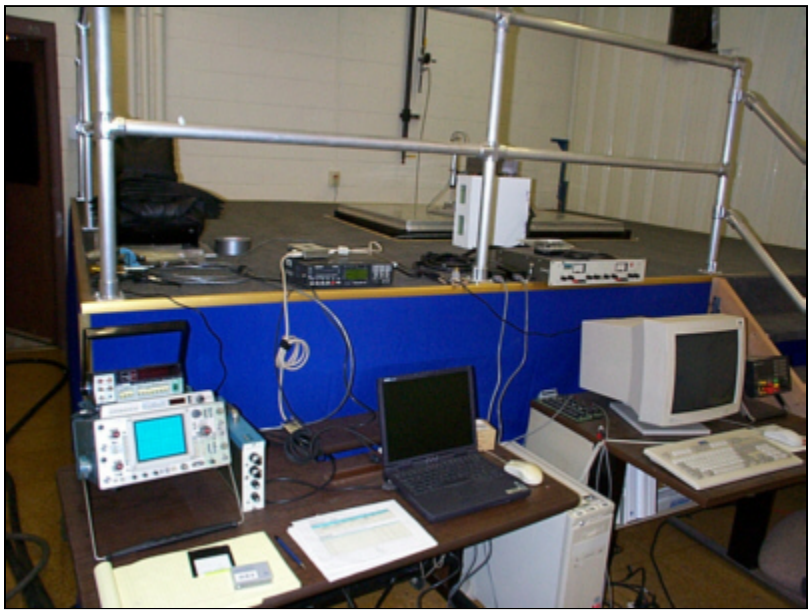
Researcher monitors instrumentation for analyzing toxic fumes produced by a blasting agent detonated in the chamber

NIOSH Mining Laboratory

Whole Body Vibration Laboratory

The Whole Body Vibration Laboratory contains a single axis vibration table that enables researchers to study whole-body vibration. This table is capable of producing vibrations in various waveforms from frequencies below 1 HZ to 15 HZ. The table can produce accelerations in excess of 10G's and has a maximum travel of 6 in. This equipment also has the capability of reproducing vibrations recorded from field tests, once the data has been converted to displacement units. Using this feature, vibrations from computer generated data, either random or specific, can be produced. This capability is useful when simulating vehicle environments. For example, data can be generated to simulate the accelerations of a vehicle's wheel striking a bump or hole. The vibration platform is used in investigations that seek to decrease neck and back injuries and improve machine designs so that equipment operators are isolated from vehicle vibrations and shock loadings. Recent projects evaluate various seat suspension systems and investigate the use of rheonetic technology to improve these systems and increase operator isolation from vibrations. Rheonetic technology has the ability to adjust suspension system damper performance in real time.

Strategic Goals: Cumulative injuries; Traumatic injuries
Site: Pittsburgh Research Laboratory
Building: 152
Equipment: Vibration Table



Whole Body Vibration Laboratory

NIOSH Mining Major Equipment

20-Liter Explosion Chamber

The 20-liter chamber is used to conduct research on the explosion hazards associated with dusts, gases, and hybrid mixtures encountered in the mining industry. It can measure explosion characteristics such as flammability limits, explosion pressures, rates of pressure rise, and explosion temperatures. Associated instrumentation includes pressure transducers, optical dust probes to measure dust dispersion, and infrared pyrometers to measure explosion temperatures. Test data from the various instruments are collected by a high-speed, PC-based data acquisition system. Some of the standard test procedures developed by NIOSH researchers for the 20-liter chamber have been adopted by ASTM International as part of its consensus standard test methods for measuring explosion characteristics. Explosion test chambers based on this design are used by several other government agencies and private testing laboratories to evaluate explosion hazards in other industries.

Strategic Goals: Mine disasters
Quantity: 2
Site: Pittsburgh Research Laboratory
Building: 143

Dust explosion venting from 20-liter chamber

60 mm Split Hopkinson Pressure Bar

The 60 mm Split Hopkinson Pressure Bar (SHPB) is a unique device, originally built to study oil shale dynamic behavior at Lawrence Livermore National Laboratory. This semi-truck sized device features a Nitrogen gas gun, pressure bars, axial confinement capability and sophisticated monitoring electronics. The SHPB is used to measure the dynamic strength attenuation of materials used in close proximity to blasting, geologic material that is the target of blasts, and adjacent geologic material that will form the back (ceiling) of the new opening. In conjunction with ultrasonic tools, the SHPB can also be used to track accumulation of damage in these materials from repeated dynamic loads.

Strategic Goals: Ground control
Quantity: 1
Site: Missile Site
Laboratory: Dynamic Materials Testing Laboratory

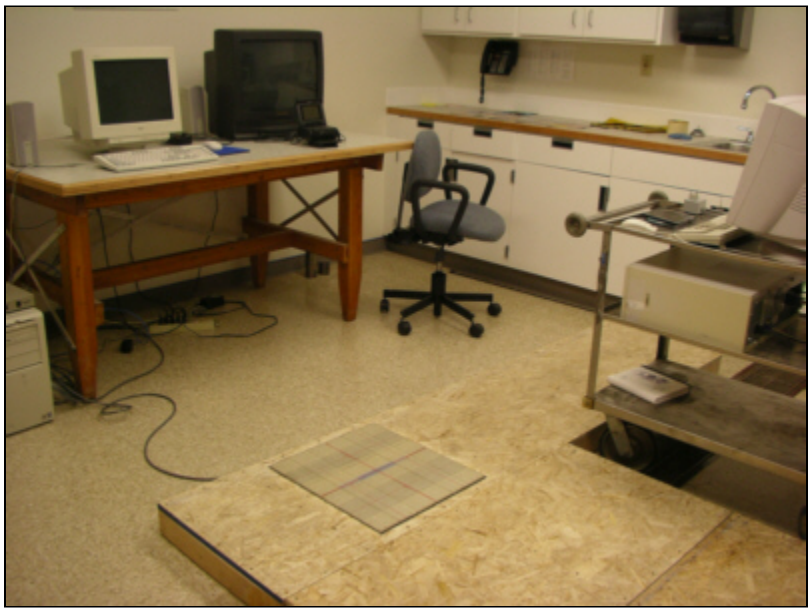
Split Hopkinson Pressure Bar

NIOSH Mining Major Equipment

AMTI Biomechanics Platform

The AMTI biomechanics platform simultaneously measures three force and three moment components along the X, Y, and Z axes. The forces and moments are measured by strain gauges attached to proprietary load cells near the four corners of the platform. The gauges from six Wheatstone bridges have four active arms, each with eight or more gauges per bridge. Three of the output signals are proportional to the forces parallel to the three axes and the other three outputs are proportional to the moments about the three axes. AMTI´s NetForce software is a flexible data acquisition system designed to facilitate the use of AMTI´s multi-axis force platforms for biomechanics and industrial force measurements. NetForce allows the user to monitor and save data from up to six multi-axis transducers, providing a seamless interface for AMTI´s Ethernet, RS-232, and analog data format products.

Strategic Goals: Cumulative injuries
Quantity: 1
Site: Spokane Research Laboratory
Laboratory: Human Factors Engineering Laboratory



AMTI biomechanics platform

NIOSH Mining Major Equipment

Bruel & Kjaer Investigator 2260 Hand-Held Analyzer

This hand-held 2-channel analyzer is capable of making broadband and real-time octave band measurements. It also offers building acoustics (1 or 2 channel), room acoustics, sound intensity, and narrow band (FFT) analysis with pure tone detection.

Strategic Goals: Hearing loss
Quantity: 1
Site: Pittsburgh Research Laboratory
Building: 154

Hand-held Analyzer B&K Investigator Model 2260

NIOSH Mining Major Equipment

Bruel & Kjaer Investigator 2260 with Sound Intensity Probe

Sound intensity is the time-averaged product of the pressure and particle velocity. A single microphone can measure pressure but it is not a simple process to measure particle velocity. However, the particle velocity can be related to the pressure gradient of a sound field. Using two closely space microphones, it is possible to measure the pressure gradient and relate it to particle velocity using an equation. The portable sound intensity analyzing system consists of a two-microphone probe and an analyzer. The probe measures the pressure at the two microphones and the analyzer does the integration and other calculations that are necessary to find the sound intensity.

Strategic Goals: Hearing loss
Quantity: 1
Site: Pittsburgh Research Laboratory
Building: 155

Bruel & Kjaer 2260 Investigator with sound intensity probe

NIOSH Mining Major Equipment

Bruel & Kjaer PULSE Multi-Analyzer System

This multi-channel system provides real time data collection and analysis. It is a turnkey for ISO 3741 standard for sound power solutions, which is used by several ISO 3741 accredited labs, including the PRL Acoustical Testing Laboratory. The PULSE system comprises PULSE LabShop software that runs under Windows NT, a PC, one or more DSP boards which fit into the PC, a data acquisition front-end, and transducers.

Strategic Goals: Hearing loss
Quantity: 2
Site: Pittsburgh Research Laboratory
Laboratory: Acoustical Testing Laboratory
Building: 154

The PULSE multi-analyzer system from B&K

NIOSH Mining Major Equipment

Direct Shear Test Frame

The large scale direct shear test frame (300,000 pound axial and shear forces) with programmable control is used for biaxial testing on rock, concrete, and soil samples. The sample size can vary from 1 inch diameter rock cores to 14 inch square concrete blocks.

Strategic Goals: Ground control
Quantity: 1
Site: Spokane Research Laboratory
Laboratory: Soil/Rock Properties Laboratory

Testing core samples on the direct shear test frame

NIOSH Mining Major Equipment

Drilling Equipment

The drilling equipment located at the Missile Site includes (a) a mobile trailer mounted drill capable of drilling up to 1,000 feet of 3 inch in diameter hole and 125 feet of hole using 8 inch in diameter hollow stem augers. This drill is used extensively for core drilling, and (b) three underground core drills, one hydraulically powered, and two pneumatically. These drills are used for underground core drilling and installation of in situ measuring instruments.

Strategic Goals: Ground control
Quantity: 4
Site: Missile Site

Mobile trailer-mounted drill

NIOSH Mining Major Equipment

Earthen Bermed Magazines

The PRL explosives magazine area contains four active magazines. One of these is used for storage of blasting caps and the others are used to store explosives. Each magazine is surrounded by an earthen berm. The total capacity of the magazines is 3,300 lb of explosive and 150,000 blasting caps.

Strategic Goals: Traumatic injuries
Quantity: 4
Site: Pittsburgh Research Laboratory

Earthen bermed magazine

NIOSH Mining Major Equipment

Fiber Panel Testing Device

This portable field testing device allows researchers to gather information on initial breaking strengths of shotcrete, particularly if it used near blast areas. These data will provide valuable insight into competence of shotcrete as a support, including optimal fiber mixes for different sites.

Strategic Goals: Ground control
Quantity: 1
Site: Spokane Research Laboratory
Laboratory: Soil/Rock Properties Laboratory

Testing fiber reinforced shotcrete panels at a mine site

NIOSH Mining Major Equipment

Fletcher HDDR-13-C-F Roof Bolting Machine

This Fletcher roof bolting machine is used for a variety of research testing. The HDDR is a duel-boom machine which may be configured for vacuum, mist, or wet drilling. One boom of the HDDR is equipped with a feedback system, which automatically adjusts the drilling configuration (rotation speed, thrust, etc.) to match the drill media geology with the objective of enhancing drilling performance. NIOSH has used the HDDR as a base platform for determining the effect of drilling configuration (bit size, drill steel shape, etc.) on the sound power level emission and the performance of the device. Current testing involves using the HDDR for noise source identification work to determine and rank the most prominent noise sources of a roof bolting machine during a drilling cycle for development of engineering noise controls.

Strategic Goals: Cumulative injuries; Ground control; Hearing loss
Quantity: 1
Site: Pittsburgh Research Laboratory
Building: 152

Fletcher roof bolting machine being tested in PRL´s Acoustical Testing Laboratory

NIOSH Mining Major Equipment

Frictional Ignition Apparatus

Frictional ignitions of methane in the coal mining industry are often caused by the impact of mining machine cutter bits on hard rock (e.g., sandstone) during the coal-cutting process. The Frictional Ignition Apparatus is a useful tool for studying the various mechanisms that cause frictional ignitions and for evaluating methods to reduce the frequency of their occurrence in the underground workplace. Variables that can be evaluated with the apparatus include: bit design, bit attack angle, impact speed, depth of cut, bit wear area, shank metallurgy, and ceramic coatings. The effects of methane concentration and quenching by water sprays can also be studied. The Frictional Ignition Apparatus consists of a section of a continuous miner drum with various bit blocks attached. The drum is enclosed within a plywood chamber (~100 cubic feet) that includes thin plastic blow-out panels to relieve the pressure if an ignition occurs. To conduct a test, the chamber is filled with a flammable methane-air mixture. The drum is operated at a rotational speed of 20 to 40 revolutions per minute. A digital video camera is used to record the number of strikes to ignition and the subsequent frictional ignition of methane. Hot smear temperatures are measured using a high speed infrared camera.

Strategic Goals: Mine disasters
Quantity: 1
Site: Pittsburgh Research Laboratory
Building: 152

Ignition of methane in frictional ignition apparatus

NIOSH Mining Major Equipment

Hipotronics 100-KV AC and DC High Voltage Sources

The Hipotronics 100-kV ac and dc high voltage sources are two electrical power supply systems with adjustable outputs capable of up to 100 kV. These systems utilize mobile oil-immersed transformers and are operated from within the Mine Electrical Laboratory control room. They have been used extensively in research studying the performance and safety of mine electrical cables, including conducting tests of insulation resistance, corona generation, surface tracking, and dielectric strength. They have also been used to generate high-voltage electric fields for experiments involving research to develop a power line contact alarm for mobile equipment.

Strategic Goals: Traumatic injuries
Quantity: 1
Site: Pittsburgh Research Laboratory
Laboratory: Mine Electrical Laboratory
Building: 151

Grounding the output on the 100-KV ac high voltage source after a high voltage field experiment

NIOSH Mining Major Equipment

Hipotronics 750-KVA Three-Phase and DC Power Source

The Hipotronics 750-kVA three-phase and dc power source is a system that can supply electrical power at three-phase voltages up to 13,800 V, and dc voltages up to 700 V. Capable of delivering 750 kVA continuously, the system can supply 1.8 MVA for short durations. It has been used extensively in mine electrical safety research, such as in tests relating current to temperature rise on mine electrical cables, examining the deterioration of electric motors, developing techniques to distinguish between motor starts and short circuits, and evaluating protective relays and explosion-proof enclosures during simulated electrical faults.

Strategic Goals: Traumatic injuries
Quantity: 1
Site: Pittsburgh Research Laboratory
Laboratory: Mine Electrical Laboratory
Building: 151

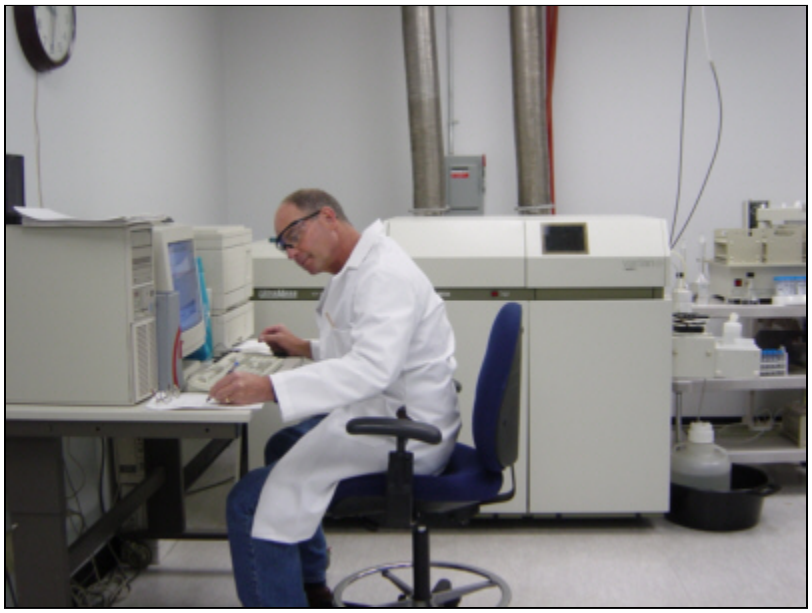
NIOSH engineer adjusts the voltage level on the Hipotronics 750-kVA three-phase and dc power source

NIOSH Mining Major Equipment

ICP Plasma Spectrometers

The Chemistry Laboratory is equipped with an inductively-coupled plasma-atomic emission spectrometer (ICP-AES) and an inductively-coupled plasma-mass spectrometer (ICP-MS). The ICP-AES and ICP-MS are used for elemental chemical analysis of just about any material or substance (waters, biological materials, inorganic materials of all sorts, environmental samples, geological samples, etc.). Samples have to be dissolved prior to analysis. A wide range of concentrations can be measured, down to parts per trillion in solution by the ICP-MS.

Quantity: 2
Site: Spokane Research Laboratory
Laboratory: Chemistry Laboratory



Preparing samples for analysis by the ICP mass spectrometer

IMPAC 3636 Mark II Free Fall Shock Testing Machine

The IMPAC 3636 Mark II free fall shock testing machine, manufactured by MTS Systems Corp., is a free-fall testing machine of unique design for performing a wide range of shock tests. One testing procedure is to simulate impulsive (short duration) forces experienced by heavy equipment operators that may contribute to sprains and strains and other lower back injuries. Once these operator g-forces are characterized in the field, researchers can simulate conditions which could cause injuries on the MTS shock testing machine. Researchers can then design and test engineering controls to reduce operator injury.

Strategic Goals: Cumulative injuries
Quantity: 1
Site: Spokane Research Laboratory
Laboratory: Human Factors Engineering Laboratory

Drop shock testing machine

NIOSH Mining Major Equipment

Joy 14CM9 Continuous Mining Machine

Continuous miners are large underground coal cutting machines that cut the coal at the working faces of coal mines, gather up the cut coal, and transport it via an onboard conveyor to the back of the machine. From there, coal is loaded onto either another conveyor or a piece of mining equipment that carries the coal away from the working face. The 14CM9 is a drum type machine with gathering arms that operates from 1000 volts AC. It also consists of a conveying system with a 30-inch chain. The overall chain length is approximately 60' in length with 54 flights and a chain pitch of 3.25 inches. The miner is capable of operating from either onboard the continuous miner or by radio remote.

This equipment is used by all branches of PRL for various research. Recently, it was used to study remote control mining and to develop and demonstrate a close proximity warning device for continuous miner operators. The miner has and presently is being used to test the effectiveness of noise controls for continuous mining machines in a laboratory environment prior to testing in operating mines.

Strategic Goals: Hearing loss; Traumatic injuries
Quantity: 1
Site: Pittsburgh Research Laboratory
Building: 152

Joy 14CM9 continous miner

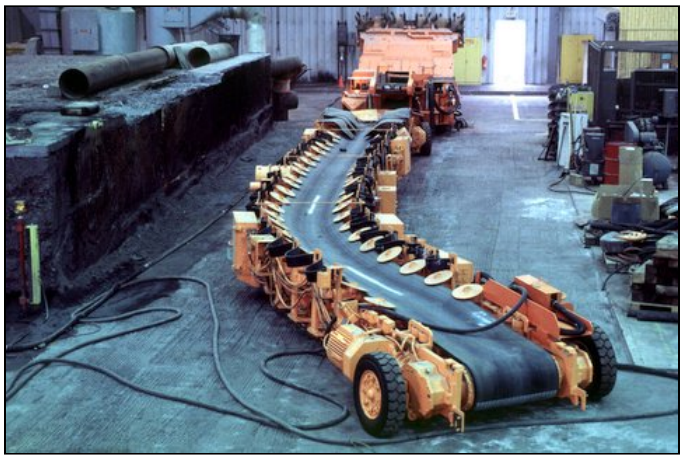
NIOSH Mining Major Equipment

Joy 3FCT-4 Flexible Conveyor Train

The Joy Flexible Conveyor Train (FCT) is a high capacity continuous haulage system that is remotely controlled by one operator. It is a flexible, moving belt system that is used to continuously convey coal from the mine face to the section or main belt. The FCT winds its way through the mine as it follows behind a continuous mining machine that extracts coal. The operator is responsible for maneuvering the FCT throughout the mine and for precisely positioning the receiving end (front hopper) such that coal is discharged from continuous mining machine onto the FCT. Our research uses the 3FCT-4 model. It is available in belt widths of 37" / 940mm and 42" / 1067mm and in system lengths of up to 420 feet / 128 meters. The 3FCT-4 can move forward or reverse at an average of 19.5 meters/minute. The 42" / 1.07m wide flexible belt enables continuous conveyance of coal rates up to 27 tons/minute or 24.5 tonnes/minute.

The 3FCT-4 is used for machine safety research. FCT operators can be in dangerous areas where the roof could fall and where they could be struck or pinned by moving machinery. This situation is made more dangerous because visibility is reduced by dust, obstructions, and low levels of light. Significant levels of noise, especially during the cutting of coal, can impair hearing and communication between the operators.

Strategic Goals: Traumatic injuries
Quantity: 1
Site: Pittsburgh Research Laboratory
Building: 152



The Joy 3FCT-4 continuous haulage system

NIOSH Mining Major Equipment

Large Fumes Chamber

The large fumes chamber is used to determine the toxic fumes produced by a new candidate permissible explosive pursuant to approval by MSHA. The chamber is constructed of 3/4-inch steel with a volume of 1,354 cubic feet or 38.3 cubic meters. One pound of high explosive is loaded into a steel cannon connected to the end of the chamber. The resulting fumes are confined in the chamber for subsequent analysis. The toxic gases measured include NO, NO_2, NO_3, H_2S, SO_2, CO, and CO_2.

Strategic Goals: Mine disasters
Quantity: 1
Site: Pittsburgh Research Laboratory
Laboratory: Toxic Fumes Laboratory (Surface)
Building: 117

Large fumes chamber

NIOSH Mining Major Equipment

Large Spherical Explosion Chamber

The Large Spherical Explosion Chamber is used to study the explosion hazards of gases and to measure the toxic fumes and residue produced from the detonation of solid explosives used in the mining industry. It has a diameter of 12 feet and a volume of 905 cubic feet or 25½ cubic meters. It can be used to measure the explosion pressures and flammability limits (upward and downward propagation) of gases. Research on the fumes produced from the detonation of explosives can be conducted in air or in an inert atmosphere (e.g., argon). Associated instrumentation includes pressure transducers, high speed video cameras, and gas analyzers to measure NO, NO_2, CO, CO_2, O_2, and SO_2. Gas samples are also collected in evacuated tubes for subsequent gas chromatographic analyses for H_2 and heavier hydrocarbons through C_5.

Strategic Goals: Mine disasters
Quantity: 1
Site: Pittsburgh Research Laboratory
Laboratory: Toxic Fumes Laboratory (Surface)
Building: 117

Large Spherical Explosion Chamber

NIOSH Mining Major Equipment

LMS Pimento Portable Noise and Vibration Analyzer

This portable device can simultaneously measure 24 channels of data from microphones, accelerometers, etc. Time data or spectral data may be acquired. In addition, the Pimento may be used to measure frequency response functions of a structure.

Strategic Goals: Hearing loss
Quantity: 1
Site: Pittsburgh Research Laboratory
Building: 154

LMS Pimento portable noise and vibration analyzer

NIOSH Mining Major Equipment

MB Dynamics 110 Electromechanical Shakers

The Modal 110 shakers can be driven by an electrical signal from a data acquisition system to provide a force input to a structure. The resulting sound pressure, sound intensity, and/or surface vibrations can then be measured. These devices can also be used to measure frequency response functions of machinery. The Modal 110 shakers can provide up to 110 lb of input force from dc to 5 kHz. They can be used to pinpoint areas on structures that have the highest vibrations and to determine path of energy flow through structures. They can also combine with NSID techniques to rapidly identify noise sources.

Strategic Goals: Hearing loss
Quantity: 2
Site: Pittsburgh Research Laboratory
Building: 153

MB Dynamics Model 110 electromechanical shaker

NIOSH Mining Major Equipment

Million Pound Compression Test Frame

This compression test frame has a 1,000,000 pound capacity. It is equipped with programmable control and data collection features and is capable of testing specimens up to 6 inches in diameter to determine unconfined compressive strength and rock modulus.

Strategic Goals: Ground control
Quantity: 1
Site: Spokane Research Laboratory
Laboratory: Soil/Rock Properties Laboratory

Million-pound test frame

NIOSH Mining Major Equipment

Mine Roof Simulator

The Mine Roof Simulator provides unique capabilities to evaluate the integrity, stability, and load performance characteristics of large specimen structures and equipment. The simulator´s biaxial load frame can accommodate specimens up to 16 feet high, 20 feet wide, and 20 feet long. Precision load testing is achieved by closed-loop, servo controlled actuators with six degrees of freedom control of the lower platen. Up to 3 million pounds of vertical force can be applied through a 24-inch stroke of the lower platen. Horizontal loads of up to 1.6 million pounds can be applied simultaneously by horizontal displacement of the lower plane through a 16-inch stroke.

Strategic Goals: Ground control
Quantity: 1
Site: Pittsburgh Research Laboratory
Laboratory: Safety Structures Testing Laboratory
Building: 155

Mine Roof Simulator

NIOSH Mining Major Equipment

Mobile Diesel Powered Propeller Fan

The mobile diesel powered propeller fan is a 54-inch Spendrup, three bladed propeller fan that is rated at 60,000 cfm. The fan is powered by a Duetz F2L1011F diesel engine. The unit is mounted on a single axial trailer for highway use, and includes all safety items required by the Mine Safety Health Administration (MSHA) for use in metal/non-metal underground mines. The fan is very useful for performing ventilation research in large-opening mines because it can be transported easily to any mine site location and driven directly to the underground test sites. The transportability of the fan unit greatly decreases our response time to address specific ventilation problems encountered by our stakeholders. Electricity is not always readily available at the required locations of the ventilation tests, and considerable time and effort is often required by the cooperator to provide power to the test sites. The mobile diesel powered propeller fan eliminates logistics problems associated with the use of conventional electric fans, further enhancing the research capability of the unit. The fan has been used to conduct various research tasks in large opening mines related to face ventilation, mine-wide ventilation, and silica dust near an underground stone crusher.

Strategic Goals: Mine disasters; Respiratory diseases
Quantity: 1
Site: Lake Lynn Laboratory
Facility: Lake Lynn Experimental Mine

Portable diesel powered propeller fan

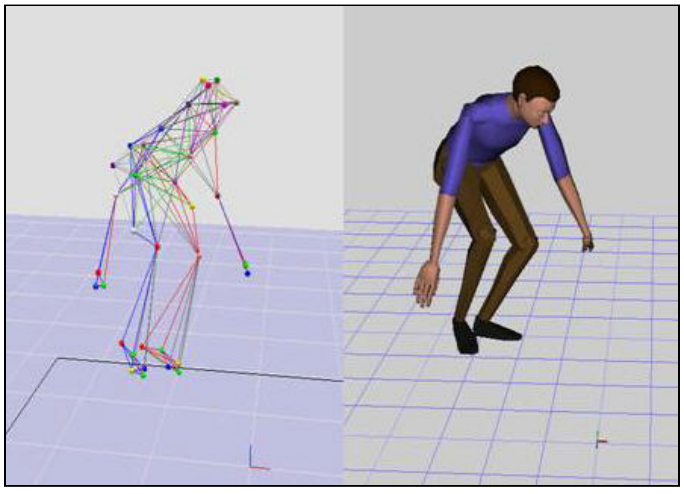
NIOSH Mining Major Equipment

Motion Analysis Eagle i Motion Analysis Capture System

The motion analysis capture system monitors and records a subject´s motions using optical markers on the subject. The resulting data is used to animate many types of digital subjects such as virtual humans and/or CAD models of machines. The gathered data is much more accurate than data from traditional, frame-by-frame animation techniques as it tracks real motions of the actual subject. The application of motion capture is well-documented with many examples from running, walking, spine studies, foot, shoulder, motor control applications, machine-human interaction studies and more.

The Eagle Digital System consists of 12 Eagle Digital Cameras, the EagleHub, and EVaRT software, which can capture complex motion with extreme accuracy. Real-time capabilities allow one to see capture results at the same instant as the subject is performing a specific task. Jack, a motion simulation and analysis software is used. It comes with a module that provides an interface to the motion-capture system. Motions represented by the optical markers are transferred into Jack, where researchers can examine both position and orientation of each motion. Jack can also be used for low back analysis and design of virtual humans.

Strategic Goals: Cumulative injuries; Traumatic injuries
Quantity: 1
Site: Pittsburgh Research Laboratory
Laboratory: Motion Analysis Laboratory
Building: 152



Test subject motion tracked (left) and Jack´s virtual human mapped (right)

NIOSH Mining Major Equipment

OROS OR38 Multi-Analyzer/Recorder

This portable, 8-channel device is capable of making sound level and vibration level measurements in 1/3-octave bands. When used with an intensity probe, this instrument can be used to perform sound intensity measurements.

Strategic Goals: Hearing loss
Quantity: 1
Site: Pittsburgh Research Laboratory
Building: 154

OROS OR38 multi-analyzer/recorder

NIOSH Mining Major Equipment

Programmable Controlled Tension-Compression Test Frame

The tension compression test frame has a 20,000 pound capacity and is equipped with programmable control and data collection. This machine is capable of cyclic loading for earthquake simulation and fatigue evaluations.

Strategic Goals: Ground control
Quantity: 1
Site: Spokane Research Laboratory
Laboratory: Soil/Rock Properties Laboratory

Tension-compression test frame

NIOSH Mining Major Equipment

Robotron 50-KA High Current Source

The Robotron 50-kA high current source is an electrical power supply capable of delivering up to 50 kA ac current with precisely controlled triggering and pulse duration. This power supply features a liquid-cooled transformer and a processor-based output controller. It has been used to examine the thermal characteristics of electrical conductors under short circuit conditions as part of research studying the performance and safety of mine electrical cables. It can also be used to study the performance of circuit over-current protection devices such as fuses and circuit breakers.

Strategic Goals: Traumatic injuries
Quantity: 1
Site: Pittsburgh Research Laboratory
Laboratory: Mine Electrical Laboratory
Building: 151

Attaching an electrical cable to the Robotron 50-kA high current source in preparation for an electrical safety experiment

NIOSH Mining Major Equipment

Scanning Electron Microscope And X-Ray Elemental Analysis System

The Scanning electron microscope (SEM) provides high-resolution electron imaging of burned and unburned coal dust and other particles down to a size of 1 micrometer or less. X-rays generated by the imaging high-energy electron beam are collected and the energy analyzed to determine the elements contained of the material in the image area (or portions thereof) and their relative amounts. Both the electron image and x-ray scans are collected in digital form under PC control and saved in standard formats compatible with standard word processing programs. The images and elemental analyses are used for research purposes in the Ventilation and Explosion Prevention program area to better understand the causes, effects, and mechanisms of explosions. The SEM is also used in forensic studies requested by the Mine Safety and Health Administration in their investigations of coal mine explosions, ignitions, and other incidents. Assistance is also provided to other NIOSH researchers inside and outside PRL who request SEM/x-ray analyses for various research purposes.

Strategic Goals: Mine disasters
Quantity: 1
Site: Pittsburgh Research Laboratory
Building: 143

Scanning electron microscope and x-ray elemental analysis system

NIOSH Mining Major Equipment

Servo Controlled MTS Load Frame

The MTS (Material Testing System) has an axial load capacity of one-million pounds. The servo-controlled system can test specimens in load, stroke, or strain control while the data from LVDT´s (Linear Variable Distance Transducers) are recorded and analyzed in real-time. Sample preparation equipment, including lapidary saws, drills, and grinders, support the research facility while the ASTM Rock Testing Standards are the testing protocol.

Strategic Goals: Ground control
Quantity: 1
Site: Pittsburgh Research Laboratory
Laboratory: MTS Rock Mechanics Testing Laboratory
Building: 156

Servo controlled MTS load frame

NIOSH Mining Major Equipment

Small Scale Burn Tunnels

Two small scale burn tunnels are used to measure fire resistance and flammability of solid combustibles, such as conveyor belting and noise abatement materials. Levels of smoke and toxic gases are also measured in order to assess the relative hazards produced during the combustion of sample materials under forced ventilating air-flow.

The two tunnels have a square cross-sectional area of 0.21 m^2, with one of the tunnels having a length of 7.9 m and the other a length of 4.9 m. The tunnels are connected via transition ducting to an exhaust fan that supplies the forced ventilating air-flow. Adjustable sliding plates within the transition ducting can be used to set ventilation air velocities within the tunnels in the range of 0.5 m/s to 3.0 m/s. Gas sampling ports, located within the transition ducting, are used to extract gas samples for subsequent measurement via on-line, continuous gas analyzers.

Combustible materials are mounted on metal racks and ignited at the open end of the tunnel using a methane-air burner. Samples are typically 0.23 m wide and can be of various lengths. In addition to measuring the gas temperature of the combustion product gases, thermocouples may be imbedded with the materials at fixed distances to determine flame spread rates. The tunnels are also useful for determining the effects of air velocity on their burning characteristics.

Strategic Goals: Mine disasters
Quantity: 2
Site: Lake Lynn Laboratory

Small scale burn tunnel

NIOSH Mining Major Equipment

Temporary Magazine

Explosives received after hours are stored in the temporary magazine until they can be moved to permanent magazine storage.

Strategic Goals: Traumatic injuries
Quantity: 1
Site: Pittsburgh Research Laboratory

Temporary magazine

NIOSH Mining Major Equipment

Tension-Compression Test Frames

Three tension compression test frames are capable of testing specimens up to 24 inches in diameter. Full scale range varies from 25,000 lbs on the small machine to 400,000 lbs on the largest. These machines are used to measure the physical properties of materials.

Strategic Goals: Ground control
Quantity: 3
Site: Spokane Research Laboratory
Laboratory: Soil/Rock Properties Laboratory

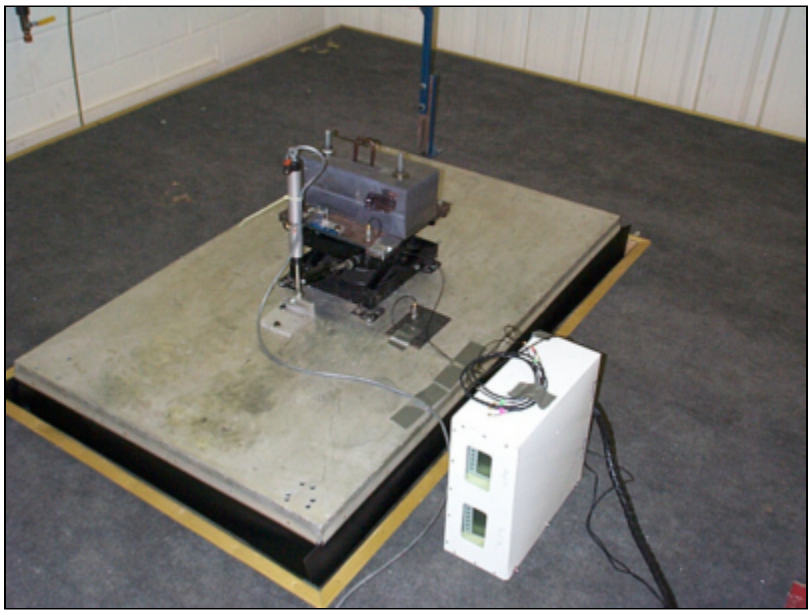
Three tension-compression test frames

NIOSH Mining Major Equipment

Vibration Table

The Whole Body Vibration Laboratory at the Pittsburgh facility contains a single axis vibration table that enables researchers to study whole-body vibration. The table can produce vibrations from computer generated data, either random or specific, in various waveforms from frequencies between 1 - 15 HZ, accelerations in excess of 10G's, and a maximum travel of 6 in. It can also reproduce vibrations recorded from field tests, making it useful for simulating road vibrations

Strategic Goals: Cumulative injuries; Traumatic injuries
Quantity: 1
Site: Pittsburgh Research Laboratory
Laboratory: Whole Body Vibration Laboratory
Building: 153



Vibration table in the Whole Body Vibration Laboratory

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Chapter 2
What does the Mining Program do?

2.1 Overview of Chapter 2

The Mining Program conducts a focused set of research and prevention activities that has been designed to meet the needs of mineworkers and related stakeholders. The previous chapter explained the basis for the Program Plan and presented the Plan. This chapter summarizes the processes used to develop the research portfolio, the projects currently in the portfolio, and the customers, stakeholders, and partners of the Program.

The overall process beginning with defining and conducting the research and ending with effecting improvements to mineworker safety and health is complex. A logic model has been prepared to illustrate the more important interrelationships.

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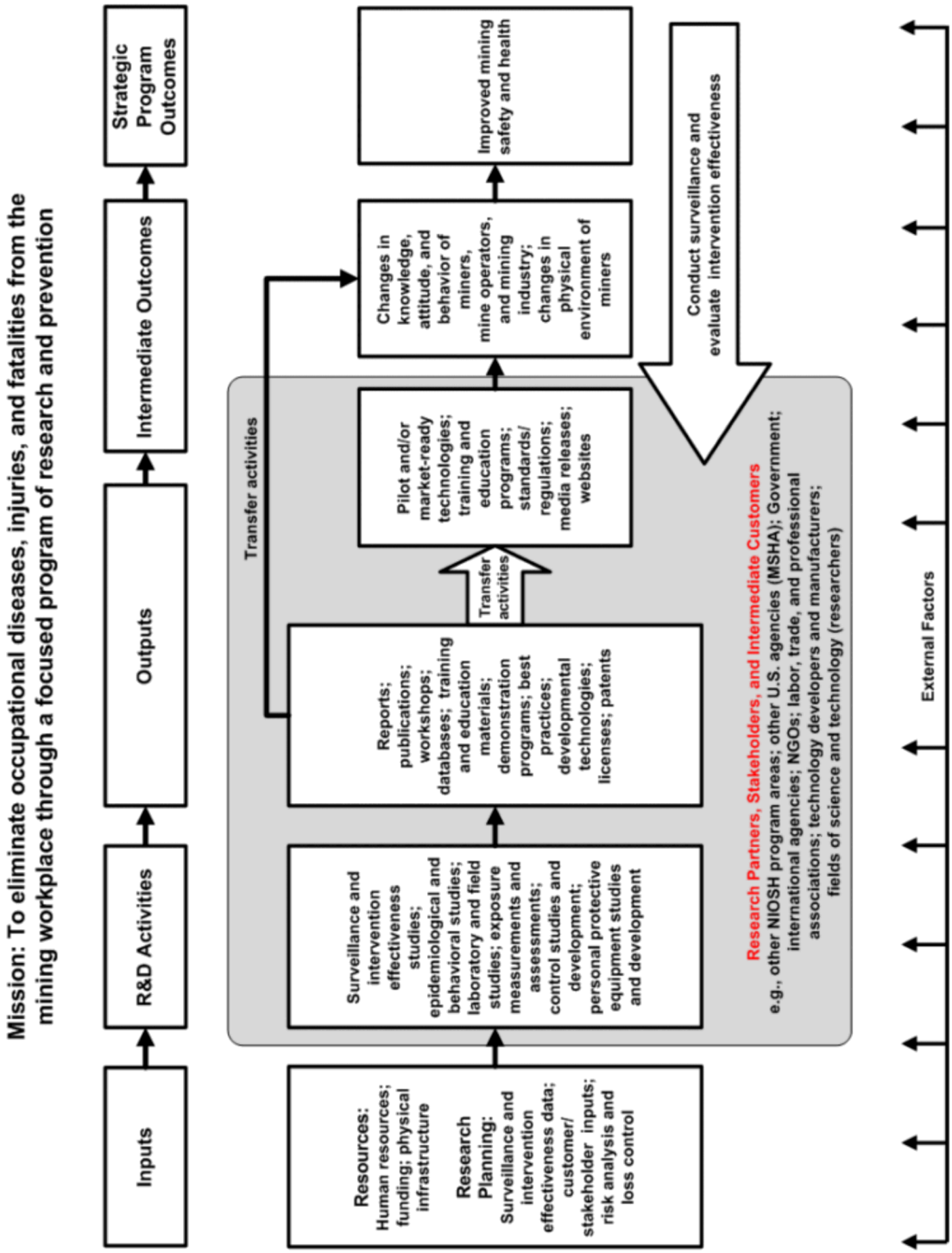
2.2 Logic Model



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2.3 Project Planning and Evaluation

Project Planning

The Mining Research Plan described in Chapter I establishes the general areas of research need. This section summarizes the administrative processes for populating the research portfolio. In December of each year a call is issued for concept papers on possible new projects for the upcoming fiscal year beginning the following October. An example of the call for concepts is shown below:

From: Niezgoda, Karen A.
Sent: Thursday, December 09, 2004 4:45 PM
To: All - NIOSH/PRL
Subject: FY2006 New Concepts

The calendar may still say 2004, but it's time to start developing the FY2006 research program. The first step is the preparation of Concept Papers.

We will continue to initiate new projects aimed at high-priority mining-specific health and safety problems. Priorities for new research projects have been established based on: 1) stakeholder needs, 2) surveillance data, and 3) available resources. These priorities include:

- Demonstration of Intervention Effectiveness:
  - Reducing the recurring high fatalities from powered haulage in both underground and surface mines, falls of ground in underground mines, and working around machinery/equipment in both underground and surface mines.
  - Reducing the recurring high injury incidence from handling materials, slips/falls, MSD's (especially among aging miners)
  - Reducing the recurring areas of unacceptable disease prevalence (silicosis, pneumoconiosis, hearing loss)
- Dust Monitoring and Control
- Diesel Monitoring and Control
- Hearing Loss Prevention/Engineering Noise Control

The Concept Papers should be submitted through your supervisory chain to Karen Niezgoda by January 31, 2005. You are encouraged to discuss concepts with your supervisor prior to the preparation of a paper.

Concept papers should follow the attached format.

The concept papers are evaluated by the laboratory lead team for program needs, likelihood of success, and potential impact. Some concepts are rejected or deferred. The submitters of the most promising concepts are asked to prepare full project proposals for external peer review and possible project initiation in the beginning of the following fiscal year. The process for preparing these full proposals and the external peer review process are described in the document *"Procedures for External Peer Review of Intramural Projects"* below. Two example proposals are also provided.

A few concepts may appear promising, but the research idea needs a great deal of additional work before a complete proposal can be prepared. Such concepts may be funded as pilot projects for one year to test feasibility or to gather additional information. Full project proposals must be prepared for these projects and receive favorable external peer review before they are fully funded to completion.

Appendix A contains forms and instructions for submitting full research project proposals for new intramural projects in the NIOSH Mining Program. Such proposals are normally evaluated by external peer reviewers to help ensure the quality of the research done in the Program. The format of the proposals is based on the R01 research grant application format used by NIH and CDC, and is similar to the format used for NIOSH NORA proposals.

Project Evaluation

Once projects are underway, they receive various types of internal and external review. Project plans are prepared and submitted as part of the NIOSH IRIS management information system. In addition, each calendar year work plans are prepared, that also include more detailed schedules of the tasks to be completed on each project. The individual performance plans of the project leaders and other project staff contain deadlines for completion of key research project tasks. Formal and informal reviews are conducted to ensure that projects remain on track. As a result of reviews projects: may be terminated and resources directed elsewhere; may receive additional resources: or may have their scope or milestones significantly altered. Branch chiefs schedule periodic meetings with staff to review progress on individual projects. These project meetings are sometimes also attended by the laboratory managers. All projects are reviewed annually at the "mid-year reviews" at which presentations are made on each project for branch staff and managers from both mining laboratories and the Office of the Associate Director for Mining and Construction.

Some of the more critical and visible on-going projects receive external review as well. The Mine Safety and Health Research Advisory Committee reviews some of the more critical projects and provides advice on progress and future direction. The projects in areas included in partnerships are reviewed at periodic meetings. These partnerships are described in section 2.6 - Partnerships.

Review processes extend to the research results when they are prepared for presentation and publication for the outside world. All research publications are subject to internal and external peer review. Publications for peer-reviewed journals are reviewed internally by branch and laboratory management before they are submitted to the peer-reviewed journal editor. In addition such papers may also be sent for review by MSHA or other NIOSH divisions if they impact MSHA regulations or research in other parts of NIOSH. Papers which are to be submitted for publication in non-peer reviewed journals or conference proceedings are also given at least three technical reviews, one by a reviewer within the laboratory, and two by reviewers external to the laboratory. Appendix B describes the process for review of research papers and contains flowcharts illustrating the publication review processes.

2.4 Research and Development Portfolio

Our Research Portfolio includes the following research projects categorized by the primary Strategic Goal addressed. Each project is described in subsequent pages:

Strategic Goal 1 - Respiratory diseases: Reduce respiratory diseases in miners by reducing health hazards in the workplace associated with coal worker pneumoconiosis, silicosis, and diesel emissions.

Research Projects:

1. Assessment of Personal Particulate Exposure
2. Characterizing Diesel Emissions in Underground Mines
3. Advanced Spray Dust Capture Principles for Mine Dust Control
4. Control of Silica Dust Exposures in Underground Coal Mining
5. Dust Control for Longwall Mining
6. Improving Ventilation Technology in Large Opening Mines
7. Miners´ Response to Personal Dust Monitor Feedback
8. Coal Workers' Health Surveillance Program (CWHSP)
9. Reducing Underground Miners´ Exposure to Diesel Emissions
10. Selection and Evaluation of Diesel Emission Controls for Outby Underground Coal Mine Equipment
11. A Cohort Mortality Study With A Nested Case-Control Study Of Lung Cancer And Diesel Exhaust Among Non-Metal Miners
12. Silica Dust Control in Metal/Nonmetal Mining
13. Surface Mine Dust Control
14. Ultrafine Aerosols From Diesel-Powered Equipment

Strategic Goal 2 - Hearing loss: Reduce noise-induced hearing loss (NIHL) in the mining industry.

Research Projects:

1. A Health Hazard Study of Surface Drilling Operations
2. Cross-Sectional Survey: Noise Exposure Patterns/Sources
3. Definition and Assessment of Engineering Noise Controls
4. Engineering Noise Controls for Roof Bolting Machines
5. Health Communication Interventions for Hearing Loss Prevention
6. Hearing Loss Prevention: Hearing Protection and Audibility Considerations
7. Pilot Study on Coal Cutting Noise Related to Continuous Mining Machines

Strategic Goal 3 - Cumulative injuries: Reduce repetitive/cumulative musculoskeletal injuries in mine workers.

Research Projects:

1. Ergonomics Evaluation and Improvement of Mobile Equipment
2. Ergonomics Process Effectiveness in Mining
3. Reduce Injury & MSD Risk from Human-Machine Interaction
4. Successful Aging for Miners Through Ergonomics (SAME)

Strategic Goal 4 - Traumatic injuries: Reduce traumatic injuries in the mining workplace.

Research Projects:

1. Evaluating Roadway Construction Work Zone Interventions
2. Lockout/Tagout, Jammed, and Moving Machinery Controls
3. Mobile Mining Equipment Warning Systems
4. Protocol for Evaluating Quality of Explosives in the Field
5. Reducing Electric Arc-Induced Injuries in Mining
6. Remotely-Controlled Bulldozer on Coal Stockpiles
7. Safety Enhancements for Off-Road Haulage Trucks
8. Safety Solutions to Prevent Mining Materials-Handling Accidents
9. Smart Wearables for Hazardous Work Environments
10. Surface Blasting Safety and Health
11. Virtual Reality for Mine Safety Training

Strategic Goal 5 - Mine disasters: Reduce the risk of mine disasters (fires, explosions, and inundations); and minimize the risk to, and enhance the effectiveness of, emergency responders.

Research Projects:

1. CCER Standard
2. Coal Mine Face Methane Control and Monitoring
3. Design Guidelines for Mine Ventilation Stoppings
4. Fire Hazard Reduction in the Metal and Nonmetal Mining Industry
5. Investigation of Methane Control Issues in Underground Mines
6. Lake Lynn Laboratory
7. Long Term Field Evaluation (LTFE)
8. Mine Rescue and Response
9. Prevention and Mitigation of Gas/Dust Explosions
10. Prevention and Mitigation of Mine Inundations
11. Reducing Fire Hazards in U.S. Coal Mines
12. Remote Methods for Addressing Coal Mine Fires
13. SCSR Training Modules
14. Smoke Management and Fire Modeling for Underground Mines

Strategic Goal 6 - Ground control: Reduce ground failure fatalities and injuries in the mining industry.

Research Projects:

1. Development and Evaluation of Innovative Roof Support Technologies
2. Fragmentation Methods and Ground Control Safety
3. Fundamental Studies of Factors Responsible for Falls of Ground
4. Ground Stability Through Advanced Mine Design
5. Guidelines for Eliminating Hazardous Ground Conditions From Underground Stone Mines
6. Identification and Control of Rock Burst Hazards
7. Preventing Injuries from Falling Rock in Underground Coal Mines
8. Reduce Groundfall Hazards in Nevada
9. Roof Fall Evaluation and Mediation in Weak Rocks
10. Slope Stability Hazards Recognition
11. Stability Assessment with Seismic Monitoring

Strategic Goal 7 - Surveillance and training: Determine the impact of changing mining conditions, new and emerging technologies, training, and the changing patterns of work on worker health and safety.

Research Projects:

1. Chemical Hazards in Coal Mining
2. Chemical Hazards in Mining
3. Disseminating Safety and Health Interventions Via the Internet
4. Education and Training for an Evolving Mining Work Force
5. Evaluation of Heat Stress and Interventions in Surface and Underground Mines
6. Hazard Evaluation and Technical Assistance
7. Health Communications Program
8. Surveillance of Mine Safety Hazards
9. Surveillance: National Survey of the Mining Population
10. Workplace Stress Among Underground Coal Miners

Ongoing Research Project related to Respiratory Diseases

Assessment of Personal Particulate Exposure

PURPOSE: Reduce respirable dust-related health concerns by developing portable, mine-worthy devices capable of providing timely measurement of coal and silica dust, diesel aerosols, and other airborne contaminants.

RESEARCH SUMMARY: Assessment of workplace exposure to particulate matter is a critical step in eliminating dust-related occupational illness and disease. During 1990-99, coal workers´ pneumoconiosis caused the deaths of 15,036 U.S. miners. Between 1987 and 1996, silicosis, excluding carcinomas potentially caused by silica, prematurely shortened Americans' lives by 33,000 years. In 1988, NIOSH recommended that whole diesel exhaust be regarded as a potential occupational carcinogen.

Current industrial hygiene particulate assessment methods do not provide timely data to an industry with a workplace as dynamic and unique as mining. The intent of this project is to study and develop various tools that can be used to assess mineworker exposure to airborne particulate. Real-time measurement tools will enable workers and management to take corrective action before dust levels can affect workers' health.

Two specific devices are in development. A mine-worthy and accurate personal dust monitor (PDM) has been designed and built based on a tapered element oscillating microbalance, an inertial-oriented, momentum compensated mass sensor. The PDM meets the NIOSH accuracy criteria and provides timely data to miners wearing the unit. Laboratory evaluations of this device are completed and field trials are well along. New Mine Safety and Health Administration rules regarding compliance-based underground dust measurements are on hold pending the outcome of this research. A fast, accurate, and economic method to measure diesel exhaust particulate has also been developed, based upon the NIOSH-patented dust dosimeter. It relies on the measurement of increased differential pressure across a filter that is inserted into an engine tailpipe. The Australian government is considering rulemaking involving the adoption of this device into their mines.

Personal Dust Monitor provides data to miners in time to take action to prevent overexposures

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STRATEGIC GOAL:
Respiratory diseases

KEYWORDS:
mining, assessment, coal, silica, diesel

Acceptance by regulatory agencies, miners, and industry personnel of the instruments developed will make it more likely that particulate levels are maintained within acceptable limits. The successful outcome of the work will result in new tools and approaches to particulate monitoring, designed to protect worker health. These technical advancements will be transferred to industry through mine visits, briefings, conference presentations, and formal and informal workshops.

Ongoing Research Project related to Respiratory Diseases

Characterizing Diesel Emissions in Underground Mines

PURPOSE: Protect miners working in underground mines from diesel-powered equipment emissions through improvements in diesel particulate emission measurement techniques.

RESEARCH SUMMARY: Long-term exposure to elevated concentrations of diesel exhaust has become a concern because diesel particulate matter (DPM) is considered to be a carcinogen by several organizations. Approximately 30,000 underground miners are exposed to excessively high DPM concentrations (greater than 500 g/m3). Since DPM consists of over 80% total carbon (TC), the Mine Safety and Health Administration (MSHA) initially chose TC as the surrogate for DPM. TC is the sum of organic carbon (OC) and elemental carbon (EC) fractions. The problem with TC is the number of other TC sources, besides DPM, in the mining environment. Research has shown that these TC interferences, such as mineral dust and vapor-phase OC, can be eliminated or corrected, but airborne contaminants like, cigarette smoke and oil mist, cannot.

Sampling package for DPM field measurements

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STRATEGIC GOAL:
Respiratory diseases

KEYWORDS:
diesel, air monitoring, aerosols, ultrafines, real time

In light of the problem with TC interferences, EC, with NIOSH influence, has become the surrogate for DPM. The problem with EC as a surrogate is that the relationship between EC and total DPM can change, depending on engine duty cycle and other factors.

Because of programmatic effort, several notable outcomes have been accomplished. MSHA has changed the DPM concentration surrogate from TC to EC. This change allows MSHA personnel to take interference-free samples to more accurately evaluate miner exposures. DPM cassettes, designed through Bureau of Mines/NIOSH research and manufactured by SKC, Inc., have become the standard DPM sampling technique. MSHA, industry, and labor have agreed on an interim DPM exposure limit. Finally, the underground mining industry, labor, and government have created a partnership to address issues relative to DPM exposure.

Several other diesel emission monitoring problems related to miner health exist that are being studied under this project. The relationship between EC and total DPM must be investigated, especially as new emission control technologies are implemented. Novel methods for determining and characterizing diesel emissions need to be developed. Finally, the industry is in need of a device that will enable personnel to determine real-time DPM concentrations in the mining environment

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Ongoing Research Project related to Respiratory Diseases

Advanced Spray Dust Capture Principles for Mine Dust Control

PURPOSE: The objective of this research is to reduce mine worker exposure to respirable coal and/or silica dust by increasing the dust capture efficiency of mine water spray systems.

Dust generated from rotary cutting saw at a dimension stone shop

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STRATEGIC GOAL:
Respiratory diseases

KEYWORDS:
silica, coal mine dust, mining, control technology

RESEARCH SUMMARY: Coal workers´ pneumoconiosis (CWP) and silicosis are debilitating and sometimes fatal occupational lung diseases that afflict mine workers at underground and surface mining operations. The number of mining deaths between 1990 and 1999 related to CWP was 15,036. From 1990 to 1999, there were 2,405 deaths related to silicosis. For 880 of the silicosis deaths, the associated industries were recorded on the death certificates with 203 (23.1%) attributed to coal and metal/nonmetal mining combined. For this same time period, the percentage of coal mine dust samples that exceeded the 2.0 mg/m^3 dust standard was nearly 9%, while the percentage of dust samples exceeding the allowable silica limit for coal, metal, and nonmetal mining were 30%, 12%, and 7%, respectively. These data illustrate the severity of lung disease in mining and the inadequacy of control technologies for consistently maintaining compliance with the mandated dust standards.

Laboratory tests have been completed to quantify the air moving capability of different spray nozzles, as well as, the dust capture efficiency of these sprays for multiple operating pressures. This information was used to develop a water-powered scrubber that moves approximately 500 cfm of air with a high dust capture efficiency, yet operates at water pressures below 250 psi.

Future research will focus on using this fundamental spray characteristics knowledge to improve existing dust control systems and/or develop new control applications. Laboratory research work for improving the dust capture efficiency of coal mining machine mounted spray systems is planned for future testing in the full scale dust gallery. Successful technologies will then be tested at operating mine sites. Recently, arrangements have been made to conduct a dust survey in early spring at a dimension stone shop to evaluate a water-powered scrubber. This scrubber will be installed to evaluate its effectiveness for reducing silica dust generated by a rock cutting saw.

Planned project outcomes are to develop and demonstrate improved, user-oriented, spray systems for mining and cutting machines that can reduce airborne respirable dust by more than 30%. A measure of project outcomes would be to have these spray system developments adopted or implemented in a notable segment (30%) of the mining industry within 5 years of project completion.

Ongoing Research Project related to Respiratory Diseases

Control of Silica Dust Exposures in Underground Coal Mining

PURPOSE: Develop controls that reduce silica dust exposures for operators of continuous mining machines and roof bolting machines to prevent the development of silicosis.

Canopy air curtain installed on roof bolter in underground coal mine

RESEARCHER:
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STRATEGIC GOAL:
Respiratory diseases

KEYWORDS:
silica, dust, underground mining, control technology

RESEARCH SUMMARY: In underground coal mines, the two occupations with the highest risk of excessive exposure to respirable silica dust are the continuous mining machine operator and the roof bolter operator. The Mine Safety and Health Administration (MSHA) analyzed nearly 31,000 personal samples for these occupations during the period 1999-2003. Nearly 12% of these samples exceeded the federal dust standard of 2 $\mu g/m^3$ while 20% of these samples exceeded a silica dust concentration of 100 $\mu g/m^3$; the maximum allowed under MSHA regulations. Overexposures continue to occur with miners still contracting coal workers´ pneumoconiosis and silicosis, both debilitating and fatal lung diseases.

To lower the silica dust exposures of roof bolter operators, NIOSH developed a canopy air curtain that reduced dust levels under the air curtain by approximately 50% in laboratory testing. The canopy air curtain was modified for retrofit onto a roof bolter and tested at an operating underground mine. Results indicate that dust levels for the operator working beneath the drilling canopy were reduced but not to the level found in the lab. NIOSH is working with the bolter manufacturer and mine operator to modify the size and flow characteristics of the tested air curtain to improve its dust reduction potential and application to other bolting machines.

Wet head continuous miners introduce water via sprays located behind each cutting bit on the cutting drum instead of via a spray bar positioned back from the cutting drum. This places sprays closer to the cutting with the potential to reduce airborne dust levels. NIOSH has completed an evaluation of a wet head miner that was operated with exhaust curtain ventilation. Some improvements in dust levels at the operator were measured. Future studies are planned to evaluate wet head technology for miners that are operated with blowing face ventilation.

Airflow from the dust scrubber on the continuous miner can be redirected to the face through a series of louvers in an attempt to contain and capture more of the dust generated at the face, thus reducing the dust exposure of the miner operator. NIOSH worked with a coal company to test redirected scrubber flow. Results showed that the dust exposure of the shuttle car operators was reduced over 50%. The impact on the exposure of the miner operator was much less, indicating

a need to research and optimize the balance between the redirected scrubber flow and the face ventilation flow. Laboratory tests will be completed to develop guidelines regarding the use of redirected scrubber exhaust for control of respirable dust, with special attention given to balancing redirected and primary airflows.

Ongoing Research Project related to Respiratory Diseases

Dust Control for Longwall Mining

PURPOSE: The objective of this research project is to lower the risk of developing debilitating lung diseases by reducing respirable dust exposure to mine workers at longwall mining operations.

Conducting dust sampling on longwall face

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STRATEGIC GOAL:
Respiratory diseases

KEYWORDS:
coal mine dust, underground mining, control technology

RESEARCH SUMMARY: Longwall mining operations now account for approximately 51% of the coal produced underground in the United States. Unfortunately, substantial increases in coal extraction rates also result in the generation of more respirable dust. From 1996 through 2000, compliance dust samples exceeding the federal dust standard of 2.0 mg/m3 were 18% and 15% for jack setters and shearer operators, respectively. Health surveillance data also indicates that overexposure to respirable dust in underground coal mines continues to lead to the development of lung disease.

Laboratory research has been conducted to evaluate and optimize control parameters that impact dust generated by the shearer. These results provide operators with guidance on dust control resulting from changes in face air velocity, water spray pressure, water quantity, spray system design and cutting direction. Additional laboratory testing will be conducted to optimize external sprays system designs for high coal operations.

Laboratory testing has also been completed to evaluate shield dust entrainment in high velocity airstreams up to 2000 fpm. Results have shown that significant increases in respirable dust levels were observed as air velocity increased. Future tests will evaluate the ability of water sprays to reduce respirable dust entrainment in these high velocity airstreams.

Benchmarking surveys have been conducted on six longwall faces across the country to quantify dust levels from various sources, define current operating practices, and determine the relative effectiveness of existing control technologies. Four additional surveys will be completed and a "best practices" document produced to assist operators in applying effective control technologies.

Successful completion of this research project will result in developing improved dust control technologies/practices that can be adopted by longwall operators throughout the United States. The goal is to reduce dust exposure of longwall mine workers by 30% over a 5-year period as these controls are implemented.

Ongoing Research Project related to Respiratory Diseases

Improving Ventilation Technology in Large Opening Mines

PURPOSE: To improve the air quality in metal/nonmetal mines to reduce the risk of adverse health effects from worker exposure to airborne contaminants such as diesel particulate matter (DPM), toxic fumes from blasting, and silica dust.

Propeller fans installed for main mine ventilation in a large opening stone mine

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STRATEGIC GOAL:
Respiratory diseases

KEYWORDS:
underground mining, ventilation, diesel, airborne contaminants

RESEARCH SUMMARY: Virtually all underground stone mines and many other metal/nonmetal mines have large openings creating ventilation airflows with low velocities. Due to the ventilation inefficiencies common to these mines, the underground workers are exposed to a variety of potentially harmful substances through the air they breathe. Reductions in worker exposure to these contaminants can be achieved by improving the ventilation airflow in these mines. These goals are particularly timely in that the metal/nonmetal mining industry is confronted with new DPM regulatory exposure limits that were set forth in 2002, with more stringent restrictions scheduled to take place in 2006.

Practical methods to improve ventilation airflows in large opening mines are being investigated. Several methods have been conceived, developed, and evaluated in operating large opening stone mines that have been shown to improve the general air quality in the underground workplace. These methods include: (1) identifying the proper fans for use in large opening mines; (2) including ventilation needs as an integral part of the mine planning process to aid the development and use of efficient generic ventilation designs for all mines; (3) developing a computer program to determine the approximate air flow volume necessary to meet statutory air quality (DPM) requirements based on the diesel equipment in use at an individual mine site; and (4) improving the construction methods and materials used to construct stoppings for directing mine ventilation air to the critical areas of large opening mines to reduce worker exposure to airborne contaminants.

Although there have been many general improvements in large opening mine ventilation practices resulting from the current research effort, the current state of the technology for addressing very site specific contamination areas in large opening mines is still the random and unscientific placement of auxiliary ventilation fans in the working areas. Additional research will develop optimum methods for getting higher volumes of non-contaminated mine ventilation air to the working areas, i.e., increasing the ventilation efficiency. This will be accomplished by developing novel mining

methods to direct the ventilation airflow to the working areas, including the use of using long stone pillars and auxiliary fans. At the conclusion of the research effort, Best Practices for improving ventilation airflow in large opening mines will be made available to the metal/nonmetal mining industry to reduce workers exposure to airborne contaminates in large opening mines.

Ongoing Research Project related to Respiratory Diseases

Miners´ Response to Personal Dust Monitor Feedback

PURPOSE: To document how coal miners can use real-time information from their personal dust monitors (PDM) to reduce their exposure to respirable dust.

Interview with coal miner concerning his understanding and utilization of new PDM

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STRATEGIC GOAL:
Respiratory diseases

KEYWORDS:
coal miners, pneumoconiosis, mine safety and health, lung diseases

RESEARCH SUMMARY: Although the most recent data on the prevalence of Coal Workers' Pneumoconiosis (CWP) in the United States indicates that it is declining, substantial numbers of CWP cases continue to be diagnosed. In recent years, CWP has contributed to the deaths of approximately 1,000 people in the U.S. each year. A PDM has recently been developed via a NIOSH contract with Rupprecht & Patashnick Co., Inc. As with the introduction of any new technology, it is very important to systematically document how workers react to it and make use of it. It is hoped that miners will use the real time dust exposure information provided by their PDM to make adjustments to their work place or work procedures that reduce their exposure to respirable dust. However, no one knows precisely how miners performing a wide variety of tasks and jobs are actually going to make use of this new information. This study will ensure that the strategies miners discover for using PDM information are well documented and quickly shared throughout the coal industry. The information for this study will be collected through one-on-one structured interviews with approximately 20 miners at each of 5 mines located throughout the major coal producing regions of the U.S. A structured interview guide has been developed and pilot tested at two mines. This study will help reduce the incidence of lung disease among coal miners, leading to improvements in their longevity and quality of life. The outputs of this project will include publications and presentations on how coal miners can use information from PDMs to reduce their exposure to respirable dust. Also, materials will be developed for (a) teaching miners about the capabilities and use of their PDM, and (b) teaching PDM maintenance personnel about how to download data, clean the unit, and program it for the next shift of sampling.

Ongoing Research Project related to Respiratory Diseases

Coal Workers' Health Surveillance Program (CWHSP)

PURPOSE: The Federal Coal Mine Health and Safety Act of 1969 (as amended by the Federal Mine Safety and Health Act of 1977) is intended to protect the health and safety of underground coal miners. The Act authorizes a program for early detection and prevention of coal workers' pneumoconiosis carried out by NIOSH in cooperation with the Mine Safety and Health Administration (MSHA). These activities are specified in the Federal Regulations, 42 CFR 37, "Specifications for Medical Examinations of Underground Coal Miners" and are administered through the Coal Workers' Health Surveillance Program (CWHSP).

Mobile Occupational Safety and Health Unit

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STRATEGIC GOAL:
Respiratory diseases

KEYWORDS:
coal miners, coal workers´ pneumoconiosis, silicosis, pneumoconiosis, chest x-rays, surveillance, B-Readers

RESEARCH SUMMARY: The CWHSP includes: certification of x-ray facilities; training, testing, and certification of physician readers (B Readers); classification of chest radiographs for pneumoconiosis; communication of individual examination results to miners; notification to miners with evidence of pneumoconiosis about options to transfer to low dust areas (Part 90); and provision of data to evaluate the respiratory health of underground coal miners. The CWHSP maintains a radiographic examination data base utilized by NIOSH for surveillance purposes and by researchers involved in developing strategies to reduce the incidence and progression of coal workers' pneumoconiosis.

During the early 1970s, one of every three miners examined in the program who had worked at least 25 years underground had radiographic evidence of pneumoconiosis. A recent analysis of over 25,000 miners who were examined from 1996 to 2002 indicates that the proportion of underground coal miners affected has greatly decreased, to about one in 20. However, recent analyses (including novel analyses of disease progression) also suggests that certain groups of miners - those who work in certain mining jobs, in smaller mines, in several geographic areas, and among contract miners - remain at elevated risk. These new findings are driving targeted assessments and preventive interventions, making more effective use of CWHSP data than has previously been done. A recent extension of the CWHSP, implemented by NIOSH in cooperation with MSHA, has been helpful in highlighting the continuing occurrence of pneumoconiosis among surface coal miners, who have not been eligible for the ongoing radiographic examination program mandated by Federal law.

Starting in FY06, in collaboration with MSHA, CWHSP enhancements will be implemented. A recently acquired Mobile Occupational Safety and Health Unit (see photo) is expected to help increase miner participation in programs for early detection of dust-related lung disease. Results are intended to facilitate preventive actions, through the derivation of representative current estimates of the burden, distribution, and determinants of occupational lung disease in relation to coal mining in the U.S.

Ongoing Research Project related to Respiratory Diseases

Reducing Underground Miners´ Exposure to Diesel Emissions

PURPOSE: Reduce diesel exhaust gas and particulate matter levels in underground mines by providing scientific and technical data on the effects of available and novel control technologies measured by both established and experimental methods.

NIOSH Mobile Engine Dynamometer

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STRATEGIC GOAL:
Respiratory diseases

KEYWORDS:
mining, diesel, control technology, methods development

RESEARCH SUMMARY: Approximately 30,000 underground miners have been found to be exposed to diesel particulate matter (DPM) at levels as high as 500 µg/m3. Promulgation of regulations by the Mine Safety and Health Administration (MSHA), limiting exposure of coal, metal, and nonmetal underground miners to DPM, is resulting in a rapid implementation of various novel technologies for control of DPM and gaseous emissions. Many of these emission control technologies have been evaluated under highly controlled laboratory conditions that are not representative of real-use conditions. The effectiveness of these technologies in the mine environment has a direct consequence on the success of the rule to control miner exposures to DPM.

Recognizing this situation, NIOSH has responded by conducting in-mine evaluations of many of these control technologies and by developing a unique research facility to supply this critical knowledge. A research lab has been established at the NIOSH Lake Lynn Laboratory which employs a mobile engine dynamometer. It is operated under tightly controlled conditions, yet the exhaust is released into the prevailing ventilation as is the case in mining, resulting in obtaining near-laboratory-quality data under operating conditions.

Several major controlled in mine evaluations of various control technologies have been evaluated and the information disseminated to the industry. Currently, at the Lake Lynn Lab, tests are being conducted to determine the effects on DPM concentrations by a control technology that uses water to cool the exhaust and follows that with a disposable pleated element filter, as is the practice in coal mines. The testing of other more novel emission control technologies will follow. As it matures, this program will amend itself to find answers to real-world concerns regarding miner health and emission control.

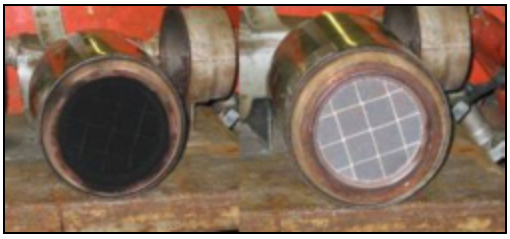
The plan is to publish and present Lake Lynn Laboratory work and production mine study results in peer-reviewed journals, at conferences, at mining community meetings, and at workshops organized through the NIOSH partnerships with both coal and the metal/nonmetal mining industry.

Ongoing Research Project related to Respiratory Diseases

Selection and Evaluation of Diesel Emission Controls for Outby Underground Coal Mine Equipment

PURPOSE: Provide the mining industry, labor, and regulatory agencies with scientific, technical, and engineering research on controlling of diesel particulate matter (DPM) and gaseous emissions through laboratory and field evaluations of existing and emerging control technologies.

RESEARCH SUMMARY: Approximately 30,000 underground miners have been exposed to DPM at levels as high as 500 µg/m3, an excessively high level. The publication of a Mine Safety and Health Administration (MSHA) proposed rule to regulate underground miner exposure to DPM, along with a NIOSH initiative, has resulted in the formation of a coal partnership for the purpose of investigating, testing, and promoting effective control technologies. The success of the coal partnership, resulted in the metal/nonmetal industry also forming a partnership with NIOSH that also continues to be supported under this project.



Evidence of the effectiveness of a DPM filter

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STRATEGIC GOAL:
Respiratory diseases

KEYWORDS:
mining, diesel, airborne contaminants

Emission control technologies are evaluated on a mobile engine dynamometer at the NIOSH Lake Lynn Laboratory and at mine field sites provided by the partnerships. This work includes; 1) the selection of potentially viable emission controls, 2) resolving issues related to their use, and 3) information dissemination and education to facilitate their implementation in mines.

This project is also introducing modern clean engine technology into underground mines. The engine subcommittee of the coal partnership, headed by NIOSH, is actively engaged in devising a policy that will permit the use of insulating materials to supplement water-jacketing so that modern clean engines can be used in permissible power packages.

This effort has provided real-world emissions-reduction data for a number of filter media and fuel formulations through laboratory and isolated zone studies in operating mines. The quality of this work has earned both high praise and respect from our constituents and has allowed us to forge new initiatives.

Modern, super-clean, electronically controlled engines are accepted at high altitude western coal mines. A recent outcome of high altitude research involves a mining operation´s decision to replace 54 diesel-powered trucks with vehicles having new low-emitting engines. This resulted from NIOSH recommendations that led an engine manufacturer to develop a new control module, enabling use at high altitude mines.

Ongoing Research Project related to Respiratory Diseases

A Cohort Mortality Study With A Nested Case-Control Study Of Lung Cancer And Diesel Exhaust Among Non-Metal Miners

PURPOSE: The retrospective cohort mortality and nested case control study is investigating risk of lung cancer in relation to quantitative measures of exposure to diesel exhaust. In addition, it will determine whether there is evidence of elevated mortality from other causes among miners exposed to diesel exhaust.

RESEARCH SUMMARY: The mortality study cohort of about 10,000 miners comprises all non-office workers from eight selected mines who were employed for at least one year during the period from the date of dieselization at the mine until the end of follow up on December 31, 1997. A standard mortality ratio analysis will be undertaken, overall and by level of diesel exhaust exposure. Poisson regression and Cox proportional hazard modeling of mortality will be carried out using exposures derived from the exposure assessment phase of the project.

Workers in a underground non-metal mine

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STRATEGIC GOAL:
Respiratory diseases

KEYWORDS:
mining, diesel exhaust, mortality, lung cancer

The nested case control study is based on deaths from lung cancer ascertained during the follow up stage of the cohort study. Four controls will be selected for each case from among members of the cohort who were alive at the time that the case died, matching on mine, year of birth, gender, and race/ethnicity. Information on smoking (active and passive) and other potential confounders (e.g., employment in high risk occupations for lung cancer, diet, and certain medical conditions) will be ascertained by interview of next of kin of deceased cases and controls and direct interview of living controls. Conditional logistic regression will be used to determine risk of mortality from lung cancer for various measures of diesel exhaust exposure, including cumulative exposure and average intensity.

Information from comprehensive industrial hygiene surveys at each working mine, together with past exposure and surrogate data, will be used to construct estimates of personal exposure for input into the cohort and case control studies. The measurements include elemental carbon (currently considered the most specific measure of general diesel exhaust exposure), submicrometer combustible dust, submicrometer particulate, the organic fraction of the exhaust, NO, NO^2, CO, CO^2, nitro-polycyclic aromatic hydrocarbons (nitro PAHs) and respirable and total particulate. Information on the operating and organizational structure of each mine, together with the sampling results, will be used to define uniform exposure categories (either job based or zone based). This information will be combined with data on significant change

periods to develop a matrix of exposure levels by exposure category (zone or job). Then, by employing an exposure category/job dictionary and the job history for each person, individual exposure estimates will be developed. More detailed exposure information will be collected for each subject in the nested case control study in order to refine the exposure estimates.

Ongoing Research Project related to Respiratory Diseases

Silica Dust Control in Metal/Nonmetal Mining

PURPOSE: Reduce worker exposure to respirable silica dust in metal/nonmetal operations by developing improved control technologies.

RESEARCH SUMMARY: Chronic overexposure to respirable crystalline silica can lead to the progressive lung disease known as silicosis, which can be disabling or fatal. Data in the Mine Safety and Health Administration´s (MSHA) compliance sampling database indicates that a significant percentage of both underground and surface metal/nonmetal miners are overexposed to respirable silica dust each year. For samples collected from 2001 through 2004, 12% of all samples exceeded the permissible exposure limit (PEL), with numerous high-risk occupations having over 20% of their samples exceeding the PEL. This research program will conduct field surveys to identify dust sources for these high risk occupations, develop control technologies through laboratory and/or field studies, and transfer successful technologies to stakeholders.

Worker using Clothes Cleaning Process to remove dust

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STRATEGIC GOAL:
Respiratory diseases

KEYWORDS:
silica, control technology, underground mining, surface mining

To date, research has been conducted to: 1) develop optimized pressurization and filtration systems for enclosed cabs on mobile mining equipment and associated implementation guidelines, 2) develop a cost-effective method for cleaning work clothes in an enclosed booth and associated instructional video, 3) evaluate existing dust controls and develop improved ventilation controls for iron ore processing plants, and 4) demonstrate the effectiveness of improved mine-wide and localized ventilation systems in limestone mines for diluting dust and reducing residence time.

Future research will address: 1) the development and testing of control technologies to reduce worker exposure to silica dust in dimension stone shops, 2) the development of a stand-alone, clothes cleaning booth, which will increase its application in the industry 3) the benchmarking of controls for the silica sand industry and preparation of a handbook through a cooperative effort with Industrial Minerals Association - North America, and 4) the identifying of major dust sources for mobile workers to develop controls to reduce these exposures.

Successful outcomes will be measured by the effectiveness of the control technologies to lower exposure to respirable silica dust and the willingness of industry to adopt these control technologies at their mines and processing plants. A measure of this success would be a 50% reduction in the silica compliance samples for high risk occupations that exceed the permissible exposure limits over a five year time period.

Ongoing Research Project related to Respiratory Diseases

Surface Mine Dust Control

PURPOSE: The objective of this project is to improve the understanding of dust generation principles, evaluate and improve current control technologies, and develop new control technologies to provide a broad-based approach towards reducing silica exposure in surface mining operations.

Dust sampling on a surface mine drill

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STRATEGIC GOAL:
Respiratory diseases

KEYWORDS:
surface mining, dust, silica, control technology

RESEARCH SUMMARY: Historically, Mine Safety and Health Administration (MSHA) dust sampling data has indicated that some of the most frequently overexposed mining occupations are at surface coal mines. MSHA data for the years 1996 through 2000, shows that of the 1,400 respirable dust samples collected on highwall drill operators at surface mines, over 31% exceeded the permissible exposure limit (PEL) for silica dust.

Reducing respirable silica dust exposures to surface mine workers will be accomplished through multiple efforts. A number of research tasks will address dust generated by surface drills, which is typically the greatest dust source at surface mine sites. Respirable dust reductions for surface drills will be achieved through application of engineering controls that include: using air spray nozzles to maximize dust capture under the drill shroud, developing methods to reduce/eliminate dust emissions at the dust collector´s discharge dump, determining the optimum drilling parameters for minimizing respirable dust generation and using wet drilling technology to reduce dust liberation. Testing will be conducted with full-scale test facilities located at PRL to determine optimum system parameters for using air spray nozzles. Successful lab results will lead to evaluation at working surface mine sites.

Most surface mining equipment is equipped with enclosed cabs that have the potential to provide significant protection from respirable dust, if properly operating. Cab research has focused on improving the performance of air filtration and air conditioning/heating systems. Enclosed cab integrity will be addressed by determining the effective range of operating parameters (filter loading and system integrity) and identifying effective cab maintenance guidelines. In addition, a field-test method for evaluating environmental integrity of enclosed cab systems has been developed and tested through a cooperative research and development agreement (CRADA) with a filter manufacturer. Method development is ongoing and a patent is being pursued. Demonstration of these improved dust control technologies will be completed at a limited number of mining operations.

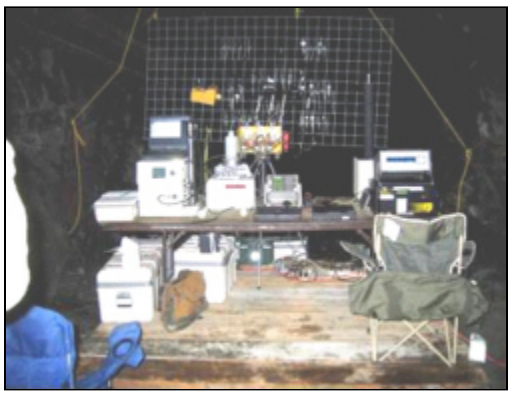
This research program has the potential to lower the silica exposure of workers by reducing dust generation during drilling and by improving the protection offered by enclosed cabs. Successful development and implementation of improved control technologies will lead to reducing overexposures by 30% within the next five years.

Ongoing Research Project related to Respiratory Diseases

Ultrafine Aerosols From Diesel-Powered Equipment

PURPOSE: Formulate control technologies to reduce miner exposure and determine associated occupational health risks through the identification of nanometer and ultrafine aerosols emitted by diesel-powered equipment.

RESEARCH SUMMARY: More than 30,000 underground miners have been found to be exposed to diesel particulate matter (DPM) at levels as high as 500 $\mu g/m^3$, an exceedingly high value. Recent promulgation of regulations by the Mine Safety and Health Administration (MSHA), limiting DPM exposures of underground miners, resulted in a swift implementation of novel technologies to control DPM and gaseous emissions. Control technologies, as well as modern diesel engines, were found to fundamentally change the physical, chemical, and toxicological properties of the emitted solid and gaseous aerosols. It is important to understand what these emissions are before prescribing solutions to control them.



Sampling diesel emissions in an underground mine

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STRATEGIC GOAL:
Respiratory diseases

KEYWORDS:
exposure, diesel, control technology

In determining particle toxicity, past research has demonstrated the importance of parameters such as size, number, solubility, and surface area and chemistry. The effects that control technologies have on the physical and chemical properties and toxicity of nanometer and ultrafine diesel aerosols will be studied in a series of tests with the NIOSH Mobile Engine Dynamometer, both at the NIOSH Lake Lynn Laboratory experimental mine and at participating active mines. State-of-the-art instrumentation will be used to directly measure size distribution and number of nanometer and ultrafine aerosols. The chemical composition of these aerosols will be determined from the collected samples using proven analytical techniques. Genotoxicity analyses, performed by the NIOSH Health Effects Laboratory Division, will investigate the effects of control technologies on nanometer and ultrafine aerosol toxicity.

Results will provide industry, labor, and enforcement agencies with a better understanding of the physical and chemical properties and toxicity of diesel-generated nanometer and ultrafine aerosols. They will assess the effects that these properties have on workers´ health, particularly asthmatic and chronic obstructive pulmonary diseases. Researchers will generate information on the effects of various control technologies and modern diesel engines on the characteristics of

aerosols and gases in mine air. These outputs should also result in a more sensitive, accurate, and relevant metric for monitoring the exposure of workers to DPM emissions. Ultimately, the industry´s acceptance of appropriately designed control technologies will reduce mineworkers´ exposure to nanometer and ultrafine aerosols.

Ongoing Research Project related to Hearing Loss

A Health Hazard Study of Surface Drilling Operations

PURPOSE: Develop engineering noise controls and a basis for hierarchical recommendations from a noise exposure analysis (NEA) to protect drill operators from hearing loss on non-cab surface drill rigs.

RESEARCH SUMMARY: Noise induced hearing loss (NIHL) is the most common occupational disease in the United States today, with 30 million workers exposed to excessive noise levels (NIOSH, NORA 1996). Further, NIOSH data indicates that at least 70% of mine workers (also engaged in drilling activities) suffer noise induced hearing loss severe enough to be classified as a hearing disability. There are similar equipment and working conditions that exist at surface drilling sites (water well, construction) which suggest that operators at these locations may also be overexposed. Recent data collected during the period of 2000-2002 by the PRL Hearing Loss Prevention Mobile Unit shows that most surface drilling professionals over the age of 40 have a noise induced hearing loss according to the 1998 NIOSH criterion.

Surface drill rig without any engineering noise controls

This project concentrates on reducing excessive noise exposures to operators and helpers on various drill rigs that lack noise control devices. Attention to drill operator´s location and activities will lead to the development of an affordable, universally fitted, protective device that protects the operator from over exposure to noise, thus filling the gap between engineering controls, administrative controls, and personal protective equipment. This information can be used to generate educational or training materials to reduce over-exposure to noise while performing surface drilling activities.

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STRATEGIC GOAL:
Hearing loss

KEYWORDS:
drilling, noise, noise induced hearing loss, hearing loss prevention

Currently researchers are in the process of developing a partial cab that can be attached to drill rigs without a cab. The partial cab has three sides to enable the operator easy access to the drill steel while still offering protection from high sound levels. In laboratory tests, the researchers identified the construction of the partial cab that would yield the highest noise reduction while keeping cost to a minimum. Results of the laboratory tests show that the reductions in the

A-weighted sound level ranged from approximately 8 to 15 dB. The Development of a Noise Exposure Analysis (NEA) database for all the field data parameters has been completed. Field site investigations were conducted at eight field sites. Every field site investigation included measuring the drill operator´s noise exposure and documenting a corresponding time-motion, (job activity) study. Findings in the database will be used to evaluate the interdependence between work practices and noise exposure levels.

The outputs and outcomes for this research are as follows: A prototype partial cab will be fabricated and attached to test rigs. Controlled tests will be conducted to ensure testing parameters in the prototype design are confirmed. Field testing of the partial cab in productive environments will then be performed at several sites to confirm the efficiency of the partial cab to reduce operator´s noise exposure levels. The NEA results will be used to develop multiple training products. They will be industry specific and focus on the work practices that have the highest noise exposure levels. These training products will be disseminated to industry representatives through conference presentations, publications and future field work with industry partners.

Ongoing Research Project related to Hearing Loss

Cross-Sectional Survey: Noise Exposure Patterns/Sources

PURPOSE: To establish representative noise exposure profiles for the various mining occupations, equipment noise levels, and characterize the exposure/source relationship.

RESEARCH SUMMARY: Noise-induced hearing loss (NIHL) is recognized by NIOSH in the NORA document as the most common occupational disease in the United States. Despite the progress achieved over the last 2 decades, overexposure to noise in the mining workplace remains a serious problem for mine workers. Every day, 80% of the Nation´s miners go to work in an environment where the time-weighted average (TWA) noise level exceeds 85 dB(A); even worse, 25% of the miners are exposed to a TWA noise level that exceeds 90 dB(A). Several studies have shown that by age 50, 90% of miners have a hearing impairment. Recent noise exposure data collected in the coal industry during project surveys indicate that nearly 50% of workers were exposed to noise levels above 90 dB(A), with some exposures nearly 6 times the permissible exposure level. Clearly, a need exists for research to ensure that the hearing of miners will be preserved.

NIOSH engineers conducting a noise survey in a dragline

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STRATEGIC GOAL:
Hearing loss

KEYWORDS:
hearing loss, research, exposure assessment

Surveillance is seen as one of the fundamental keys to this effort. The collection of baseline information that will provide a current and improved characterization of worker noise exposure patterns and mining noise sources is essential to develop effective intervention strategies for preventing hearing loss. The baseline line data will consist of worker noise dose, task observations to relate source to dose, and equipment noise profiles. It is anticipated that 5 to 10 mines and plants will be surveyed each year, with 45 to 50 mines and plants total surveyed by project end in 2007. The mining sectors investigated will include coal, stone, and sand and gravel.

Results to date indicate that upwards of 40% of all workers monitored were subject to noise exposures above 90 dB(A) TWA8. In the underground coal mines, the percentage is nearly twice as high for workers directly involved with the extraction of coal at the mine face. The data also reveals that the underground coal extraction equipment is among the noisiest equipment used in mining and is the primary contributors to worker overexposures.

The expected outputs of this research are updated data bases of equipment noise and worker noise exposures in all sectors of mining. The outcomes include a more comprehensive understanding of the noise environment in the mining industry and a more effective selection and application of both engineering and administrative controls for reducing worker noise exposures.

Ongoing Research Project related to Hearing Loss

Definition and Assessment of Engineering Noise Controls

PURPOSE: To document and evaluate noise control technologies that are used in or applicable to the mining and construction industries and then expand this base of information to other industries. Also, to understand the noise generating mechanisms to aid in the development of new noise control technology.

Researchers measure and record the sound level in the cab of an idling haul truck

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STRATEGIC GOAL:
Hearing loss

KEYWORDS:
noise, control technology, sound level, hearing conservation

RESEARCH SUMMARY: Noise induced hearing loss is the most common occupational illness in the United States today, with over 30 million workers exposed to excessive noise levels. Engineering control of noise is the long-term solution to the nation´s occupational hearing loss problem. However, in the mining industry the application of engineered noise controls has been fraught with problems. An important enabling step for the application of existing control technology, or the development of new technology, is the identification of existing controls and their effectiveness.

The measurement of engineering noise control effectiveness is done by acquiring acoustic data with and without the control in place. The measured acoustic parameters include sound pressure level, sound intensity level, and percent noise dose. If a control cannot be removed from an application, an effort is made to find a machine of similar make, model, and age without the treatment in place. In addition to being used to evaluate the effectiveness of an engineering noise control, sound intensity measurements are applicable for noise source location. Once the primary noise sources are identified, engineering controls can be more effectively implemented.

Over the course of this study it was learned that many mine operators install noise controls without knowing how much noise reduction to expect from a control before installation, or how much noise reduction is actually achieved after the control is installed. Also, it was found that in some cases acoustical materials were improperly used. As a result of this research, increased emphasis has been placed on the installation of proven noise controls as opposed to the ´try this, try that´ approach to noise control that was common in the past.

The majority of the outputs for this project has and will be numerous reports, presentations, and publications documenting the effective and ineffective noise controls on existing mining equipment. The ultimate outcome of this research is to educate mine operators and equipment manufacturers on not only which engineering noise controls are successful, but a basic understanding in noise control techniques which will aid them in developing their own application of controls for their future noise reduction efforts.

Ongoing Research Project related to Hearing Loss

Engineering Noise Controls for Roof Bolting Machines

PURPOSE: The objective of this project is to determine and implement appropriate engineering controls to reduce excessive exposure to noise on the job and prevent additional cases of Noise Induced Hearing Loss (NIHL) related to roof bolting machine operators.

RESEARCH SUMMARY: Noise is one of the most pervasive health hazards in mining. The National Institute for Occupational Safety and Health has identified occupational NIHL as one of the ten leading work-related diseases and injuries. MSHA coal noise samples from 2000 to 2002 show that 65% of the equipment whose operators´ noise dosage exceeded 100% is comprised of seven different types of machines: auger miners, bulldozers, continuous miners, front end loaders, roof bolting machines, shuttle cars (electric), and trucks. Of these, the roof bolting machine was the third most common type of equipment whose operators exceeded 100% dosage.

Roof bolting machine in the PRL Reverberation Chamber

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STRATEGIC GOAL:
Hearing loss

KEYWORDS:
mining, roof bolting machines, noise dose, sound power, noise induced hearing loss, hearing loss prevention

The relationship of noise generated by the drilling and bolting cycles of a roof bolting machine utilized in underground coal mining and the attributed noise exposure of the operator will be investigated. A noise survey of roof bolting machine operators will be conducted to identify the tasks which are significant contributors to the operator´s noise exposure. This will be accomplished by placing a dosimeter on the operator to record his noise exposure while simultaneously conducting a time-motion or task observation. The drilling and bolting duty cycles will be extracted from the data to determine how much noise exposure to the operator is generated by these individual tasks. Sound power measurements will then be conducted on the roof bolting machine in the PRL reverberation chamber, along with above ground measurements in a free-field noise environment. Additionally, underground measurements will be performed using a sound level meter to record the sound levels of the roof bolting machine thru several duty cycles. The data will be analyzed to assess the relationship of the drilling and bolting cycles to the noise exposure associated to the operator. Noise sources will be identified and ranked according to their percentage of contribution to the overall sound level generated by the drilling and bolting cycles.

From this, NIOSH will develop and test conceptual engineering controls designed to reduce the noise emission of roof bolting machines and thus, reduce the noise dosage exposure and NIHL of their operators. This information will be disseminated to the mining industry for their use in retrofitting existing equipment and as an aid for a quiet-by-design approach for developing the next generation of equipment.

Ongoing Research Project related to Hearing Loss

Health Communication Interventions for Hearing Loss Prevention

PURPOSE: To develop more effective communication and training techniques and products that give workers the motivation and skills to prevent hearing loss.

RESEARCH SUMMARY: This 3-year project, now in its final year, is showing workers how to take a more effective role in preventing hearing loss by reducing their exposure to hazardous noise. Findings from tests conducted with the Hearing Loss Prevention Unit mobile research facility indicate that 31% of the miners had a hearing impairment, a percentage that grows to 50% for miners in their 50s. A major obstacle to reducing these rates is the ineffective use of noise controls and protective devices. For instance NIOSH research on sand and gravel miners has shown usage rates of hearing protectors to be below 50%.

Miners participating in an earplug effectiveness test

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STRATEGIC GOAL:
Hearing loss

KEYWORDS:
communication, hearing loss, prevention, training, web site

This issue is being addressed though a variety of health communications techniques. The first step is to increase workers´ motivation to take effective action, and then provide these motivated workers with the knowledge and skills they need to reduce their noise exposure and protect their hearing. Specific problematic attitudes and behaviors with each health communication study are being targeted. An example would be the widespread myth that most hearing loss is a natural consequence of aging.

A Hearing Loss Simulator was developed, and its ability to motivate workers to avoid hazardous noise and protect their hearing better was studied. This Windows-based program demonstrates the "sound" of a hearing loss that results from a hypothetical noise dose set by the user. Trainees can immediately hear the muffled speech and almost-inaudible industrial warning sounds as heard "through" a hearing impairment. Trainees who heard the simulator had significantly improved knowledge about the causes and results of hearing loss, and were more motivated to take preventive action. To investigate improving knowledge and skills, a simplified "Roll-Pull-Hold" technique for the types of foam earplugs that are widely used for hearing protection was developed and evaluated. When workers followed a simple three-step procedure, their earplugs sealed their ear canals better and reduced the level of noise reaching their eardrums by an average of 9 decibels.

The simulator was released on CD-ROM and now has hundreds of users and supporting organizations that include the Mine Safety and Health Administration (MSHA), the Council for Accreditation in Occupational Hearing Conservation (CAOHC), and the National Hearing Conservation Association (NHCA). The Roll-Pull-Hold technique is being disseminated through an instructional page and 1-minute video clip on the NIOSH website. The short-term benefits of these communications interventions are expected to result in long-term exposure and hearing loss reductions, and plans are being made to conduct a long-term evaluation in a follow-on project.

Ongoing Research Project related to Hearing Loss

Hearing Loss Prevention: Hearing Protection and Audibility Considerations

PURPOSE: To develop recommendations and strategies for mine operators and mineworkers that will improve the audibility of spoken communication and hazard/warning signals in the mining environment while preventing additional cases of noise-induced hearing loss.

RESEARCH SUMMARY: Hearing protection devices are still needed in many settings where engineering and administrative controls are insufficient to reduce noise to a safe level. However, workers have reported significant concerns about the diminished audibility of speech, machine alarms, and other important sounds that result from wearing standard hearing protectors. By addressing this concern, this study will encourage the use of hearing protection in ways that minimize audibility problems.

Human subject testing of new hearing protector systems

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STRATEGIC GOAL:
Hearing loss

KEYWORDS:
noise, hearing loss, hearing protectors

There are hundreds of different hearing protectors on the market, including standard earmuffs, earplugs, and sophisticated electronic designs. Every protector has a different effect on the types of sounds they allow to reach the wearer´s ears, and the spatial cues they provide about the location of sound sources. Current research is quantifying these effects so appropriate recommendations can be made for different occupational noise environments.

Along with standard hearing protectors, new technological approaches to protection and exposure reduction are also being investigated. For instance, extensive laboratory evaluations of protectors that use electronic systems to pass selected sounds through the protector are being performed. A system that uses microphones inside the protector to provide feedback about the noise levels that actually reach the wearer´s ears was also recently evaluated. In general, the microphone placements used in this system potentially provided a usable approximation of the wearer´s true dosage.

Ongoing Research Project related to Hearing Loss

Pilot Study on Coal Cutting Noise Related to Continuous Mining Machines

PURPOSE: To determine the significance of cutting noise relative to the noise exposure of continuous mining machine operators.

A continuous mining machine cutting head

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STRATEGIC GOAL:
Hearing loss

KEYWORDS:
noise, control technology, mining, equipment

RESEARCH SUMMARY: Noise-induced hearing loss is (NIHL) is the most common occupational disease in the country. Despite 25 years of regulation, a recent NIOSH study showed that at age 51 approximately 90% of coal miners and 49% of metal/non-metal miners had a hearing impairment whereas only 10% of the non-occupational-noise exposed population had a hearing impairment. MSHA Coal Noise Data collected from 2000 to 2002 shows that 65% of the workers who were overexposed to noise operated one of seven types of equipment. Of these seven types of machines, continuous mining machines had the most noise overexposures, accounting for 35% of all noise overexposures.

The noise generated by a continuous mining machine is primarily due to three sources: the conveyor, the dust scrubber, and the cutting drum. Prior NIOSH projects have developed noise controls to reduce the sound levels generated by the conveyor and dust scrubber on continuous mining machines. However, the noise associated with cutting coal has not been addressed. This effort will focus on determining the significance of coal cutting noise to the noise exposure of continuous mining machine operators. The hypothesis is that cutting coal is a major contributor to the operator´s noise exposure. Sound levels near the continuous mining machine operator will be measured in mines while cutting and conveying coal. These sound levels will be analyzed to determine the worker noise exposure associated with each process.

NIOSH will determine if cutting noise is a significant contributor to the operator´s noise exposure. If so then candidate engineering control concepts would be evaluated and the promising concepts will be recommended for development and implementation.

Upon completion of this one year pilot study, the results will be published in a peer-reviewed journal and presented at the appropriate mining conferences. The results of the project will provide a direction for the development of engineering noise controls to reduce continuous mining machine operator noise exposure. If cutting noise is found to be significant, noise controls must be developed to reduce the sound levels generated by cutting coal. However, if cutting noise is found to be insignificant, the future direction of noise control development for continuous mining machines would then be focused on additional noise controls to address conveyor noise.

Ongoing Research Project related to Cumulative Injuries

Ergonomics Evaluation and Improvement of Mobile Equipment

PURPOSE: Reduce musculoskeletal disorders among operators of mobile equipment.

RESEARCH SUMMARY: A recent estimate shows there are approximately 540,000 operators of heavy equipment (i.e., dozers, loaders, haul trucks, etc.) in mining and construction in the United States and this number is expected to increase. Operators of mobile equipment perform various duties that expose them to a variety of risk factors in the work environment, such as whole-body vibration, awkward postural requirements, repetitive motions, poor seat design, and poorly designed cabs or controls, all of which have the potential to cause injury and expose operators to the risk of developing musculoskeletal disorders. Musculoskeletal disorders - including most sprains and strains - are the most common type of nonfatal injury in mining. In addition, loss of postural stability and improper egress are significant factors in fall injuries among these operators.

A dump truck at a construction site in Iowa

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STRATEGIC GOAL:
Cumulative injuries

KEYWORDS:
mining, construction, ergonomics, vibration, musculoskeletal disorders

Mine Safety and Health Administration (MSHA) data show that between 1999 and 2003, 4079 accidents in surface mining were classified as back injuries and contributed to nearly 173,000 lost or restricted work days (an average of 42 days lost or restricted per accident). Truck drivers (n = 535), dozer operators (n = 467), and front-end loader operators (n = 409) alone accounted for over one-third of these injuries. Another 6060 accidents during this same period were classified as injuries caused by overexertion and affected truck drivers (n = 539), dozer operators (n = 508), and front-end loader operators (n = 358).

The specific aims of this project are to (1) evaluate the ergonomic design of cabs and egress from and entry into cabs, (2) estimate the landing force required to exit mobile equipment, (3) characterize exposure to whole-body vibration at the seat/operator interface; (4) evaluate the effects of whole-body vibration on operators´ postural stability; and (5) collect work and health questionnaire data from operators of heavy mobile equipment as part of an epidemiological survey.

Some of the significant outcomes will be (1) field tests of the effectiveness of a device to reduce low back discomfort among operators of mobile equipment, (2) evaluations of cab design of mobile equipment, (3) a better understanding of the prevalence of musculoskeletal symptoms and psychosocial factors affecting operators of construction equipment, (4) evaluations of postural stability after exposure to whole-body vibration and development of recommendations for control, and (5) evaluations of landing forces as operators exit equipment and development of recommendations for control.

Ongoing Research Project related to Cumulative Injuries

Ergonomics Process Effectiveness in Mining

PURPOSE: To demonstrate ergonomics processes can effectively lower worker exposure to musculoskeletal disorder (MSD) risk factors and reduce MSD incident rates in mining environments.

RESEARCH SUMMARY: An analysis of National Occupational Health Survey of Mining (NOHSM) data showed that exposures to ergonomic risk factors for mine workers were high compared to those in non-mining occupations. Another study utilizing NOHSM data reported that at least 35% of mine workers were potentially exposed to musculoskeletal overload conditions. There have also been many studies providing evidence that well-designed ergonomics processes can improve working conditions and worker health and safety. A recently completed NIOSH project demonstrated the benefits of implementing an ergonomics process at a surface coal mine. Unlike other studies, this project established that an ergonomics process could be implemented in harsh and dynamic environments found in mining.

This mechanic is using an employee-designed support for an impact wrench. Use of the support has substantially reduced exposures to ergonomic risk factors.

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STRATEGIC GOAL:
Cumulative injuries

KEYWORDS:
mining, ergonomics, musculoskeletal disorders

During this study, researchers will continue to partner with mining companies to implement and evaluate ergonomics processes. Through communication and demonstration, partnerships with trade associations will promote the implementation of effective ergonomics processes to their members. How organizations implement ergonomics can vary widely, depending in part on organizational size, work culture, and mining methods. Similarly, relevant measures for evaluating process effectiveness also vary widely. A key element to this study will be to create a metric to assess the developmental stage of a process as well as its effectiveness. Additionally, researchers plan to (1) initiate and evaluate ergonomics processes at two or more mine sites, (2) compile recommendations for effectively applying ergonomic principles to mining work methods and equipment designs, and (3) develop and evaluate training modules that are necessary to establish, maintain, and grow an effective process. To date, PRL researchers have assisted a surface sandstone mine with integrating an ergonomics process with their existing safety and health program, have partnered with the Industrial Minerals Association - North America to raise the awareness level of its members on how ergonomics can be used to reduce MSD incident rates, and have developed task-specific interventions for dragline workstations.

The long-term goal of this study will be to reduce MSD incident rates in mining work environments. Demonstration of effective ways to proactively apply ergonomic principles to mining work activities will promote their use by the mining community.

Ongoing Research Project related to Cumulative Injuries

Reduce Injury & MSD Risk from Human-Machine Interaction

PURPOSE: To reduce mine injuries, work-related musculoskeletal disorders (MSDs), and accidents through studies of roof bolter, continuous miner and load-haul-dump (LHD) machine designs and operator tasks.

RESEARCH SUMMARY: MSHA injury data from 2000 to 2004 indicates that two of the major sources of injuries in underground mining came from powered machinery and MSDs. For the same reporting period, almost one third of all incidents could be classified as MSD related. Powered machinery comprised almost 42% of the injuries and 62% of the fatalities. Further analysis showed that the two most frequent causes of machinery related accidents were tramming equipment (roof bolters 19% and continuous miners 6%) and jarring and jolting (load-haul- dumps (LHD´s)/scoops and mantrips 14%).

This research consists of four parts: roof bolter appendage speed study, roof bolter operator low back stress analysis, machine tramming study, and jarring/jolting study of (LHD)/scoops & personnel carrier seats. These provide recommendations/interventions for reducing both the underground mine work hazards and MSDs. Mine work hazards and MSDs arise from improperly designed workstations, equipment, and/or work methods. These include machine and human-body appendage impact, operator errors, awkward postures, repetitive and forceful motions, and excessive jarring and jolting.

Top Left - Roof bolter boom arm swing data collection; Top Right - Operator low back stress computer simulations; Bottom Left - Machine tram and visual cue simulations; Bottom Right - Vehicle seat test set up to collect vibration data

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STRATEGIC GOAL:
Cumulative injuries

KEYWORDS:
mining injury prevention, traumatic injuries; MSD, whole body vibration, safe machine designs

Vertical and horizontal appendage speeds for a roof bolter are evaluated and recommendations for machine design modifications and job-task procedural changes that maximize the operator´s chances of escaping injury from contacting a moving boom arm are provided. Initial analysis of low back stress experienced by roof bolter operators showed that an operator´s standing posture, compared to a kneeling posture, significantly increases the forward bending moment, compression force and trunk muscle activity. Also, the kneeling postures in a 45-inch seam height, compared to a 60-inch seam height, increase the same muscle activity significantly for lateral movements and torso extension. Using computer models and operator job task analysis, a risk assessment methodology, detailing the relative risk from each of

the environmental hazards that affect their safety, is being developed for face equipment workers. For seated workers in LHD/scoops and personnel carriers vibration studies will be conducted to recommending engineering controls and/or ergonomic interventions for reducing the jarring/jolting related injuries.

Ongoing Research Project related to Cumulative Injuries

Successful Aging for Miners Through Ergonomics (SAME)

PURPOSE: Through the use of training programs and engineering interventions, to promote successful aging and reduce the risk of musculoskeletal injury for all ages of workers in the mining industry.

RESEARCH SUMMARY: Workers employed in the mining industry have historically been involved in physically demanding work, and as a group they are older than workers in general industry. The Bureau of Labor Statistics (2004) estimated that the median age of the coal mine worker in 2004 was 45.9 years old while the median age overall for the U.S. employee was 40.5 years. These statistics indicate that a substantial section of the mining workforce may have started experiencing the normal physical changes that accompany aging, such as reduced strength and flexibility, decreases in contrast sensitivity and dark adaptation, and reduced aerobic capacity.

Percentage of Injuries that are Musculoskeletal by Age of Mine Worker, 1992-2002

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STRATEGIC GOAL:
Cumulative injuries

KEYWORDS:
aging worker, mining, ergonomics, back injury, slips/falls

Project SAME focuses exclusively on using ergonomics to mediate age-related physical changes in mine workers and promote safer working procedures for all ages of employees. Stakeholder input and analysis of MSHA injury data indicate that the following highest priority areas should be targeted:

- Intervention efforts must target all ages of employees with the intent of limiting musculoskeletal injuries to our older workers and preventing musculoskeletal injuries in our younger workers. To address this issue, our prevention efforts will include the development of a training program to increase awareness of the changes that occur with the normal aging process and to learn how to mediate those changes through job re-design.
- The back is the most frequently affected part of the body, back injuries often re-occur with age, and back injuries tend to be more expensive than injuries that occur to other parts of the body. We are developing a better tool to assess the risk of back injury in miners and allow for effective engineering interventions.
- Slips and falls tend to occur more frequently in older workers, and they are often more severe for older workers; slips and falls can occur while walking or while getting on or off a piece of equipment. We are approaching this problem in a multi-faceted manner and plan to provide the mining industry with better suggestions for boot design, work procedures, and safer methods for ingress and egress from equipment.

We have learned that with increasing worker age come greater percentages of MSDs, more recurrent back injuries, and more slips and falls. Expected outcomes include the reduction in the percentage of MSDs with increasing age and also a reduction of MSDs for back injuries and slips and falls. Interventions from this project are applicable to industries such as construction and agriculture.

Ongoing Research Project related to Traumatic Injuries

Evaluating Roadway Construction Work Zone Interventions

PURPOSE: To develop a practical worker warning device called HASARD (Hazardous Area Signaling and Ranging Device) that industry can license and to design and construct a Work Zone Analysis System (WZAS) for recording and quantifying worker exposure around moving vehicles and equipment.

NIOSH researchers collecting data associated with a road paving project . The Work Zone Analysis System (WZAS) is being used to record multi-camera video and GPS data.

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STRATEGIC GOAL:
Traumatic injuries

KEYWORDS:
traumatic injuries, mining, construction, vehicles, hazards

RESEARCH SUMMARY: According to MSHA statistics an average of 13 miners are killed each year by being run over or pinned by mobile mining equipment. At surface mines, these accidents frequently involve large dump trucks that drive over a smaller vehicle or a worker that is in a blind spot of the truck. Over 50% of these accidents could have been avoided if the equipment operator had been adequately warned of the impending collision. In addition, highway and street construction workers are at risk of fatal and serious nonfatal injury when working near passing motorists, construction vehicles and equipment. During 1992-98, 841 highway and street construction workers were fatally injured. In 465 (55%) of these cases the death was either vehicle- or equipment-related and, most likely occurred in the work zone. In 318 of the 465 (68%) fatalities within work zones, a worker on foot was struck by a vehicle. Victims were as likely to be struck by a construction vehicle as by a passing traffic vehicle. The HASARD system has been developed to warn workers of their proximity to potentially dangerous areas around moving equipment. It has been thoroughly tested in the laboratory and is now ready for commercial licensing. A second patent on this device was granted in October 2004. Three companies have recently obtained user-development licenses and three other companies have applied for licenses and one CRADA. The WZAS was completed in May 2004 and is now being used to collect multi-camera video and GPS data at field sites. An Open Industry Briefing on "Proximity Warning Systems for Surface Mining and Roadway Construction" is currently planned to occur toward the end of 2006. A set of guidelines, for use by the surface mining and roadway construction industries, on how to implement the HASARD system on haulage trucks will also be developed by then. Both fatalities and injuries due to workers being run over or pinned by haul trucks, surface mining equipment, and roadway construction equipment are expected to significantly decline wherever this technology is successfully implemented. Also, this type of proximity warning system could be readily modified for helping to protect workers in other industries such as underground mining, manufacturing, agriculture, construction, and forestry.

Ongoing Research Project related to Traumatic Injuries

Lockout/Tagout, Jammed, and Moving Machinery Controls

PURPOSE: To develop a practical device to warn workers, especially maintenance personnel required to lock and tag out equipment, of their proximity to potentially hazardous areas around moving equipment.

The HASARD system is being field tested on a moving belt conveyor. The white cylinder in the center of the photo is the HASARD transmitting antenna.

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STRATEGIC GOAL:
Traumatic injuries

KEYWORDS:
traumatic injuries, mining, haulage, engineering

RESEARCH SUMMARY: Lockout/tagout (LOTO), required by OSHA Standard 29 CFR 1910.147, is a protective procedure workers must perform to remove hazardous energy from machinery prior to performing maintenance tasks. All energy sources for equipment must be de-energized and the switch locked and labeled with a tag warning not to activate the machinery. Lockout/tagout violations consistently rank in the top five of OSHA's most frequently cited standards. The National Stone, Sand & Gravel Association lists LOTO as one of the most important safety issues facing the aggregate industry. Belt conveyor injuries (over 400/year) have historically ranked among the most severe in the mining industry according to MSHA. Fatalities resulting from workers being caught in machinery average 150 per year, with about half related to service- or maintenance tasks. Serious nonfatal injuries from being caught in machinery, average 6800/year and are the leading cause of amputations among workers. The HASARD proximity warning device has the potential to warn workers of danger prior to conducting maintenance. It has been developed and tested in the laboratory and is ready for commercial licensing. A second U. S. patent (#6,810,353) on this device was granted in October 2004. Three companies have recently obtained user-development licenses and three other companies have applied for licenses and one CRADA. An Open Industry Briefing on proximity warning systems for underground and surface mining will be held at PRL towards the end of 2005. The project ends in 2005. A set of guidelines on how to implement the HASARD technology on remote-control continuous mining machines will be disseminated to the mining community in 2006. Both fatalities and injuries due to workers becoming caught in moving conveyors and mining machinery are expected to significantly decline wherever this technology is successfully implemented. This type of proximity warning system could be readily modified to protect workers in industries other than mining such as construction and agriculture.

Ongoing Research Project related to Traumatic Injuries

Mobile Mining Equipment Warning Systems

PURPOSE: Reduce the number of injuries and deaths of workers who operate or work near lift trucks at mining operations.

Instrumented lift truck with operator warning system being test driven at proving grounds

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STRATEGIC GOAL:
Traumatic injuries

KEYWORDS:
mine safety, warning system, rollover, control technology, lift trucks

RESEARCH SUMMARY: A common danger in the mining, agriculture, and construction industries occurs when mobile equipment is unknowingly operated in an unsafe manner. Operator errors are frequently the result of inadequate training, complacency regarding equipment operation, and taking shortcuts. Many times an operator unknowingly operates the equipment beyond its safe operating limits or fails to recognize dangers in the work environment. Unsafe operation can result in injuries and deaths of both drivers and pedestrian workers; over 100 fatalities and 20,000 forklift injuries occur yearly in the United States. Seventy percent of these accidents were caused by operator error. In 2000, the leading causes of lift truck fatalities were lift truck overturns (23%), pedestrians and workers struck by lift trucks (39%), and falls from lift trucks (10%). During 1999-2003, over 355 lift truck accidents occurred at mining operations.

Researchers from the Spokane Research Laboratory (SRL), in collaboration with the North American Coal Company (NACCO), are investigating ways to reduce the high number of injuries and deaths related to dangerous lift truck operating practices. Specific questions being addressed are (1) what are the critical operating parameters that should be monitored to prevent rollovers, collisions, and operator errors? (2) what instruments are available that could be used to monitor these parameters? and (3) what is the most effective way to alert an operator to unsafe operating and environmental conditions?

A lift truck is being retrofitted with an electronic monitoring system that continuously monitors critical operating parameters (i.e., pitch, roll, payload, lift height, loading dock edge, nearby objects) of a lift truck to determine if the vehicle is being operated safely. When a critical operating parameter is exceeded, a digital voice warning message is activated that can be heard by both the lift truck operator and any nearby workers. It can, for example, alert the operator when he or she is traveling or cornering too fast, lifting too heavy a load, or approaching the edge of a loading dock. The sensor-based monitoring system can also be used as a tool to improve lift truck operator training, evaluate training programs, and identify areas in need of additional safety training.

Field tests of the instrumented lift truck were conducted on NACCO´s proving grounds in Fairview, OR, to determine the effectiveness of the 40 installed instruments and the data acquisition system in preparation for in-depth field tests at a commercial site. The technology being developed in this project can be applied to a wide variety of other types of mobile mining and construction equipment to alert an operator or nearby workers to dangerous operating conditions and practices.

Ongoing Research Project related to Traumatic Injuries

Protocol for Evaluating Quality of Explosives in the Field

PURPOSE: The purpose of this project is to develop a suite of protocols that a blaster or mine inspector can use in the field to determine if a high explosive, blasting agent, or emulsion oxidizer are of a poor quality that could lead to an accident.

PRL technician pours kerosene on the wood cribbing in preparation for the Heavy Confinement Pipe Bomb test. When the fire is ignited, the 100 lb of material in the steel bomb will be heated to the point where it either burns off or explodes.

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STRATEGIC GOAL:
Traumatic injuries

KEYWORDS:
blasting, explosives, mining

RESEARCH SUMMARY: The explosive manufacturing business is currently very competitive. Manufactures must hold down cost of their products to maintain their share of the market. In this effort to hold down costs for explosive manufacture, quality control may suffer. With poor quality control, an explosive that is classified by DOT as a blasting agent may in reality be a high explosive. Transportation and storage requirements for high explosives are more stringent than those for the less sensitive blasting agents. Treating a high explosive as a blasting agent could lead to serious accidents. Alternatively, if a high explosive is too insensitive due to a manufacturing error, misfires will result. Protocols for evaluating the safety of explosives currently exist, but for all practical purposes these tests cannot be conducted in the field if a blaster or inspector has concerns about the quality of the blasting agent or explosive being used. PRL is developing a simplified protocol for evaluating explosive quality, and hence safety. This will not be a replacement for the original, extensive protocols. The simplified protocol will be a screening test to detect the most common hazards related to explosive quality. There will necessarily be a tradeoff between the complexity of the protocol and the ability to identify hazards. Preliminary results suggest that tests to determine detonation velocity, explosive density, and detonability by a blasting cap are practical for conduct in the field and will go a long way towards verifying whether an explosive is performing as expected. Upon completion of this project, blasters will have a way to verify that an explosive will shoot as expected, before it can result in a poor blast that would have serious safety ramifications.

Partners/collaborator in the project is the Mine Safety and Health Administration.

Ongoing Research Project related to Traumatic Injuries

Reducing Electric Arc-Induced Injuries in Mining

PURPOSE: To reduce the number and severity of electric arc burn injuries in mining.

RESEARCH SUMMARY: Systematic electric arc protection for industrial workers is specified by the National Electrical Code (NFPA 70) and the NFPA Standard for Electrical Safety in the Workplace (NFPA 70E). The scopes of NFPA 70 and NFPA 70E specifically exclude the underground mining industry due to its unique electrical needs and problems. 30CFR Parts 56, 57, 75, and 77 contain mining electrical safety provisions, but 30CFR does not require anything beyond rudimentary PPE for hazardous underground electrical maintenance work. Between 1990 and 2003, 2,326 traumatic mine electrical injuries occurred. The largest single category of electrical injury was burns from electrical arcing, which accounted for 893 (38%) of all electrical injuries. Electrical burn injuries of all types accounted for more than 21,500 lost work days. The project approach focuses on the development of a comprehensive program of engineering analysis and controls, management of work activities, training, and the use of personal protective equipment (PPE). Computer simulations are employed to estimate the arcing fault energy available from the power systems of representative mine and mineral processing plants. The systems selected represent the most dangerous mining industry sectors. Simulation results will allow the definition of boundaries or zones where protection from arc-flashes is needed for various equipment and circumstances. Findings thus far indicate a general lack of awareness of common arc-flash hazards in the mining industry. Accident reports show that two-thirds of arc-flash injuries involve circuit breakers, cables, hand tools, meters, and plugs. The equipment and PPE needed for safe troubleshooting in arc-prone situations are seldom used. Circuit breakers are often operated beyond their design parameters and many are repaired by third-party rebuilders using substandard components. Power system coordination is seldom optimum. Thirty-one victims of, or witnesses to, arc burn accidents have been interviewed. Victims now realize that their understanding of arc-flash hazards was inadequate. Many see their failure to wear arc-rated clothing, face and hand protection, use appropriate tools and

This 480-volt fused disconnect switch was recently involved in an arcing fault accident. The resulting explosion burned two experienced miners who were investigating a problem.

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STRATEGIC GOAL:
Traumatic injuries

KEYWORDS:
electrical, burn, traumatic injuries, training

meters, and work on live circuits as unsafe work practices that need to be altered by improved hazard recognition training. This project will produce practical guidelines to determine arc flash boundaries in mines and prep plants. Recommended improvements in work practices regarding the use of hand tools, meters, PPE, and other engineering controls will increase miners´ understanding of arc-flash hazards. Training guidelines will show how to most effectively present this information to the mining audience. Follow-on work will implement the guidelines as 10-minute and 30-minute training modules available to MSHA trainers. It is envisioned that the outcome of hazard recognition training, PPE, and improved work practices would be a dramatic reduction in the number and severity of arc-flash injuries in mining.

Ongoing Research Project related to Traumatic Injuries

Remotely-Controlled Bulldozer on Coal Stockpiles

PURPOSE: To improve the safety associated with the operation of bulldozers on coal stockpiles by investigating the feasibility of remote-control operation.

Voids in coal stockpiles can entrap bulldozer operators

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STRATEGIC GOAL:
Traumatic injuries

KEYWORDS:
hazards, mining, vehicles

RESEARCH SUMMARY: Environmental conditions, coal compaction, and other factors can result in voids in coal stockpiles which can entrap bulldozers used to facilitate drawdown at the top of the piles. Since 1980, there have been 19 fatalities at coal stockpiles, the majority being bulldozer operators. Efforts by MSHA and others have led to development of improved cab designs, high strength windows, and communications which have proven to save operator lives during dozer cover-ups. Providing remote control of the dozer has the potential to totally eliminate the danger to the operator by removing him/her from the machine. Previous attempts to remotely control the dozer were never fully implemented due to a variety of issues. One drawback was that the operator, when removed from the dozer, lost the feel of the machine due to time lags in the controls. This resulted in significant inefficiencies during remote operation compared with on-board control. Addressing this issue, NIOSH has developed a new approach to remote-control which can closely mimic the feel of the machine for the operator by adding visual, audio, and vibratory cues. Both MSHA and ConsolEnergy have expressed a need for this work. The overall objective of this new project would be achieved through several phases. Phase I would investigate the feasibility of using a 360-degree camera installed on a dozer to provide visual feedback to the remote operator. This camera would continuously transmit a panoramic image to a receiver at the operator location. The machine operator, equipped with a head-mounted sensor that tracks head movement, would view an image that one would see if actually operating the machine. Dozer movements would be wirelessly controlled via joysticks at the industrial remote-control station using drive-by-wire technology with virtually instantaneous response. In conjunction with this feedback, a stereo sound system would replicate dozer audio in real time. The success of this initial phase would warrant a follow-up (Phase II) investigation to further refine and improve machine remote operation. Here, the feasibility of using a motion table to provide feedback of machine movement to the remote operator would be investigated. Such a system would use accelerometers on the bulldozer to sense movement. This data would be transmitted back to the remote operator seated on a motion pod incorporating six-degrees of freedom. Thus the pod would simulate and record machine movements. The anticipated

outcome of a successful demonstration of a remotely-operated dozer would, in the long term, be an increased adoption of this method for stockpiles in mining. This development would result in a reduction in incidents and fatalities from dozer cover-ups by removing the dozer operator from the stockpile.

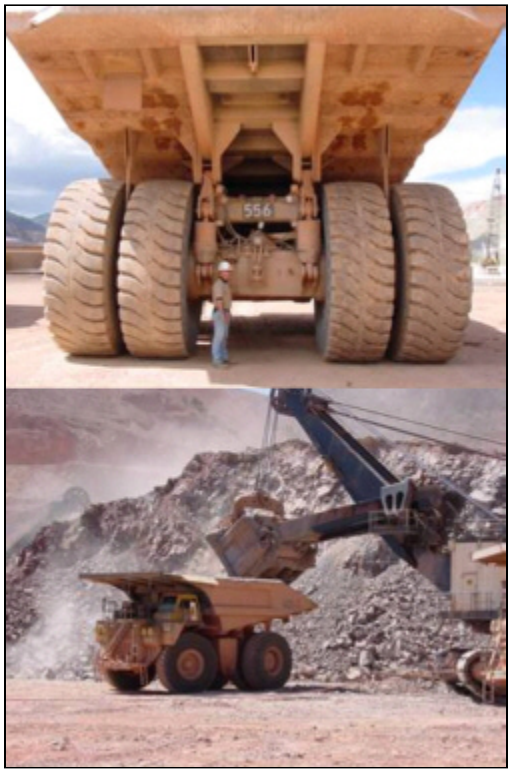
Ongoing Research Project related to Traumatic Injuries

Safety Enhancements for Off-Road Haulage Trucks

PURPOSE: (1) Develop and test interventions that will decrease accidents involving off-highway dump trucks in surface mining operations and (2) disseminate this information to the mining industry, standard-developing organizations, and MSHA to aid in the implementation of effective interventions.

RESEARCH SUMMARY: An average of 675 accidents and 21 fatalities involving powered haulage equipment occurs each year in metal/nonmetal and coal surface mining operations. Three major problems areas are being addressed by this project:

Accidents attributed to the lack of visibility near large haulage equipment. These accidents fall into two main categories: collisions between mining equipment and smaller vehicles, workers on foot, structures, or other equipment; and driving or backing over the edge of an embankment, stock pile, dump point, or other change in terrain. In surface coal and metal/nonmetal mines and quarries, 24 fatalities occurred between 1999 and 2003 that fell into these accident classifications, accounting for 12% of all surface mine fatalities. Dump trucks were involved in 58% of these accidents. To address this problem, researchers are studying available sensor and camera technology to assess which systems are effective in preventing collisions and can handle the conditions of surface mining. To date, a combination of an off-the-shelf radar system and a camera has been thoroughly tested at a surface mine. Preliminary tests have also been conducted on innovative systems developed in cooperation with outside organizations, including a GPS-based system and a stereovision system.



The scale of large mining equipment can be a major factor in accidents. The truck in these pictures is 42 feet long.

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STRATEGIC GOAL:
Traumatic injuries

KEYWORDS:
surface mine safety, blind spots, maintenance, mechanic, slips, falls, powered haulage

Accidents that occur during truck maintenance and tire changing. Mine personnel responsible for equipment maintenance are subject to frequent and heavy lifting, exposure to hazardous substances (oil, gas, hydraulic fluid, antifreeze, welding fumes etc.), working in cramped or awkward spaces, high-pressure hoses and vessels, and a variety of other hazards. Injuries and

fatalities have occurred as a result of exploding vessels, falls from equipment, hand tool use, and falling materials, all of which were directly related to equipment maintenance activities. A thorough examination of fatality and injury data associated with powered haulage maintenance and repair will be conducted to prioritize safety training areas. Potential interventions and overviews of current best practices will also be studied.

Injuries that occur during stepping down from or getting onto equipment. Another issue being addressed is the topic of slips and falls, in particular, accidents associated with accessing large mobile equipment. An average of over 300 accidents per year is reported to MSHA that fall in the mount/dismount category. Improved methods and systems for equipment access are being tested on dump trucks and dozers in cooperation with mining companies and equipment manufacturers.

Ongoing Research Project related to Traumatic Injuries

Safety Solutions to Prevent Mining Materials-Handling Accidents

PURPOSE: Prevent fatalities and injuries associated with materials handling in underground metal and nonmetal mines and in Western surface mining operations.

Loading roof bolt supplies from supply trailer to scoop

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STRATEGIC GOAL:
Traumatic injuries

KEYWORDS:
materials-handling, mechanization, manual tasks, safety solutions, mine safety

RESEARCH SUMMARY: Handling materials by lifting, pulling, pushing, and shoveling (MSHA classification code 09) has been the leading cause of accidents in the U.S. mining industry for every year between 1994 and 2003. The incident rate over this time was slightly more than 2 accidents per 100 employees, not including contractors. During this 10-year period, 58,491 reportable accidents resulted in over 1,000,000 actual days lost from work. In 2003, materials handling was the leading class of reportable mining accidents in every state except Delaware. In the West, stone mines led the way in materials-handling accidents with 3,298 accidents from 1999 through 2003, followed by metal mines (2,537 accidents) and sand-and-gravel operations (1,488 accidents). In every year between 1994 and 2003 except one, the activity of loading and unloading supplies or materials (MSHA activity code 028) caused more accidents in Western mines than any other activity. Many of these accidents were due to manually lifting, pulling, and/or carrying loads that turned out to be too heavy.

Because work tasks in the mining industry are so diverse, the intent of this research was never to conduct detailed ergonomic investigations, but to recommend specific tasks for detailed ergonomic analysis in other PRL or SRL projects; find the contributing factors in materials-handling injuries; develop interventions; and assure delivery to and implementation by industry of useful products. This work is to be accomplished by developing partnerships and conducting investigations in Western stone, sand and gravel, and metal/nonmetal mines; developing training and physical fitness programs designed to prevent materials-handling injuries; conducting national and international searches for proven systems, techniques, and devices that have reduced or replaced manual tasks; and assessing the effectiveness of injury reduction efforts.

In the last 3 years, SRL´s materials-handling research has been specifically directed to investigating two of the top three tasks that cause the most injuries in underground coal mines - loading and unloading supplies and materials and moving power cables. Two mechanical aids have been developed for loading/unloading tasks: the mobile manipulator system and the

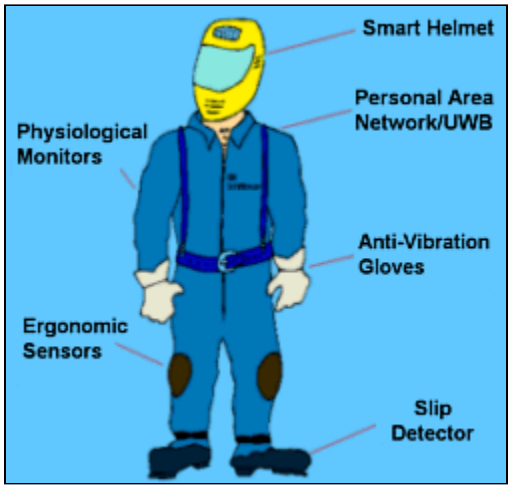
in-mine hoist. A third study involves seeking methods to automate cable handling. We have also developed an innovative in-mine training aid on safe ways to perform certain materials-handling tasks in underground coal mines and developed the concept of sharing safety solutions. Two safety solutions have been placed on the NIOSH mining Web site.

Ongoing Research Project related to Traumatic Injuries

Smart Wearables for Hazardous Work Environments

PURPOSE: This project will investigate the feasibility of wearable technologies to reliably collect and display information that will provide an improved awareness to the worker of existing and impending dangers.

RESEARCH SUMMARY: Miners are constantly exposed to a dynamic and unpredictable hazardous environment. For instance, slipping and tripping hazards are created by mine conditions such as water, mud, uneven floors, and mine-floor obstacles; moving machinery in the confined mine environment creates pinning and striking hazards. We infer from Mine Safety and Health Administration (MSHA) data (1999 to 2003) that the most severe underground mining nonfatal lost-time injuries are for the categories of slips/falls and powered haulage because these injuries resulted in the most lost workdays; a median of 29 lost days for each category. Miners must constantly be able to monitor this hazardous environment in real-time so they can be aware of impending and existing hazards; however, current access to this crucial data is limited. The research scope is for underground coal mining face workers, it is expected this research will readily be applicable to other mining methods and commodities.



Wearable technologies could alert miners of existing or impending hazards

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STRATEGIC GOAL:
Traumatic injuries

KEYWORDS:
mining, protective equipment, hazards, sensors

The specific aims of the research are: 1) identification of hazards for which smart wearable technologies and equipment are appropriate; 2) identification of the uses and limitations of smart wearable technologies with respect to miners in the mine environment; 3) the determination of barriers to effective use of smart wearable technologies. Multiple tasks are defined to realize the specific aims. The first task is to study the mine environment and analyze MSHA accident data in order to determine the crucial environmental parameters needed by mine workers to identify hazards. The second task is to conduct a literature review on appropriate sensor, monitoring, and display devices that will enable the collection, processing, and displaying of crucial hazard information to miners. The third task is to examine and evaluate wearable technologies, as identified by task 2, in terms of wearabilty. The parameters for wearablility include placement, shape, human movement requirements, size diversity, attachment methods, weight, and accessibility. The final task concerns the dissemination of findings through various publications.

The research findings will address the feasibilities and limitations of wearable technology for making miners aware of impending and existing mine hazards. The findings will identify specific mine hazards that could be identified, in real-time, by using wearable technology. The results will be used to determine if additional research is warranted.

Ongoing Research Project related to Traumatic Injuries

Surface Blasting Safety and Health

PURPOSE: Protect miners from hazards associated with blasting at surface operations involving coal, metal, and nonmetal mining.

RESEARCH SUMMARY: This project represents an extension and expansion of research that was formerly investigated by two projects: "Investigation of Flyrock Injuries and Fatalities" and "Toxic Fumes from Blasting."

In recent years, the use of explosives near housing developments has increased. To prevent flyrock that will damage homes or nearby businesses, the blaster ensures that the blast is well confined, i.e., the ground barely moves as it is blasted. However, this provides no way to release the blasting fumes. Thus, the fumes stay in the ground and may travel underground to nearby homes and other confined spaces. The composition of these fumes typically includes carbon monoxide (CO), nitric oxide (NO), nitrogen dioxide (NO_2), and ammonia (NH_3). Since 1988, there have been at least thirteen documented incidents of toxic fumes migration into homes and other confined spaces resulting in several hospitalizations and one fatality. Research is being conducted on the migration of CO and other toxic fumes from blast sites to provide blasters with guidelines for protecting workers and neighbors from fumes poisoning.

Following the detonation of a blast at a field site in Latrobe, PA, a PRL researcher samples for toxic gases in a nearby monitoring borehole

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STRATEGIC GOAL:
Traumatic injuries

KEYWORDS:
blasting, explosives, flyrock, mining

An ongoing hazard in blasting, flyrock and the lack of blast area security, account for the majority of blasting-related injuries and fatalities in surface mining. During FY2001, flyrock and blast area security issues in the mining industry were reviewed and reported. This review of flyrock and blast area security issues is being extended to the construction industry. A training video detailing the hazards due to flyrock and the lack of blast area security will be prepared in cooperation with industry.

Partners/collaborators in the project are the Mine Safety and Health Administration, Institute of Makers of Explosives (IME), and United Mine Workers of America (UMWA).

Ongoing Research Project related to Traumatic Injuries

Virtual Reality for Mine Safety Training

PURPOSE: Create training modules for the Virtual Reality Mine Safety Training (VRMST) software developed at SRL for evaluation in training programs at operating mines.

SRL researchers test a fire evacuation training module using the VRMST software on a multi-user mobile pc network

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STRATEGIC GOAL:
Traumatic injuries

KEYWORDS:
virtual reality, computer-based training, mine safety training, game

RESEARCH SUMMARY: Accident report narratives often cite inadequate or insufficient training as a root cause for many fatalities and serious injuries in the mining industry. The research question becomes, Can virtual reality (VR) software be shown to be an effective training medium and can it be successfully incorporated into the training program at operating mines? Through experiencing virtual reality training, can mine workers be better prepared to identify and manage hazardous operating conditions?

Numerous training topics are adaptable to the virtual reality training medium. First, project staff will identify appropriate topics for adaptation to VR training modules. Existing training materials will be used as the basis for the virtual experience to provide a proven basis, and allow evaluation of the effectiveness of the VR modules. These training scenarios will be recreated in the VRMST software using mine maps, equipment models, audio scripts, and digital imagery. The modules will undergo rigorous in-house testing prior to release for evaluation.

The software will increase worker safety by graphically illustrating the results of bad choices and incorrect decisions without actually exposing the trainee to danger. The simulations developed by this project are meant to enhance current training techniques by providing simulated hands-on, accurate, interactive training environments for workers. The inherent flexibility of this type of simulator will allow easy and rapid updating and modification of the training modules, based on stakeholder feedback. The development of the VR scenarios will rely on computer graphics technology developed for the personal computer game industry. This technology is affordable, widely distributed, and provides rich, complex, and flexible virtual environments that can be tailored to meet the training needs of the mining industry as well as the construction and agricultural industries. The software could ultimately be distributed via the Internet to allow end-users to receive frequent software updates, share user-created scenarios, and participate in on-line, multi-user training.

Ongoing Research Project related to Mine Disasters

CCER Standard

PURPOSE: Develop certification standards for the approval of self-contained, closed-circuit breathing apparatus used for escape from atmospheres considered to be immediately dangerous to life and health.

RESEARCH SUMMARY: Closed-Circuit Escape Respirators (CCERs) or Self-Contained Self-Rescuers (SCSRs which is a term used by the mining industry) are used by approximately 50,000 underground mine employees. The overall objective is that no miner should be forced to rely upon an SCSR that might be unsafe for a mine escape. Escape means taking a miner on foot and under oxygen from the deepest point in the mine to a point of safety. A review of the past history of problems encountered with SCSRs during CPIP Investigations reveals that, approximately 40% of the problems involved reliability issues.

Inspection of Self-Contained-Self-Rescuers at an underground coal mine

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STRATEGIC GOAL:
Mine disasters

KEYWORDS:
Self-Contained Self-Rescuers, SCSRs, respirators, underground mining

Storage of CCERs in harsh environmental conditions, such as heat, cold, and humidity, and the daily wearing of the respirators on and around vibration-generating equipment and tools and during physical work, can result in damage that degrades the respirators´ performance, despite their protective cases. NIOSH field evaluations of certified CCERs conducted systematically and in response to the concerns of users have identified damaged respirators that failed to meet the performance criteria under which they were certified. In some instances, the designs of these respirators, however, did not allow the wearer or employer to evaluate the condition of a particular respirator prior to its use in either an evacuation drill or an actual emergency. Respirator manufacturers have since added design improvements to allow users to check the potential for certain types of damage, but current certification requirements do not specifically govern the inclusion of such checks. Furthermore, current performance testing requirements for CCERs, some of which were established in 1919, rely on a non-uniform testing regime in which differences between human subjects involved in the testing can produce varying test results. The improvements being proposed would establish a consistent testing regimen for evaluating the life support capability of CCERs.

Finally, the current certification requirements are the cause of a risk communication and risk management problem. The requirements compel NIOSH to certify these respirators as providing protection for a specific duration applicable to the particular class of respirator. These durations may be misleading to employers and users, however, because the duration for which one of these respirators will provide effective protection in the workplace, versus in laboratory testing, will depend on the body weight and physical condition of the user and on the amount of exertion required by the escape.

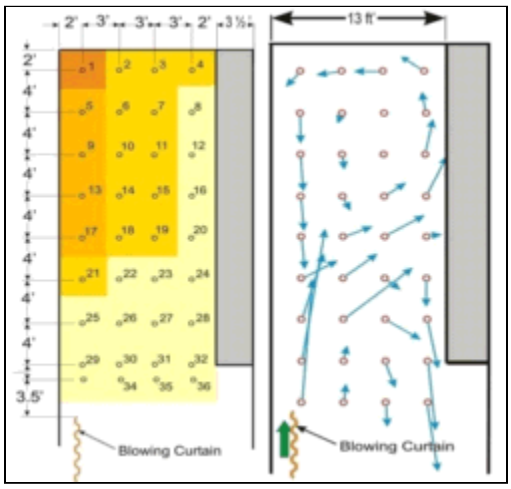
To address the reliability issues involved with the current units, the new standards will incorporate: ruggedness and hazard testing; breathing and metabolic simulator (BMS) testing for capacity, performance, and wearability testing requirements; early detection audits by non-destructive and post certification testing; and voluntary registrations.

Ongoing Research Project related to Mine Disasters

Coal Mine Face Methane Control and Monitoring

PURPOSE: Reduce or eliminate hazardous frictional ignitions at coal mine working faces through improved face ventilation and enhanced positioning of machine-mounted methane monitors.

RESEARCH SUMMARY: Large volumes of methane can be released at the mining face during coal extraction. When the lower explosive limit (LEL) is exceeded, this methane-air mixture is capable of being ignited if it contacts hot cutting bits on a mining machine. These frictional ignitions can injure, sometimes fatally, those working in the vicinity. To prevent frictional ignitions, an adequate quantity of fresh air must be provided to the mining face to dilute methane below the LEL. In addition, continuous methane monitoring is essential to assure that the LEL has not been exceeded.



Face-release methane levels and ventilating air flow data

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STRATEGIC GOAL:
Mine disasters

KEYWORDS:
mining, methanometer, ventilation, underground technology, control technology, simulation

To determine the effectiveness that different ventilation techniques have on diluting and carrying-off methane emissions at the mining face, researchers are conducting ventilation studies in a full-scale coal mine face gallery. Three-axis ultrasonic anemometers are placed at predetermined locations to measure airflow speed and direction. Results have shown that variables, such as air quantity and entry width, can affect airflow patterns and methane concentrations near the face. Presently, research is being performed to more accurately define the relationship of face air velocities and methane levels.

Studies are also evaluating the relationship between air velocities and the accurate detection of methane at typical machine-mounted methane sensor locations. Preliminary results have shown that these methane-sampling locations are not ideal. Research will determine the practicality of moving the machine-mounted continuous monitor to different locations on the machine. This work will determine which locations provide; 1) a more accurate indication of true methane concentrations, and 2) the fastest response-times to changing face methane levels. Ideally, the results will optimize the location of the monitor, minimizing the potential for methane ignitions at the face.

Research products will provide guidelines for improving face airflow and controlling face methane levels with the goal being to reduce or eliminate methane ignitions at the working face. To enhance face worker safety, it is imperative that advancements in face ventilation and methanometer placement be reviewed, accepted, and incorporated into the mining industry´s face ventilation plans. To promote these findings a research-derived transfer of technology will be provided to MSHA, private industry, labor organizations, and miners. These outputs will be in the form of written publications and both formal and informal presentations.

Ongoing Research Project related to Mine Disasters

Design Guidelines for Mine Ventilation Stoppings

PURPOSE: To develop engineering guidelines for underground mine ventilation stoppings that will help to ensure the compatibility of these structures with in-service load conditions to prevent premature failures that can lead to disastrous conditions. A secondary objective is to develop light-weight materials into satisfactory construction designs to reduce the potential of material handling injuries.

Full-scale verification testing in the NIOSH Experimental Coal mine of the transverse loading capacity of a mine ventilation stopping

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STRATEGIC GOAL:
Mine disasters

KEYWORDS:
coal mining, code of federal regulations, mine ventilation stoppings, mine seals, ASTM E-72

RESEARCH SUMMARY: Nearly all commodities of bedded deposit formations mined by underground methods use some form of permanent stoppings to control ventilation. Hundreds of thousands of these critical structures are constructed each year in underground mines. Failure of these structures can lead to disastrous fires and mine explosions. The current focus of this work is to develop engineering design guidelines for stopping construction in underground coal mines. The current Code of Federal Regulations (CFR) protocols do not fully address the in-service load conditions for these ventilation control structures and allow a wide range of stopping designs with varying transverse load capabilities to be installed in any mine environment. This can lead to dangerous conditions where the ventilation control capability can be less than expected and inadequate in certain conditions. New protocols that will provide a parametric study of the variables that impact the loading and stability of these structures need to be developed and discussed with the Mine Safety and Health Administration´s Technical Support. This will lead to more relevant design guidelines for stoppings that will ultimately provide for safer mining conditions by constructing stoppings suitable to control normal ventilation pressures and certain levels of over pressurization when the need arises. The preliminary research efforts have shown that arching is a more valid representation of the loading behavior that occurs in the mine compared to the free-standing analysis currently considered in the CFR. It has been demonstrated that arching can increase the transverse load capacity of stoppings by more than an order of magnitude. A new protocol to evaluate the transverse loading capability of stoppings through biaxial half-wall testing of dry-stacked block stopping constructions in the Mine Roof Simulator load frame has been developed and verified through full-scale testing in both the NIOSH Experimental Coal Mine and Lake Lynn Laboratory. Preliminary design equations have been developed for conventional dry-stacked block stoppings from this work and complete design guidelines prepared at the conclusion of the project.

Ongoing Research Project related to Mine Disasters

Fire Hazard Reduction in the Metal and Nonmetal Mining Industry

PURPOSE: The purpose of this research project is to reduce the incidence of fires and injuries due to fire through a comprehensive program of education, training, and basic and applied research that addresses the unique fire safety problems within the M/NM mining industry.

RESEARCH SUMMARY: The annual number of fires occurring within the M/NM mining industry is comparable to the number occurring within the coal mining industry. This project is divided into four major tasks that address the fire safety problems within the M/NM mining industry. PRL possesses unique facilities and expertise to address these problems and to conduct the research necessary for their solution. Research on fires involving large vehicles/equipment will be used to develop improved fire control and prevention techniques and improved fire extinguishment and suppression systems, including improved systems for protection of equipment operators and novel systems for prevention of re-ignition of flammable fuel vapors from ruptured hydraulic or fuel lines.

Experiment to evaluate the effectiveness of a cab detection/suppression system

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STRATEGIC GOAL:
Mine disasters

Research on the fire resistance and flammability of combustible materials will seek to identify those combustibles most in need of more stringent fire resistance ratings and to develop and recommend tests that satisfy these needs, such as noise abatement materials, hydraulic fluids, and conveyor belting.

Research on early-warning fire detection will be used not only to develop and improve upon current fire detection technology, such as intelligent smoke sensors, but also to develop strategies and guidelines for the deployment of fire sensors and systems for a diverse range of applications.

The development of fire safety training and educational materials, including hands-on training and workshops, will be developed for the M/NM industry in order to increase worker awareness to the hazards of fire and the appropriate techniques for prevention and response.

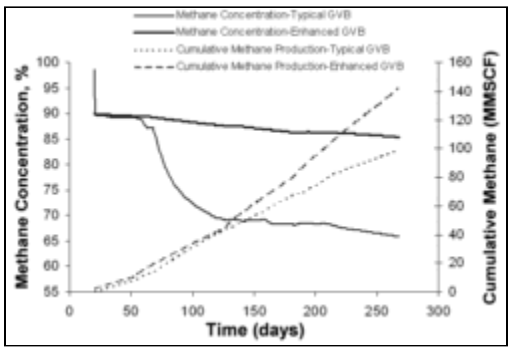
Outputs of the project will include publications and presentations in peer-reviewed journals and at peer-reviewed conferences and fire safety training workshops that address the needs of the M/NM mining industry. The target outcome of the project is to reduce the rate of occurrence of fires and injuries due to fire by 25% in the first two years following project completion with further reductions in subsequent years. Such reductions result in significant benefits, not only in terms of reduced injuries and fatalities but also in terms of improved operating efficiency and cost of mining.

Ongoing Research Project related to Mine Disasters

Investigation of Methane Control Issues in Underground Mines

PURPOSE: To investigate existing and evolving methane control issues in coal mines and develop control strategies to reduce the risk of explosions in the underground workplace.

RESEARCH SUMMARY: The inability to quantitatively forecast and control methane accumulations and emissions represents a significant risk for explosions in the underground workplace, and may have contributed to 106 U.S. coal miner deaths in 17 explosions since 1980. Recent explosions have occurred at mines in West Virginia (3 fatalities and 3 injuries, 2003), Alabama (13 fatalities, 3 injuries, 2001), and Utah (2 fatalities and 8 injuries, 2000). The inability to control methane emissions can be the product of: (1) inadequacies in the ventilation and/or methane control system configurations; (2) the inability to forecast the methane emission consequences of changes in mine design, or geologic conditions; or (3) uncertainty as to how to remediate methane emission problems. Frictional ignitions are an additional, poorly understood explosion hazard, and may be the source of a 1998 mine fire in Utah which eventually resulted in the abandonment of the mine.



Comparison of methane concentrations and cumulative methane drainage volumes using existing well completions vs. optimally completed and produced gob gas venthole configurations on a simulated 1,450-ft wide longwall panel

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STRATEGIC GOAL:
Mine disasters

KEYWORDS:
explosions, underground mining, ventilation

This research effort is designed to investigate and quantify the geotechnical factors and mine design practices influencing methane emissions and the occurrence of frictional ignitions. It is expected that the primary initial outcome will be a set of methane control best practices. A comprehensive research methane emission and gas flow predictive model is also being developed. A version of the research model will be integrated with ventilation models commonly used in the mining industry so that methane control strategies can be evaluated and included in the ventilation planning process. Rock samples are being collected from historically friction ignition prone mines for geotechnical characterization to develop a qualitative incendivity index and will be used as input to ignition control technology techniques.

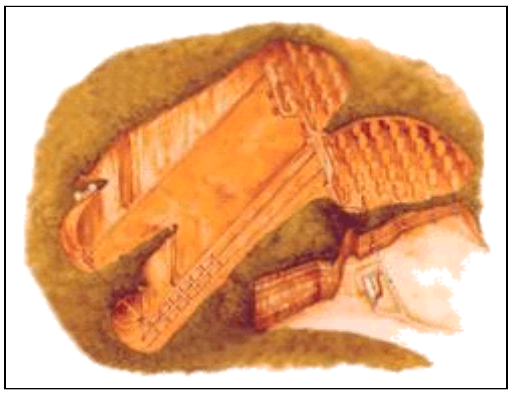
The adaptation of commercially available reservoir modeling software has successfully simulated gas flows in a longwall mining scenario. The simulations have shown that for the Pittsburgh Coalbed, the industry trend towards wider panels will probably result in increased methane emissions. Various gob gas venthole configurations have also been simulated to evaluate potential optimized methane drainage strategies for longwall panels of increased panel widths. Two unique empirical methods for predicting longwall face emissions for increased

longwall face lengths have been presented to industry. An analysis of historical frictional ignition data has shown that the majority of these events occurred in the Mary Lee/Blue Creek and the Pocahontas No. 3 coalbeds. Most frictional events occurred on continuous miner sections associated with operating longwalls.

Ongoing Research Project related to Mine Disasters

Lake Lynn Laboratory

PURPOSE: Provide a modern, full-scale realistic laboratory for underground and surface research that significantly contributes to the enhancement of workplace safety and health for miners and other workers.



Experimental mine at Lake Lynn Laboratory

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STRATEGIC GOAL:
Mine disasters

KEYWORDS:
Lake Lynn Laboratory, health and safety, explosions, fires, explosives

RESEARCH SUMMARY: Lake Lynn Laboratory near Fairchance, PA, provides an isolated surface facility and a full-scale underground mine to conduct large-scale research in mine disaster prevention and response, as well as numerous other research areas of national interest requiring the study of large-scale surface and underground safety and health problems. The ability of Lake Lynn to simulate virtually any underground coal mine geometry provides a practical, realistic research laboratory for mining research under various controlled conditions of ventilation, humidity, pressure, and temperature. To facilitate the underground research, electrical power, compressed air, water, communications, video lines, natural gas lines, and a unique high-speed data-gathering instrumentation system have been incorporated into the design at the site. The surface facilities provide an isolated environment in which large-scale research and testing can be conducted in a realistic, yet environmentally controlled manner.

On-going research at Lake Lynn includes the development and evaluation of fire suppression systems and early warning technologies, development and evaluation of mine seals and other ventilation structures, evaluation of prototype mining equipment and sensors, noise control studies, ventilation studies, roof support technologies, evaluation of explosive incendivity and toxic gases, determination of explosion limits for combustible dusts and ignitability of mists and vapors, mine rescue team training evaluations in smoke-filled entries, and respirable dust deposition and diesel particulate studies. The information generated as a result of the research conducted at Lake Lynn is vital to the mining industry in the development of improved technology and practices to protect mining personnel from the many hazards associated with their jobs. Although the primary mission of Lake Lynn is in support of mine safety and health programs, the unique characteristics of the facility make it attractive for research in support of other industrial problems. Cooperative research within these areas is often conducted on a resource availability, cost-reimbursement basis. This project supports and coordinates all of the Lake Lynn research efforts; enhances the research capabilities of Lake Lynn; and maintains safety, health, and environmental controls at Lake Lynn.

Ongoing Research Project related to Mine Disasters

Long Term Field Evaluation (LTFE)

PURPOSE: To monitor the reliability of Self-Contained Self-Rescuers (SCSRs) deployed in US underground coal mines.

RESEARCH SUMMARY: After an underground mine fire or explosion, the mine atmosphere may become oxygen deficient or filled with smoke and toxic gases. Respiratory protection is necessary for successful escape from the mine. Only closed-circuit breathing apparatus known as SCSRs can provide the life support capacity necessary for emergency escape.

SCSRs have been deployed in US underground coal mines since 1981, and the LTFE began shortly after, as a joint USBM/MSHA project to monitor their reliability and assure their proper functioning in the event of emergency use. Today, the LTFE collects and tests nearly 200 SCSRs per year.

As a result of LTFE investigations, many problems with SCSRs have been discovered, ranging from quality control failure, aging, mine environment impact, as well as poor inspection procedures. As a result, about 55,000 SCSRs have been recalled or decertified, and recommended changes in inspection procedures or donning instructions have affected about 70,000 SCSRs. Because of lessons learned from the LTFE design changes have been and are continuing to be made to improve the performance and reliability of SCSRs.

Escape Training using Self-Contained-Self-Rescuers in an underground coal mine

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STRATEGIC GOAL:
Mine disasters

KEYWORDS:
Self-Contained Self-Rescuers, SCSRs, Long Term Field Evaluation, LTFE, mine escape

Ongoing Research Project related to Mine Disasters

Mine Rescue and Response

PURPOSE: To improve the state of readiness for emergency responders and increase the chances of survival for personnel escaping from underground emergencies.

RESEARCH SUMMARY: Our Nation´s miners often rely on emergency responders to save their lives in the event of an underground emergency, such as a fire or explosion. Approximately 650 underground coal mines and 240 underground metal/nonmetal mines operate in the United States and employ a workforce of 44,000 miners. There are currently 260 mine rescue teams with about 1,700 members. These dedicated groups of miners often put their lives in jeopardy to save others. It is important that team members are provided with the latest personal protective equipment, be well trained, physically and mentally fit, and fully understand the hazards that may await them during rescue operations. Miners are often the first responders to an emergency, such as a fire, and must decide if they should fight the fire or evacuate the mine.

Mine Rescue Team training

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STRATEGIC GOAL:
Mine disasters

KEYWORDS:
emergency responders, mining, training, fire

This project enhances the safety, preparedness and effectiveness of mine emergency responders, including evacuating miners, fire brigades, and mine rescue teams, by developing and conducting realistic training simulations and improving technology for rescue, exploration, recovery, fire fighting and evacuation. The mine fire preparedness and response capabilities of mining operations are assessed by the development of comprehensive checklists. Methodologies and training interventions to enhance the accurate communication of information and decision making during the initial phase of mine emergencies are also being developed, evaluated and implemented.

Realistic training simulations for mine emergency responders have and continue to be developed, conducted and evaluated in collaboration with State mining agencies and mining companies. These simulations are held at the NIOSH Lake Lynn Laboratory and at operating mines and include training for exploration, rescue and recovery operations, combating liquid fuel and conveyor belt fires, and the evacuation of miners in smoke filled passageways. Over 135 mine rescue simulations have been conducted and over 2,500 miners participated in the various training exercises. The participants gain a better awareness of the hazards associated with mine emergencies, increase their response skills and confidence levels, and enhance the

operational effectiveness of rescue teams and command centers. Improved technologies for mine emergency responders have also been identified and evaluated. These include chemical light shapes, lighted vests, strobe lights, laser pointers, lifelines, a patented lighted team link line, wheeled stretchers, thermal imaging cameras, and state-of-the-art communication systems.

Ongoing Research Project related to Mine Disasters

Prevention and Mitigation of Gas/Dust Explosions

PURPOSE: To reduce hazards in mining through basic and applied research on the prevention and mitigation of gas and dust explosions and the education of mining personnel on explosion hazard recognition and prevention.

RESEARCH SUMMARY: While much progress has been made in preventing disasters in mines, explosions still occur, often producing multiple fatalities. In an explosion, all underground miners are at risk. There were serious underground coal mine explosions in July 2000 at a Utah mine (2 fatalities and 8 injuries), in September 2001 at an Alabama mine (13 fatalities and 3 injuries), and in January 2003 at a West Virginia mine (3 fatalities and 3 injuries). Explosions are caused by accumulations of flammable gas and/or combustible dust mixed with air in the presence of an ignition source. Research on gas and dust explosions is needed as a basis for the development of techniques and strategies for explosion prevention, suppression, and mitigation.

Collection of floor dust sample after explosion in the Lake Lynn Experimental Mine

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STRATEGIC GOAL:
Mine disasters

KEYWORDS:
explosions, mining, ventilation

This project studies explosion propagation and explosion combustion mechanisms through full-scale tests at the Lake Lynn Experimental Mine (LLEM) and through laboratory tests in a 20 liter chamber. The LLEM research includes the effects of turbulence and confinement on the initial stages of a gas explosion, the requirements for transition from a small gas explosion to a full-scale propagating dust explosion, and flame propagation in large volumes of nonuniformly mixed methane. In conjunction with these LLEM tests, there is a task to improve the supporting documentation/research used by the Mine Safety and Health Administration (MSHA) in investigating explosion disasters. In a collaborative task with MSHA, an in-situ meter has been developed to quickly determine the explosibility and/or the incombustible content of coal and rock dust mixtures in coal mines, thereby improving sample analysis and rock dusting practices.

The results of this research so far have been communicated to stakeholders in four briefing reports to MSHA, two conference papers, a book chapter, and a peer-reviewed journal paper. Achievements include the development of improved forensic procedures for use by MSHA in investigating mine explosion accidents and the development of improved laboratory test methods as consensus standards for the determination of explosibility characteristics. Additional recommendations on the best practices to prevent and/or mitigate explosion hazards are

expected. The outcome of this research effort will be a reduction in the risk for gas/dust explosions in the underground workplace through an increased understanding of the causative factors for these events, the development of improved control technologies, and educating the workforce to recognize and prevent explosions.

Ongoing Research Project related to Mine Disasters

Prevention and Mitigation of Mine Inundations

PURPOSE: Minimize hazards associated with water/slurry impoundments in an underground coal mine by developing a set of guidelines that discuss physical, geological, structural, and safety issues for consideration when designing a safe and efficient bulkhead system.

Hydrostatic testing of mine seal at Lake Lynn Laboratory

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STRATEGIC GOAL:
Mine disasters

KEYWORDS:
ventilation, ground control, underground mining

RESEARCH SUMMARY: While much progress has been made in preventing disasters in mines, inundations still occur and have the real potential of producing multiple fatalities. Many mining operations rely on bulkheads or ventilation seals to provide a barrier between impounded water and active mine works. Since 1995, there have been over 100 inundation accidents reported by MSHA where mining has cut into underground bodies of water. These inundations serve to illustrate the potential risk to miners while working near such large impoundments.

NIOSH personnel met with personnel at (4) Mine Safety and Health Administration (MSHA) District Offices, the West Virginia Office of Miners´ Health Safety and Training, and Pennsylvania´s Department of Environmental Protection to document locations of bulkhead installations. While in the field, researchers toured mining operations in WV, MD, KY, and AL to gain first hand knowledge of operational issues related to bulkheads. Deep mine inspectors, permit reviewers, mining engineers, design engineers, and bulkhead construction firms were also contacted to better understand the permitting process. To date, in-depth reviews of 28 permit applications have been completed. The data from permit reviews along information gathered during site visits has been entered into a comprehensive Bulkhead Installation data base containing information on existing bulkhead designs and performance case histories. The data base is helping researchers identify trends in design, intended purpose, pressure rating, emergency relief options, and emergency response plans. Full scale hydrostatic testing of mine ventilation seals that can be exposed to hydraulic pressures was conducted at the Lake Lynn Laboratory to provide data on leakage rates and failure mechanisms. Uniaxial compressive testing was performed on core samples taken from the test ventilation seal. The field information and full scale testing data will be culminated into a comprehensive design manual that considers the strength of the bulkhead structures and addresses the parameters that affect the system design such as overburden depth, barrier pillar strength, proximity to adjacent mine works and surface impoundments, method of reducing water elevation, evacuation routes, and emergency planning.

The expected outcomes are: (1) better evaluation measures for bulkhead designs; (2) improved designs that interface with mine strata to better protect miners from a massive in-rush of water or mine waste; (3) identify key factors that have resulted in successful bulkhead designs and rock interfaces over the last 15 years.

Ongoing Research Project related to Mine Disasters

Reducing Fire Hazards in U.S. Coal Mines

PURPOSE: To reduce the occurrence of spontaneous combustion in underground coal mines, particularly in mines that have appreciable levels of methane, and to reduce the fire hazards in coal mines associated with flame cutting and welding operations.

Inert gas injection into borehole to control mine fire

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STRATEGIC GOAL:
Mine disasters

KEYWORDS:
fires, spontaneous combustion, flame cutting and welding

RESEARCH SUMMARY: Most spontaneous combustion fires occur in worked-out areas that are not accessible and require remote detection and extinguishing efforts. This hazard is a particular concern in mines with both a high spontaneous combustion risk and high levels of methane, since most ventilation schemes utilized to remove methane from the mine exacerbate the spontaneous combustion hazards. An understanding of how various ventilation practices affect spontaneous combustion is needed. Research is required to develop ventilation methods that both remove the methane and minimize the risk of spontaneous heating. Case studies are being conducted to determine the causative factors and the role of ventilation in the heating events. The information from these studies, along with experiments to characterize gob ventilation, is being incorporated into computational fluid dynamic models to evaluate ventilation schemes to dilute methane and minimize the self-heating risk in spontaneous combustion-prone mines. In addition, models are being developed to evaluate various sealing and inert gas techniques to combat self-heating in gob areas. This research will result in improved ventilation practices and technologies to reduce the number of fires and the risk of spontaneous combustion fires in mines with both a high spontaneous combustion risk and high levels of methane.

Analyses of fires in the coal mining industry for the period 1990 - 2002 indicated that 110 of the 560 reported fires were the result of either flame cutting or welding operations. These fires resulted in 70 injuries and 2 fatalities. In a 2003 mine accident, a shaft explosion in West Virginia due to flame cutting caused 3 fatalities and 3 injuries. The root causes of flame cutting and welding fires are being determined and improved methodologies and technologies are being developed and evaluated to prevent these types of fires. Accident investigations are being scrutinized, workers interviewed, and flame cutting and welding operations at operating mines are being observed. Procedures, regulations, and other standards and existing guidelines are being analyzed to determine the root causes of cutting and welding fires in the coal sector and

identify possible interventions. Training procedures and preventive equipment are being developed and evaluated. This research will result in new guidelines for flame cutting and welding in coal mining operations and a reduction in the number of fires and injuries due to flame cutting and welding operations.

Ongoing Research Project related to Mine Disasters

Remote Methods for Addressing Coal Mine Fires

PURPOSE: To provide, through technology testing and improvement, more reliable remote mine fire suppression technology and to directly transfer these improvements to the coal mining industry.

NIOSH researcher observes the movement of fire-fighting foam at the Lake Lynn Experimental Mine

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STRATEGIC GOAL:
Mine disasters

KEYWORDS:
underground mining, explosions, fires, remote seals, compressed-gas foam

RESEARCH SUMMARY: Mine fires constitute one of the greatest threats to the health and safety of those working underground. Since 2000, a total of 17 mine fires have occurred in the United States. On average, three mine fires occur each year and over the period from 2000 to the present, a maximum of five mine fires have occurred in a one-year period. These statistics suggest that mine fires are occurring with alarming regularity, yet there has been no improvement in the technology for fighting a mine fire. Although not all mine fires cause fatalities, they have the potential for catastrophic results. Improvements in remote fire fighting technology are needed to reduce miner exposure and possibly save the lives of those that may become trapped.

Mine seals are often constructed when access to the fire zone is impossible. A correctly constructed mine seal is designed to close-off the mine opening to prevent the inflow of oxygen and isolate a fire zone. Underground observations suggest that the currently available technology used to construct remote mine seals often fails to fully close the mine opening. Thus it is impossible render the mine atmosphere inert because air can move freely move into the fire zone. Remote fire-fighting methods are usually restricted to sealing the mine and inerting the mine with gas. This results in dangerous atmospheric conditions that are extremely hazardous to mine rescue and recovery personnel. Gas-enriched foam systems have recently been used to remotely fight underground fires, but they have not been fully evaluated in a controlled mine environment to determine the best chemical formulation and method for application. It is believed that gas-enhanced foam offers promise given a sufficient underground life and the capability to efficiently move and migrate through a mine opening to the fire.

Remote mine seal construction and gas-enhanced foam technology are being tested and evaluated in the Lake Lynn Experimental Mine. At this site, full-scale explosions and deep-seated mine fires can be initiated to test technology under real-life conditions. The goal of this work is to fully integrate the improved technology into the mine fire-fighting arsenal very soon after completion of the work. This will be accomplished through a focused, industry-wide Technology Transfer effort and direct interaction with the state and federal regulatory officials who manage and monitor mine fire suppression efforts.

Ongoing Research Project related to Mine Disasters

SCSR Training Modules

PURPOSE: To enhance SCSR care, maintenance, and inspection protocol so that miners keep SCSRs in good condition and all units that fail inspections are removed from service.

RESEARCH SUMMARY: SCSRs are used by approximately 50,000 underground mine employees. Training in care, maintenance and inspection is paramount to ensure that the device functions properly when donned by a mine worker during an emergency. The modules will be available from the NIOSH and MSHA Internet sites. NIOSH, in joint participation with MSHA, will initiate an intervention strategy for introducing these modules to the mining industry through their Educational Field Specialists. In addition, the agencies are collaborating on the effectiveness that these training modules have on SCSR user readiness.

Proper donning method for SCSRs

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STRATEGIC GOAL:
Mine disasters

KEYWORDS:
Self-Contained Self-Rescuers, SCSRs, respirators, underground mining

The intent of the project is to continue the development of specific SCSR care and maintenance training modules for each NIOSH certified SCSR. Each module will have information and training content specific to the type of SCSR. The objective of this intervention is to improve workers' understanding of the care, maintenance, and inspection procedures to ensure that SCSRs are kept in good condition and to remove all units that fail inspection from service. The modules use the previously approved ACSE SR100 Care and Maintenance Training Module as a template to develop SCSR specific training modules representing the three remaining manufacturers' units. The training module components include a 16-minute video, a CBT training exercise, an instructor's guide and a sticker. Each module contains five elements, which include daily inspection, 90-day inspection, donning sequence, use/care/maintenance, and sensory expectations.

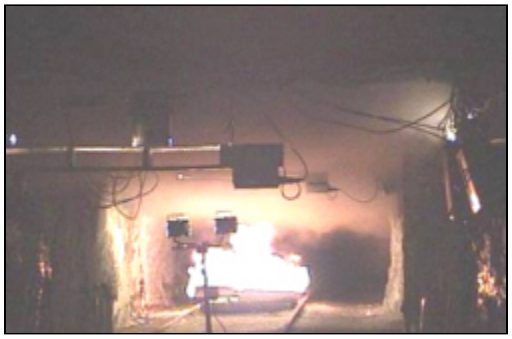
All materials are developed in cooperation with the specific manufacturer to ensure content validity. MSHA is participating in an Interagency Agreement to produce the training modules at their training academy, Beckley West Virginia. Development and distribution of the modules is supported by the United Mine Workers of America (UMWA), Bituminous Coal Operators Association (BCOA), and MSHA.

Ongoing Research Project related to Mine Disasters

Smoke Management and Fire Modeling for Underground Mines

PURPOSE: To develop a real-time mine fire simulator with mine ventilation and smoke control decision making capability based on mine fire sensor data to determine the most effective smoke management methods to provide safe miner egress and safe access for fire-fighters.

RESEARCH SUMMARY: Fires continue to be a major hazard in underground mines. During a mine fire, the operator usually has very limited fire sensor information. This data could be more efficiently applied to emergency smoke management and fire suppression decisions if an interactive mine fire simulator was available. There is no existing strategy to control the movement and dilution of smoke associated with an underground mine fire. Therefore, the primary and only response to a mine fire is egression from the mine or fire region. Without a scientific understanding of fire development and smoke transport, safe and effective smoke management methods cannot be deployed to avert the hazards of toxic smoke and low visibility under emergency mine fire conditions.



Smoke reversal from a small diesel fire

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STRATEGIC GOAL:
Mine disasters

KEYWORDS:
fires, underground mining, ventilation

The mine fire simulator will be developed for applications to miner safety in underground mines. In support of this project outcome, in-mine fire and smoke transport experiments, fire spread modeling with advanced computational fluid dynamic (CFD) programs, optimum sensor site location experiments, fire risk assessment strategies, and smoke leakage experiments will be conducted. The effects of ventilation upon smoke leakage from a fire in a return airway into an intake airway under low air flow conditions will be evaluated experimentally. As an outcome smoke control measures will be developed and evaluated. Thus far, it has been determined experimentally and computationally that the ventilation required to prevent smoke rollback along the roof from a fire in a mine entry can be specified by a mathematical relationship. This function will be incorporated into the mine fire simulator.

As a mine fire emergency preplanning tool, the simulator will provide the development of strategies for smoke control and the development of a smoke control plan based upon anticipated mine fire scenarios. As a real-time emergency tool, the fire simulator will provide the mine operator with real-time data to evaluate and manage ventilation during a mine fire to allow miners safe egress from the mine. In both cases, the simulator will be forward looking with recommendations for diluting the smoke and toxic gases to acceptable levels for safe egress from the mine and for the safe approach of fire fighters.

Ongoing Research Project related to Ground Control

Development and Evaluation of Innovative Roof Support Technologies

PURPOSE: To facilitate the development of new roof support technologies through industry partnerships with various support manufacturers, and to ensure that these new support technologies meet basic safety standards before they are commercialized for use in underground mines.

Prestressing unit used to preload a Can support

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STRATEGIC GOAL:
Ground control

KEYWORDS:
coal mining, roof support, underground mining, emerging technologies

RESEARCH SUMMARY: Ground control is a fundamental aspect of all underground mining. Historically, between 30 and 40 pct of the fatalities in underground mines are caused by the unstable roof rock falling in on the miner, and this percentage has been increasing in recent years. Roof support systems are routinely installed in all mines in an effort to prevent these catastrophic roof falls from occurring. Due to the importance of ground control, roof support manufacturers continually strive to develop new roof support technologies that provide superior ground control at less cost. Our goal is to make sure that new support technologies are properly designed to ensure the safety of mineworkers. Through a cooperative program with the various support manufacturers, each new support technology is rigorously tested in NIOSH's unique Mine Roof Simulator. During the development of a new support system, this testing identifies design deficiencies so that they can be corrected. Once the support system satisfactorily passes this testing protocol, then the performance characteristics and its limitations are determined in order to optimize the safe use of this support in the mine. Nineteen new or modified roof support systems produced by seven different companies were evaluated this past year. These products are then implemented into the NIOSH Support Technology Optimization Program (STOP). This is a design software system that allows anyone to compare the performance of the various products and to match the appropriate support with the conditions in a particular mine to provide the most effective and safe ground control possible. NIOSH also provides technical guidance to the Mine Safety and Health Administration regarding the approval of new support technologies and participates in several technology transfer efforts each year to promote the safety advantages of these improvements in roof support.

Ongoing Research Project related to Ground Control

Fragmentation Methods and Ground Control Safety

PURPOSE: Investigate the complex relationships between fragmentation, rock scaling, ground support, and safety in mines that use drilling and blasting as the primary excavation method.

RESEARCH SUMMARY: Rock falls are one of the most serious causes of fatal injury to underground miners. From 1998 through 2002, the fatal injury rate in underground mines was 56.2 (i.e., the number of fatalities per 100,000 full-time-equivalent workers). Of these, the Mine Safety and Health Administration (MSHA) classified 43.3% as being caused by falls of ground.

Metal and stone mines typically excavate rock using explosives. If too much is used, the rock surrounding the opening can be excessively fractured, and workers can be endangered by loose and falling rock when they enter the workplace. Fractured, weakened, and/or loosened rock must be either scaled or supported. Both of these activities are extremely hazardous.

Split Hopkinson pressure bar test facility

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STRATEGIC GOAL:
Ground control

KEYWORDS:
blasting, fragmentation, overbreak, supports, scaling, rock falls

The research problem addressed by this project was whether advanced fragmentation techniques could be used to minimize the hazards associated with rock falls. These techniques include various controlled blasting methods and new products, such as electronic detonators and string emulsion, that have the potential to reduce excessive fragmentation of surrounding ground and preserve more of the inherent strength of the rock. Such techniques have been applied in many civil engineering projects and have been introduced in some sectors of the mining industry. Although these methods promise better ground control safety, the benefits have rarely been quantified.

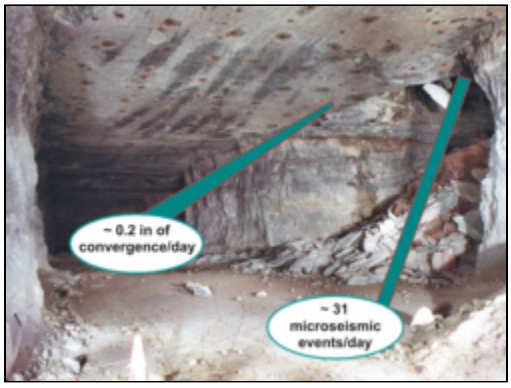
In this project, researchers seek to quantify the interaction of fragmentation, rock scaling, and support methods, allowing them to be optimized as a single system. The first step in this research is to study and classify the dynamic response of rocks. A 60-mm split Hopkinson pressure bar was set up to measure the extent of fracturing in different types of rock. Assessment methods are being developed to evaluate the extent of rock fracturing. A follow-up project that builds upon this work is planned that will use a systems approach to look at not only blasting, but also the drilling, scaling, and support portions of the mining cycle. Future work includes single-hole blast testing, development of an RMR-based blasting model, improved mathematical models, field verification tests, and demonstrations at mine sites. This information will be used to reduce hazards related to rock falls at mining operations.

Ongoing Research Project related to Ground Control

Fundamental Studies of Factors Responsible for Falls of Ground

PURPOSE: This project serves to design, test, and demonstrate the potential of monitoring technologies to warn of roof fall occurrences.

RESEARCH SUMMARY: Reducing the number of ground fall injuries is a central goal of the NIOSH mine safety research program. This research effort is aimed at advancing our basic understanding of the causes of ground falls and using this knowledge, in conjunction with state-of-the-art monitoring technology, to warn of large roof fall occurrences. Central to this project will be the collection of microseismic and roof deflection information from several sophisticated monitoring systems at field sites where roof falls occur. These monitoring data will be compared with actual field observations to determine: the characteristics of the detectable roof falls; the timing sequence between roof falls and measurable microseismic activity; trends in the data to warn of roof falls; and limitations in this technology to anticipate roof falls.



Monitoring rock failures and roof movements to warn of roof falls

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STRATEGIC GOAL:
Ground control

KEYWORDS:
fall of ground, ground control, roof falls, rock failure, mining induced seismicity

The ability to determine the location and timing of roof falls has been a long standing goal of safety professionals. The combination of microseismic monitoring and roof deflection measurements produces complementary information that more completely characterizes the pre-fall behavior of roof rock strata. This enhanced technology provides the kind of information needed by on-site personnel responsible for worker safety, to anticipate the occurrence of hazardous roof falls.

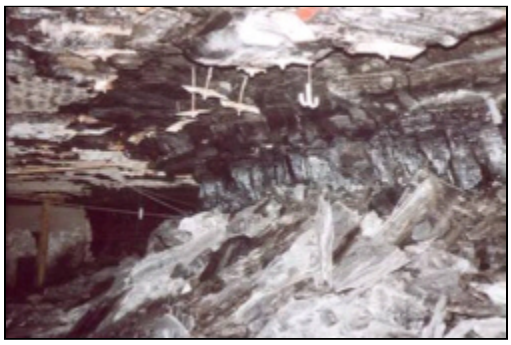
NIOSH is in the process of deploying several monitoring systems at mines with known roof fall problems so that an extensive database of microseismic emissions and roof-to-floor convergence and roof beam sag measurements can be established. These sites are from mines with varying geologies, stress conditions, and mining methods. It is recognized that several years will be needed to collect enough data to adequately prove or disprove the viability of this technology. In 2001-2003, several roof falls were monitored at an underground stone mine in southwestern Pennsylvania. In 2004, the microseismic database from the Moonee Colliery longwall coal mine in Australia was obtained and event trends were compared with roof fall occurrences. In early 2005, a South African microseismic monitoring system was deployed at an underground stone mine in northern West Virginia. In late 2005, a Canadian microseismic monitoring system is scheduled to be

deployed in a deep, steeply dipping stone mine in central Pennsylvania. In each case, monitoring will continue for 6 to 12 months and information on the geology, stress field, and mining methods will be collected. Additional field sites will be added in the future to continue to broaden NIOSH´s database.

Ongoing Research Project related to Ground Control

Ground Stability Through Advanced Mine Design

PURPOSE: This project seeks to reduce injuries and fatalities from ground falls in underground coal mines by developing state-of-the-art design tools for three related ground control problem areas: 1) deep cover coal pillar recovery, 2) high horizontal stress control and 3) multiple-seam mining.



Multiple-seam interactions can result in severe pillar loading and subsequent failure

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STRATEGIC GOAL:
Ground control

KEYWORDS:
underground mining, ground control, pillar recovery, horizontal stress, multiple seam mining

RESEARCH SUMMARY: In the 10 year period from 1995 through 2004, ground fall fatalities have averaged about 8 per year and accounted for almost 44% of all fatalities in underground coal mines. To meet increased coal demand, the industry must extract resources under more extreme and potentially dangerous ground control conditions. Interaction with stakeholders reveals three recurrent ground control problems in extreme conditions, namely, pillar recovery at depth, high horizontal stress control and multiple-seam mining.

Traditional room-and-pillar mine design methods used for shallow mines (less than 750 ft) do not work well in deeper mines. NIOSH researchers developed design guidelines for deep cover pillar recovery that reduce the likelihood of an uncontrolled roof collapse or a massive pillar collapse. The recommendations have been incorporated into the Mine Safety and Health Administration-approved Roof Control Plans at more than 100 operating coal mines throughout the United States.

The magnitude of maximum horizontal stress and whether it will induce mine roof damage under particular circumstances has remained elusive. NIOSH researchers found that horizontal stress in a mine roof depends on the roof rock modulus. A field study critically examined horizontal stress variation and displacements in a mine roof. Numerical models were created that simulated the observed behavior. NIOSH researchers developed a modeling procedure that uses sufficient geologic detail and the proper horizontal stress variation to create realistic numerical simulations of observed mine roof behavior.

The multiple-seam mining portion of the project is developing design tools for evaluating and controlling potential multiple-seam mining interactions using a combination of statistical analysis of a case history database and numerical models of the failure mechanics. Over 200 case histories of multiple seam mining interactions have been carefully documented. Sophisticated computer models are being utilized to understand the failure mechanics resulting from multiple seam mining. Development of rational multiple- seam mining guidelines that are based on the failure mechanics and the case history database is underway.

Some expected outputs from this work are:

1. Suggested guidelines for sizing coal pillars for recovery under deep cover.
2. Techniques for evaluating and controlling multiple seam hazards in underground mines.
3. Design methodology and guidelines for multiple seam operations.

Ongoing Research Project related to Ground Control

Guidelines for Eliminating Hazardous Ground Conditions From Underground Stone Mines

PURPOSE: Develop design guidelines for maximum roof spans and minimum pillar dimensions in underground stone mines. The effect of temperature and humidity on excavation stability will in addition be assessed and incorporated into the design guidelines.

RESEARCH SUMMARY: Fall of ground accidents have been the largest single cause of fatalities in underground stone mines in the decade 1994 through 2003, while the fall of ground injury rates have remained essentially unchanged since 1995. The room-and-pillar method is used in all underground stone mines. The dimensions of the pillars and the roof spans in these mines are largely based on past experience without consideration of the local geotechnical parameters that affect stability. A result is that roof falls can occur unexpectedly and pillar dimensions can be inadequate to support the overburden. In addition, anecdotal evidence seems to indicate that fluctuations in mine air temperature and humidity affect the stability of the roof and ribs. This project has the objective to develop an engineered approach to stone mine layout design so that ground fall accidents can be reduced or eliminated.

Roof fall caused by excessive horizontal stress in a limestone mine

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STRATEGIC GOAL:
Ground control

KEYWORDS:
fall of ground, stone mining, pillar design, roof span design, ground control

The research will largely be based on the statistical valuation of the performance of existing underground stone mine layouts. Field data will be collected at more than forty operating mines representing a variety of geological and operating conditions. The field data will be supplemented by monitoring of roof and pillar behavior at selected sites. Laboratory testing of rock strength properties and numerical analysis of roof and pillar failure mechanics will be conducted to better understand the mechanisms of failure and stability. These studies will provide statistical as well as analytically based results that identify critical parameters affecting stone mine stability. The results of the studies will be used to develop a methodology for designing roof spans and pillar dimensions in underground stone mines.

The outcome of the project will be guidelines for improved techniques for underground stone mine design resulting in the reduction of potentially hazardous ground conditions and improved safety of mine workers.

Ongoing Research Project related to Ground Control

Identification and Control of Rock Burst Hazards

PURPOSE: Reduce ground failure and injuries associated with rock bursts (earthquakes) in deep hard-rock mines.

RESEARCH SUMMARY: Mines in the Coeur d´Alene Mining District where rock-burst-related roof falls occur have a fatality rate eight times greater than the industry average for all causes of death. Ore from the platinum mines in Montana is being extracted from greater depths, and conditions that favor rock bursts are being encountered. Currently, five underground hard-rock mines in the United States have geologic and mining conditions that could generate rock bursts. These mines employed 2,239 (14%) of the 14,492 workers in metal/nonmetal mining.

Observing the damage to roof supports and rock following a rock burst

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STRATEGIC GOAL:
Ground control

KEYWORDS:
rock burst, underhand mining, seismic system

In the past, researchers at SRL have developed backfilling, destressing, and underhand mining to alleviate the hazards and protect miners from bursts. Currently, researchers are monitoring rock-burst prone mines to identify hazards before they become a problem. They have developed PC-based, in-mine seismic and electromagnetic monitoring systems to identify rock burst failure mechanisms and an Internet-based seismic monitoring system for real-time surveillance of seismic activity at targeted mines.

For example, wall strain and electromagnetic emissions are being investigated to determine if either can be used to develop a system that could warn of impending bursts. Partners in the research are the Stillwater Mining Co. (Stillwater and East Boulder mines); Hecla Mining Co. (Lucky Friday Mine); Coeur Silver Valley, Inc. (Galena Mine); the Montana Bureau of Mines and Geology, Office of Earthquake Studies; the Montana Tech Foundation; and Gonzaga University. Successful development of an early warning system could reduce injuries caused by rock bursts because miners could be evacuated to safe areas before a burst.

Ongoing Research Project related to Ground Control

Preventing Injuries from Falling Rock in Underground Coal Mines

PURPOSE: To reduce the risk of injury from rock falls by removing the barriers that limit the use of surface control technology. The barriers include: a lack of understanding of the geologic conditions that lead to small rock falls, a lack of knowledge about successful surface control techniques, inadequate installation procedures and equipment, lack of engineering design guidelines, and support and production costs.

Roof bolter advances his own protection using the Personal Bolter Screen (PBS) developed by NIOSH

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STRATEGIC GOAL:
Ground control

KEYWORDS:
underground mining, roof falls, roof fall injuries, roof support, ground control

RESEARCH SUMMARY: Each year, about 500 reported injuries (and usually 1-2 fatalities) result from relatively minor falls of rock from the roof in coal mines. These injuries occur in areas that have been supported and should be safe. Various surface control techniques are used in mines to control minor rock falls of the roof. However, current technologies are often ineffective, and they can be expensive and time-consuming to install. As a result, mine operators are often reluctant to use these technologies. This project is designed to reduce barriers to the use of surface control and improve the effectiveness of the surface control systems.

Research has identified the use of welded wire screen as the single most effective surface control to prevent rock falls between bolts. Dramatic reductions in injuries have been documented at mines that use screening on cycle. Routine use of screen is not common in coal mines. A number of installation "best practices" have been documented and are now being actively promoted in a series of underground screen installation demonstration sites. Another barrier to the adoption of roof screen is the perception that it is difficult to install and may, in fact, cause injuries. An ergonomics study using a simulated coal mine is being conducted to determine the ideal loads and positions related to transporting and installing screen. A training video that documents the benefits of roof screening has been developed and is currently being distributed.

Another project goal is to help identify rock types that are most prone to rock falls. Rock that is sensitive to moisture can deteriorate, swell, and fracture. Laboratory testing and down hole geophysical methods have shown promise in identifying weak rocks.

Some expected outputs from this work are:

1. Personal Bolter Screen technology for rock fall prevention
2. Training video: "Make It Safe with Roof Screen."
3. Ergonomic "best practices" for roof screen installation.

4. Suggested procedures for identifying weak, moisture sensitive rock prior to mining.

Ongoing Research Project related to Ground Control

Reduce Groundfall Hazards in Nevada

PURPOSE: Reduce groundfall injuries in Nevada underground mines excavated in weak rock masses. Develop new mining techniques using proven mine design techniques and adapting them to underground mines in weak rock.

Portable Australian round-panel tester for fibre-reinforced shotcrete

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STRATEGIC GOAL:
Ground control

KEYWORDS:
shotcrete, stability, weak rock mass, design curves, rock mass rating (RMR)

RESEARCH SUMMARY: Underground mining is one of the most hazardous occupations worldwide. Most of the fatalities associated with underground mining are attributed to either groundfall or haulage. In the United States during the 1990´s, injuries and fatalities from falls of ground were an order of magnitude higher in mines excavated in weak rock masses than in underground mines in stronger rock (Mine Safety and Health Administration at www.MSHA.gov).

To address the controlling and confounding factors involved in determining risk exposure in underground mines in weak rock masses, a twofold research approach was adopted. The first was to collect data to establish mine design criteria (rock mass ratings, span widths, and estimated loss of slough). The second was to study the use of fibre-reinforced shotcrete as a type of ground support. By conducting rigorous field tests and analyzing the data from the fiber-reinforced shotcrete used as immediate support at the Rodeo Mine, NIOSH personnel were able to provide information on new underground support design criteria that will lead to a safer working environment for underground miners.

Nevada Gold Book. An underground mine design manual for weak rock mass conditions in hard-rock mines has been developed. It contains information that relates span curves, rock mass rating (RMR) values, stope design curves, and ELOS values. This manual has been adopted at most mines in Nevada, Idaho, Montana, and Colorado.

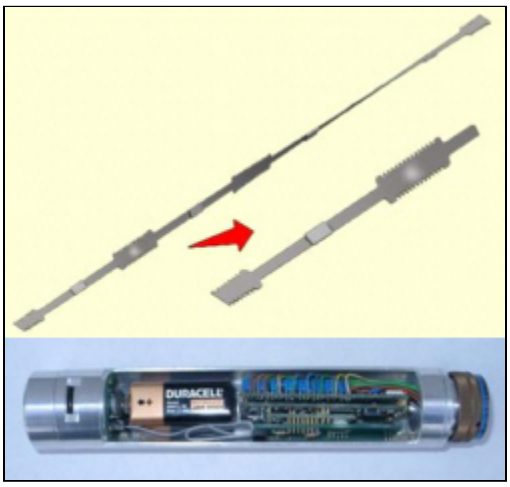
Shotcrete. NIOSH and the Barrick Gold Mining Company collaborated at Barrick's Rodeo/Meikle gold mines in Nevada to evaluate and compare the use of fibre-reinforced shotcrete to the use of steel screens with shotcrete. A field test of the two methods was conducted in a production test drift from May to October 2002. Analysis of test results by both Barrick and NIOSH SRL personnel confirmed a statistically significant improvement in ground control when fibre-reinforced shotcrete was used. Subsequently, Barrick decided to utilize fibre-reinforced shotcrete for 30% of its underground shotcrete applications.

Shotcrete Field Test. An Australian round panel test system was designed, built, and tested during FY04. This system gives mines the ability to test the strength of shotcrete in situ for immediate design and engineering parameters. Several mines have utilized these tests to improve underground support.

Ongoing Research Project related to Ground Control

Roof Fall Evaluation and Mediation in Weak Rocks

PURPOSE: Reduce the number of accidents and fatalities caused by mining in weak ground by developing accurate knowledge of how roof supports perform in weak rock, how fracturing is induced by excavation in weak rock, and how best to support adequately such ground or arrest the fracturing mechanism.



Top - Rock strain strip (ROSS); Bottom - Miniature data acquisition system (MIDAS)

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STRATEGIC GOAL:
Ground control

KEYWORDS:
roof support, rock strain, roof falls, numerical models

RESEARCH SUMMARY: Weak rock is a significant factor in roof falls, which are a leading cause of fatalities and injuries in underground mines in the United States. From 1998 to 2002, the incident rate for underground fatalities was 56.2 per 100,000 equivalent full-time employees ; falls of ground accounted for 43.3% of all underground fatalities. During the same period, the incident rate for nonfatal injuries and illnesses was 7.8 per 100 full-time equivalent employees; fall of ground accounted for 1.25 per 100 full-time equivalent employees.

It has been shown that borehole roughness affects anchorage capacity. Anchorage capability is especially critical in weak roof where the rock is especially prone to fracturing. In this project, researchers seek to address the question of whether borehole roughness can be measured with a simple device to indicate the anchorage capacity of a fully grouted bolt. In this regard, two new tools have been developed at NIOSH to study rock strength: a rock strain strip (ROSS) and a miniature data acquisition system (MIDAS). A ROSS is grouted into a borehole to measure strain in the roof of a mine opening. A MIDAS is used to read the strain sensors of a ROSS without the need for long cables to hook up to a computer. Research to date indicates that ROSS's are able to measure anchorage slip in fully grouted bolts.

Numerical models are being used to study failure mechanisms in weak rock. Therefore, this portion of the research project is directed to studying whether numerical models adequately simulate the fracturing mechanism. Results to date support this hypothesis, but further advances in discrete element modeling are needed to build the case. With models that simulate these observed failure mechanisms, researchers can determine if fracturing can be limited with rock supports to reduce the rock falls.

It is expected that this research will improve the performance of roof bolts in weak rock and determine ways to arrest or minimize the propagation of mining-induced fractures around an underground opening. Such improvements should increase stability around underground openings in weak rock and reduce the number of roof falls.

Ongoing Research Project related to Ground Control

Slope Stability Hazards Recognition

PURPOSE: Reduce injuries and fatalities associated with slope failures in surface mines and falls of ground in large underground openings.

RESEARCH SUMMARY: Slope stability research was focused to answer three specific questions.

Rockfall from highwall crushed operators cab on this excavator

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STRATEGIC GOAL:
Ground control

KEYWORDS:
surface mining, slope stability, hazard recognition, highwall, rock fall, backfill, rock fall, stability

- First, can new technologies be adapted to improve the recognition of mine slope hazards? One goal is to incorporate emerging technologies into tools that can provide more complete and more timely slope stability information. Emerging technologies include several remote-sensing techniques that can warn workers of hazardous rock slopes. Recorded data and images will allow study of rock falls and unstable ground. A hyperspectral imager developed at Carnegie Mellon Research Institute and an interferometric radar system developed in collaboration with Brigham Young University were tested in field trials at mine sites. Digital image analysis and real-time change detection using video technology have also been tested, demonstrating that rock displacements and falling rocks can be detected and recorded.
- Second, are there engineering solutions to reduce rockfall hazards by improving catch bench designs? Computer programs were developed in collaboration with Dr. Stan Miller, University of Idaho, to assess the effectiveness of a rock slope bench design to catch falling material. Functions and applications of the programs have been presented at professional conferences; more are planned. The software and a user´s guide will be made available in a NIOSH publication.
- Third, are there better ways to make miners aware of slope stability hazards? A training video was produced to address issues of mine slope safety. Taping was completed in 2003, and the video The Sky is Falling was released in 2004. Web-page material that will provide access to slope hazards information, published reports, and other materials will be published on the Internet.

Ongoing Research Project related to Ground Control

Stability Assessment with Seismic Monitoring

PURPOSE: Reduce hazards from rock mass instabilities in the underground mining workplace through (1) hazard mitigation studies that make use of seismic monitoring tools and (2) knowledge and technology transfer to industry.

RESEARCH SUMMARY: Rock bursts, coal bumps, and other large-scale dynamic failures represent serious ground control problems facing miners in certain industry sectors. These low-probability/high-consequence events often result in severe injuries or death and have the potential to affect an entire underground workforce. An inability to address these problems effectively can result in resource abandonment and/or mine closure and a significant economic impact on entire communities.

Installation of a remotely powered wireless seismic monitoring station

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STRATEGIC GOAL:
Ground control

KEYWORDS:
rock bursts, coal bumps, mine collapse, mining-induced seismicity, strata mechanics

Research personnel engage in joint projects with the mining industry using seismic monitoring tools to advance worker safety through several different avenues. These include (1) providing worker awareness of unusual ground response to mining, (2) forensic analyses of catastrophic failures, (3) guidance in rescue efforts, and (4) evaluation of hazard mitigation measures.

Several types of seismic monitoring systems have been developed and/or adapted for these different applications. They range from simple, low-cost, single-sensor seismic stations to sophisticated, multi-channel, wireless computer-network-based distributed data collection, processing, analysis, and display systems. Current project work involves a combination of technology transfer activities and ground control research. Project personnel are helping one western Colorado coal mine operator develop its own full-scale seismic monitoring network based on NIOSH´s wireless methods. The network will monitor seismicity in the vicinity of mine workings adjacent to an earthen dam and reservoir and will cover an area of approximately 50 square kilometers (20 sq. mi.). A temporary network will also be installed at a second Colorado coal mine in response to a request for assistance in characterizing mine-related seismic hazards at that property.

Data collected with these networks will be used to address the following research questions: (1) What are the failure mechanisms of damaging coal bumps and where do they originate? and (2) how close can mining approach a body of water and still avoid the hazards associated with dynamic rock mass failures?

Ongoing Research Project related to Surveillance and Training

Chemical Hazards in Coal Mining

PURPOSE: The purpose of this new pilot project is to evaluate the feasibility of using two existing information sources created pursuant to MSHA and US EPA regulations to update estimates of coal miners´ exposure to hazardous chemicals.

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STRATEGIC GOAL:
Surveillance and training

KEYWORDS:
mining, chemicals, exposure

RESEARCH SUMMARY: Very little information is available in the literature describing quantitative exposure assessment of chemical exposure of coal miners. No comprehensive evaluation of potential chemical exposures in the mining industry has been performed since data collection for the National Occupational Health Survey of Mining (NOHSM) was completed in 1989. The NOHSM inventory may be obsolete or incomplete due to changes in mining technology and waste management regulations that have created or changed potential exposure sources. Examples of potential exposure sources in coal mining include welding fumes, solvents, lubricants, and coal preparation chemicals. Some of these chemical agents are recognized as presenting acute and/or chronic toxicity. This lack of data is a significant data gap that impedes an adequate understanding of the occupational health risks of coal miners.

Nine mines with varying operational characteristics (surface/underground, small/large, preparation plant present) will be solicited to provide NIOSH with a copy of their hazard communication (hazcom) inventory list maintained pursuant to 30 CFR 47. A questionnaire requesting information about the mine´s waste management activities has been developed, reviewed and will be included in the solicitation. The most current EPA TRI reports will be downloaded for the same nine mines responding to the hazcom inventory solicitation.

Hazcom inventory information received from the selected mines and from the associated EPA TRI report will be compared to NOHSM chemical inventory data for the coal sector to determine if gaps exist. Information from the questionnaire on hazardous waste management practices and the EPA TRI data reports will be examined to identify any potential chemical exposures attributable to hazardous waste management activities.

Each collected data set (hazcom and TRI) will be qualitatively compared to the NOHSM chemical inventory data set and to each other to identify any change(s) in the type(s) of chemicals reported since NOHSM was completed. Successful utilization of these data sets will allow for an estimation of current chemical exposures in the mining industry. Also, any non-representation of chemicals between the two collected sets will be identified.

Ongoing Research Project related to Surveillance and Training

Chemical Hazards in Mining

PURPOSE: (1) Investigate and evaluate potential chemical hazards in mining workplaces, (2) develop control or mitigation methods for chemical hazard exposures, (3) develop new analytical methods to determine metal concentrations in mining workplaces accurately, and (4) communicate the health effects associated with chemical exposures to workers.

RESEARCH SUMMARY: Many mine workers are exposed to chemicals, dusts, mine gases, and welding fumes. Overexposure to these substances may cause significant acute or chronic health problems. Some chemicals cause acute injuries or illnesses such as dermatitis, burns, and poisonings. Others cause or contribute to chronic health problems such as heart or kidney disease or cancer. Chronic exposure to cadmium and lead are known to cause renal damage. Neurological dysfunctions can occur as a result of exposure to mercury, lead, cadmium, manganese, aluminum, and arsenic. In a study involving 1,400 welders from Alabama, 6% to 10% were found to have probable Parkinson´s disease, which was 7 to 10 times higher than would be expected in the normal population.

Fumes generated during welding

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STRATEGIC GOAL:
Surveillance and training

KEYWORDS:
chemical hazards, welding fumes, method development

Specific Aim 1: Can laboratory-based and field portable analytical methods be developed to determine metal concentrations accurately? The goal of this research is to validate laboratory-based analytical methods and develop field-portable methods that will provide near-real-time analyses for assessing workplace exposure levels to metals. Work was conducted to evaluate a method to differentiate between the quantities of water-soluble silver compounds and total silver collected on filters. Development of a method to measure manganese in the field using workplace air filter samples will be initiated this year.

Specific Aim 2: What is the quantity and nature of fume emissions generated from welding rods commonly used in mining? According to Bureau of Labor Statistics data (2002), an estimated 20% of all miners (24,655 miners) are exposed to potentially hazardous welding fumes. This work will involve (1) identification of welding rods and welding systems most commonly used in mining, (2) determination of welding fume formation rate, and (3) determination of the size and shape of fume particles as well as elemental composition of the fume.

Specific Aim 3: Can tools be developed to raise awareness of chemical hazards in the workplace? The HazCom Helper-MSHA version was released in 2003. Recognizing that at least 15% of customer requests were from nonmining companies regulated by OSHA, project researchers developed an OSHA version of the HazCom Helper. The HazCom Helper is a compliance tool (a CD) that enables companies with limited resources to meet the MSHA and OSHA requirements for the submission of written plans concerning hazardous products at their worksites.

Ongoing Research Project related to Surveillance and Training

Disseminating Safety and Health Interventions Via the Internet

PURPOSE: Develop methods for indexing content on the NIOSH Mining Safety and Health web site to improve customer access to that information.

RESEARCH SUMMARY: Documenting tax funded research is critical to our mission. The Internet is the most efficient and desired means for disseminating public information, but studies show that most federal web sites don´t disseminate information effectively. The NIOSH mining web site is no exception. The site currently consists of very broad topic pages which can contain hundreds of documents. Better indexing methods are needed to help our customers find information.

This project will use knowledge management techniques to index NIOSH mining web content. The ANSI/NISO/ISO Dublin Core standard will be used to track metadata for each web resource. A faceted thesaurus (adhering to ANSI/NISO Z39.19-2003) of standardized mining safety and health keywords will be developed. These keywords will be used to index web content.

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STRATEGIC GOAL:
Surveillance and training

KEYWORDS:
mining, safety, health, knowledge management, Internet

In the short term, this work will improve customer access to our web-based safety and health information. We´ll be able to guide customers through interrelated web content in an organized manner, as well as improve accuracy of free text searches. Cataloging our web resources will also improve web site maintenance. We´ll be able to track what type of content we have or don´t have, who is responsible for maintenance, date of last review, etc. We´ll also be able to identify more precisely the type of information that is most requested by our customers.

At the same time, this work is being designed for compatibility with emerging web technologies and activities of the World Wide Web Consortium (W3C). These new technologies are being developed to support a future "Semantic Web" which, if realized, will improve web resource discovery worldwide.

The result will be a new mining web that provides easier access to and dissemination of NIOSH´s mining health and safety research knowledge database.

Ongoing Research Project related to Surveillance and Training

Education and Training for an Evolving Mining Work Force

PURPOSE: To assess safety and health training needs for a demographically changing mining workforce and develop appropriate related interventions.

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STRATEGIC GOAL:
Surveillance and training

KEYWORDS:
mining, training, effectiveness research

RESEARCH SUMMARY: NIOSH stakeholders stated they anticipate a change in the mining workforce in the United States within the next decade. An entire cohort of miners in the current workforce is aging and replacing them will require an influx of new miners. This phenomenon presents an opportunity to study a workforce on the cusp of change and to discover the training and communication needs of two different but interrelated demographic groups.

Specific project tasks are to (1) conduct a demographic assessment of the frequency and types of injuries of the various age groups of miners, then tailor health and safety messages to any significant differences that may exist between age groups, (2) create and assess procedures to ensure the provision of consistent health and safety messages to miners during workforce transitions, (3) develop a protocol for capturing and transferring the knowledge of experienced miners to new hires, and (4) assess age and experience related differences in acceptance of training technologies, and explore ways these differences (if any) can be positive factors for the delivery of coherent programs.

As of February 2005 this project has resulted in the publication of 15 documents and 33 presentations addressing the four project tasks listed above. (1) Data confirmed that the mining industry is in a time of changing demographics and injury experience is different for miners in different age categories. (2) A process for job procedure documentation was developed to lessen variability during knowledge transfer. (3) An on-the-job training program was created to improve passing information from experienced miners to new employees. (4) Learning preference differences between older and younger employees is reported in the literature, but an across the board preference for active learning (hands-on practice, simulation, etc.) was found at mine sites. Two seminars were also developed to provide professional development opportunities for safety and health training professionals and on-the-job trainers. Both translated adult education theory into practical strategies that can be used to train miners of any age. A computer-based training intervention for training new miners in map reading skills is under development. These project outputs will result in a better trained and therefore safer mining workforce.

Team members from the Pittsburgh and Spokane Research Laboratories have worked with partners from Twentymile Coal Company, Pennsylvania Services Corporation, J.H. Fletcher and Company, Morton Salt, Rurher´s Quarry, the State of Pennsylvania Department of Environmental Protection, and the Mine Safety and Health Administration to conduct the work of this project.

Ongoing Research Project related to Surveillance and Training

Evaluation of Heat Stress and Interventions in Surface and Underground Mines

PURPOSE: Determine if a relationship exists between overexposure to heat during mining and other related activities and increased risk of injury.

RESEARCH SUMMARY: Previous research by MSHA in 1976 and 1986 identified mine work environments as presenting a significant potential for exposures to heat in excess of the NIOSH criteria document for this stressor. The use of diesel equipment in these underground environments has increased since those studies were conducted with a concomitant increase in heat exposure.

Mine operators recognize high heat as an impediment to performance. Heat strain can result in diminished strength, judgment, skills, and safety awareness, which could be manifested as increased incident rates in work areas. A double fatality due to heat stroke occurred in Nevada in 2002 and resulted in increased interest in evaluation and prevention research.

The questions addressed in this project are (1) what are the heat stressors and the resulting strain among underground and surface miners? (2) are interventions currently available to reduce thermal stressors in hot mining environments effective? and (3) can a means be developed to monitor the physiologic status of at-risk miners in real time.

Members of a mine rescue team wearing masks and other gear that can lead to an increased heat burden

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STRATEGIC GOAL:
Surveillance and training

KEYWORDS:
heat stress, emergency response, mining, heat illness, intervention effectiveness, ergonomics, exposure assessment, prevention

To address these questions, the approach taken was to (1) identify and quantify the sources of heat in mine work environments, (2) measure the temperature response of workers to hot environments, (3) evaluate the most promising interventions to reduce the effect on the miners, and (4) transfer research results and technologies to the mining industry.

The investigative approach focuses on measuring exposure levels concurrent with monitoring miners' responses to their environment in terms of heart rate and core body temperature. Effectiveness of interventions will be evaluated by comparing the core temperature response of a miner to conditions with and without interventions. In addition to production workers, research will examine the heat load of emergency responders who are exposed to hot environments while wearing breathing apparatuses.

Ongoing Research Project related to Surveillance and Training

Hazard Evaluation and Technical Assistance

PURPOSE: Provide flexibility in technical assistance within a framework that allows researchers to identify latent or emerging hazards.

RESEARCH SUMMARY: A mechanism is needed to permit topic experts to conduct evaluations and provide technical assistance in response to stakeholder concerns that arise from an immediate hazardous or unhealthy situation. Recent examples of technical assistance include (1) collaboration with a Pittsburgh Research Laboratory project in which noise controls presently available in Western metal/nonmetal mines were reviewed, (2) an evaluation of the possible causes of a high incidence of dermatitis in miners in an underground gold mine operation, (3) an assessment of the proposed respiratory protection program for workers during the next phase of construction of the Yucca Mountain Nuclear Repository, and (4) an evaluation of the health risks associated with naturally occurring hydrocarbon seeps in a Western underground coal mine.

NIOSH investigator measures sound intensity levels at a talc mill

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STRATEGIC GOAL:
Surveillance and training

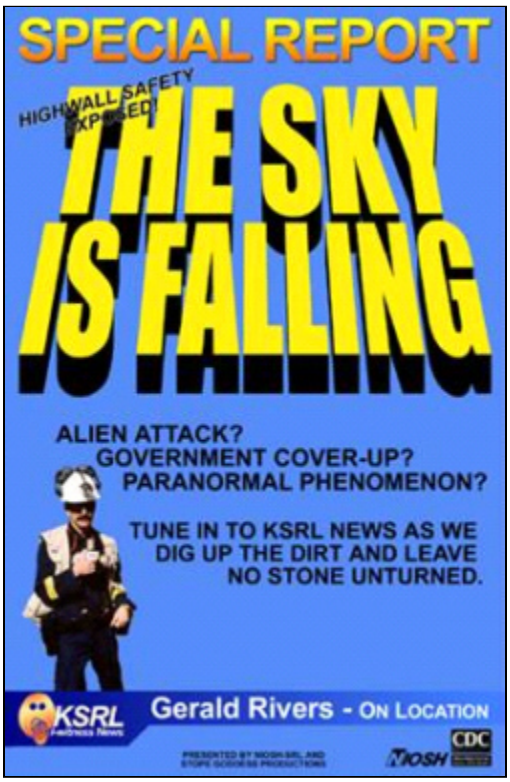
KEYWORDS:
mining, engineering controls, intervention, hazard assessment, technical assistance

Currently, research is based on long-term strategic planning and successful completion of intermediate goals. In this project, personnel will take advantage of geographic location, topic expertise, and stakeholder awareness. The project will provide flexibility to respond to requests from the mining workforce, other government agencies such as the Mine Safety and Health Administration (MSHA) and the Occupational Safety and Health Administration (OSHA), and NIOSH researchers who identify issues of concern based on health and safety statistics or other information. Results will include the development of new project ideas and identification of areas of needed research, as well as formulation of partnerships to implement and evaluate intervention strategies.

Ongoing Research Project related to Surveillance and Training

Health Communications Program

PURPOSE: Provide health communications services and guidance to SRL and PRL researchers to facilitate the continuous exchange of information and to translate research results to the widest range of customers.



RESEARCH SUMMARY: Developing a technical solution to an occupational safety and health problem will not, in itself, result in reduced injury and illness in the workplace. Instead, it is the adoption of the new device, information, or process that can have an impact. Adoption of such items requires that individuals, somewhere in the industry, change the way that they do their jobs. As such, NIOSH mining research products and information must be adopted by industry and individuals if the research is to make a difference in worker safety and health. Causing industry to adopt safer and healthier work methods is complicated by the products and by the audience. Research to improve worker safety and health is broad-based by its nature, spanning all segments of industry and the population. Research findings that can reduce injury and illness in the workplace also take many forms including new machines, processes, and knowledge. In addition, each product, target population, and application presents different barriers to adoption, requiring tailored approaches to cause change in the target population and adoption of the research results. While many researchers have earned respect among peers for their work, it can be difficult for them to fully translate research results into products or messages that are understandable or useful to a wide range of customer groups. The Health Communications teams at SRL and PRL assist in the effective transfer of research results to diverse segments of the mining and scientific communities so that they are useful to and used in the workplace.

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STRATEGIC GOALS:
Cumulative injuries; Ground control; Hearing loss; Mine disasters; Respiratory diseases; Surveillance and training; Traumatic injuries

KEYWORDS:
health communication, marketing, technology transfer, r2p, public information, outreach

The Health Communications program is made up of three components: research-to-practice education and implementation, public outreach and technology transfer, and social research that includes such issues as effective training methods, adult learning theories, evaluation of qualitative data, and the effect of socio-economic issues on mining operations. The overarching goal of this program is to facilitate the adoption of new research findings and products developed at SRL and PRL.

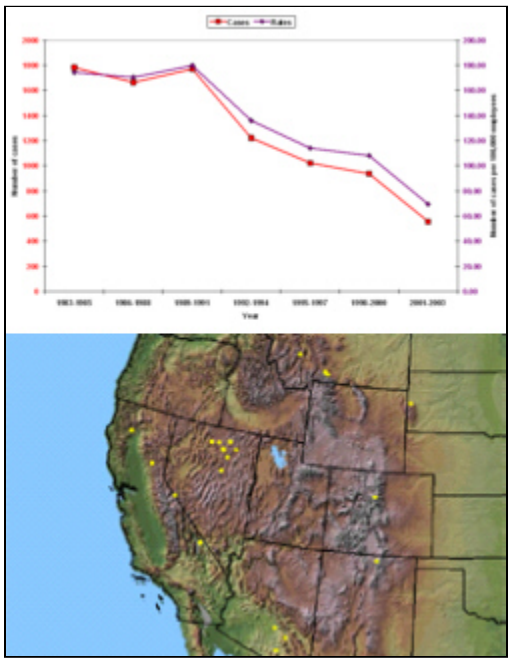
Ongoing Research Project related to Surveillance and Training

Surveillance of Mine Safety Hazards

PURPOSE: Provide surveillance services, data management, and outcome evaluation guidance to SRL researchers to help ensure that research decisions and directions are evidence-based and in agreement with NIOSH goals and stakeholder priorities. Examples include the development and demonstration of geographical information system (GIS) methodologies for spatially mapping and analyzing accident and occupational disease information.

RESEARCH SUMMARY: Surveillance as a public health component has a long and distinguished history. CDC and NIOSH have recognized the importance of surveillance in overall program design and in weighing the evidence to ensure that priorities are meaningful. The Surveillance program at SRL is intended to assist in the identification of problems and hazards in the mining and construction industries, and to assist in evaluating the impacts and outcomes of the research programs. The SRL Surveillance team collaborated with Institute-wide surveillance workers to produce a strategic plan for NIOSH surveillance.

Analysis of severe mining injuries (fatal or permanently disabling) shows that over the period from 1983 through 2003, substantial declines have occurred in both the number of cases and the incidence rates. Additional analyses are underway to further detail these declines. In particular, the aging of the mining population may be a major factor in that experienced miners have reduced risk of injury. The patterns shown below will be age- and experience-adjusted to better delineate these influences. A survey of the demographics of miners is being conducted which will aid such analyses greatly.



Top - 3-fold reductions in incidence of fatal and permanently disabling injuries have been reported over the 21-year period shown; Bottom - Spatial attributes of western underground metal mine locations with injuries suggest remoteness from urban centers

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STRATEGIC GOAL:
Surveillance and training

KEYWORDS:
surveillance, reported case data, injury and illness burden, data management, risk assessment, risk management, statistical and epidemiological data analysis, geographic information systems.

A key component of SRL´s approach is the use of geographic information systems (GIS) and methods to enhance the utility of mining injury and illness data. The spatial distribution of mining injury and illness events enters the surveillance outlook in many ways, including:

- The use of maps to identify locations for candidate mining research projects
- Associating geologic factors with potential mining fall-of-ground exposures

- Identifying states, districts and regions with clusters of injuries of specific type
- Identifying hospital cachement areas vs mine locations to facilitate rescue efforts and limiting the consequences of severe injuries

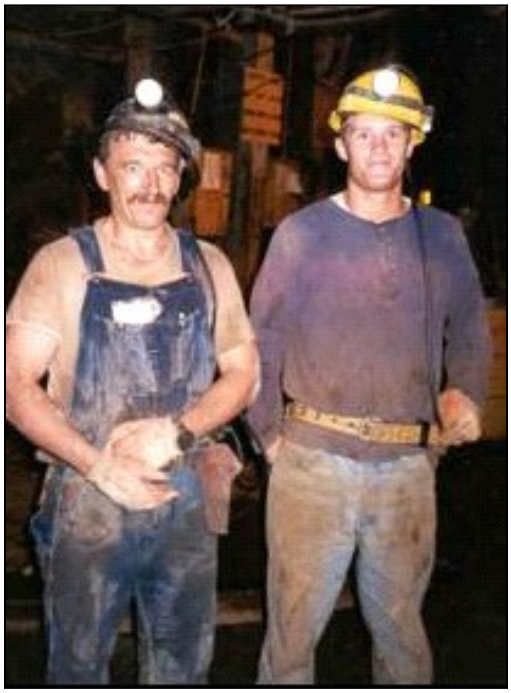
The map shown suggests that mine disasters may have consequences that are exacerbated because of the remote locations and lack of access to emergency response, rescue efforts and treatment centers.

Ongoing Research Project related to Surveillance and Training

Surveillance: National Survey of the Mining Population

PURPOSE: To improve the National Institute for Occupational Safety and Health´s (NIOSH) surveillance capability related to the occupational risks in mining by conducting a national survey of mines and mine employees.

RESEARCH SUMMARY: Due to the lack of up-to-date, appropriate, and accurate information for mine employees, NIOSH is undertaking a national survey that will provide demographic and occupational information for the mining population. The last survey of mine operator employees, the Mining Industry Population Survey (MIPS), was conducted by the U.S. Bureau of Mines in 1986. The mining industry has experienced many changes since the MIPS was conducted, thus this information is now too outdated to be considered useful for surveillance on the current mining workforce. Other available national surveys such as the Current Population Survey (CPS) and the Census 2000 are not very useful for mining industry surveillance because they do not differentiate between underground and surface workers or between direct employees and contractor personnel. Additionally, CPS and Mine Safety and Health Administration (MSHA) industry and occupational coding systems differ which leads to incompatibility for specific commodities, work locations, and work activities.



Miners from the Galena Silver Mine, Idaho

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STRATEGIC GOAL:
Surveillance and training

KEYWORDS:
surveillance, mining, databases

The National Survey of the Mining Population will be a survey of mines and their employees for each of the five major mining sectors (coal, metal, nonmetal, stone, and sand and gravel). The major objectives of the survey will be to: (1) collect some basic information about mining operations; (2) establish the demographic and occupational characteristics of mine operator employees within each mining sector; and (3) determine the number and occupational characteristics of independent contractor employees within mines.

The most important goal of this study will be to obtain denominator data so that the MSHA Accident, Injury, and Illness Report (MSHA Form 7000-1) can be evaluated in relation to the population at risk. Currently, MSHA collects data on the work location where the incident occurred, and the demographics of the injured or ill miner. Demographic and occupational data on the overall mining workforce are not collected. As a consequence, the accident data cannot

be fully exploited to study the employee-level correlates of mining accidents. The National Survey of the Mining Population will collect employee-level data that can be used to create the denominator data needed to construct accident rates for various demographic groups that reflect the population at risk.

Ongoing Research Project related to Surveillance and Training

Workplace Stress Among Underground Coal Miners

PURPOSE: Reduce health problems for miners resulting from workplace stress by examining the relationship between workplace stress in the underground coal mining industry and the salivary cortisol response to awakening (SCRA).

Worker installing a roof bolt at an underground coal mine

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STRATEGIC GOAL:
Surveillance and training

KEYWORDS:
stress, underground mining, biomarkers

RESEARCH SUMMARY: Workplace stress has been linked to increased risks for cardiovascular disease, depression, and musculoskeletal disorders. The mechanisms by which stress affects health are not established, but research suggests that they may involve maladaptive changes in the hypothalamic-pituitary-adrenal (HPA) axis, the physiological system responsible for regulating the stress response.

This study will evaluate one measure of HPA axis function, the salivary cortisol response to awakening (SCRA), for use as a potential biomarker for workplace stressors in underground coal mine workers. The SCRA will be assessed by measuring cortisol levels in a series of saliva samples obtained by subjects during the first hour after they wake in the morning. The SCRA is reported to be a reliable marker of the function of the HPA axis. Although the SCRA has been used in studies of workplace stressors, research to date has been limited by 1) small sample sizes; 2) measurement error due to subjects´ failure to obtain samples at the specific times required in the protocol; 3) measurement error due to the use of immunoassays with insufficient specificity for cortisol; and 4) inadequate assessment or control of confounding factors, including light exposure, time of awakening, duration of sleep, body mass index (BMI), and alcohol intake. This project will collect measurements of the SCRA using a much larger group of subjects (target of 400) than previous research. A sample of subjects will be monitored for compliance with the saliva sampling protocol, using an electronic monitoring device that was developed for monitoring compliance with taking medications. Human Subjects Review Board and Office of Management and Budget approval for the project has been received. It is anticipated that annual safety refresher training classes for miners will be attended by NIOSH personnel to solicit participation from miners. One such trip has been completed and an initial set of samples collected.

Successful project completion will result in: the development of a biomarker for chronic workplace stress, which can be used to screen workers under chronic stress and identify those at high risk of developing adverse health outcomes, and the development of a training module on workplace stress which can be used by mine trainers to teach miners about the effects of stress and what they can do to reduce stress.

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2.5 External Factors

External factors affect the type of research conducted, the way it is conducted, and the extent to which it will improve mining safety and health, as illustrated in Section 2.2. These factors and examples of their impact on the NIOSH mining program are presented in this section.

The priorities of the NIOSH mining program are derived from surveillance data, stakeholder input, and loss control considerations. There are other external factors which can require major changes in the direction of the research program. In general these factors are beyond the control of NIOSH, and in many cases are very difficult to predict. Some of these factors include:

- Political shifts
- Legislation
- New or modified regulations
- Global economic conditions and commodity prices
- Technology changes
- Major mining disasters

These external factors are not independent, and changes in one are often likely to affect other factors. For example, changes in economic conditions can affect mining employment and production, and also lead to political change.

The major political change affecting the direction of research is usually a change of the political party in control of the executive and/or congressional branches of the federal government. Political swings can affect the size of the NIOSH mining research budget. The relative emphasis on regulatory enforcement versus technical assistance with compliance has a very great effect on MSHA, and can also affect NIOSH mining research priorities. The relative needs for research on control technology versus surveillance research are somewhat dependent on the political and regulatory climate. The relative proportion of basic and applied research can also be affected by the political ideology of the administration in control of the federal government. For example, during the Reagan administration many applied research projects were terminated or not initiated at the direction of the President´s Science Advisor, who stated that federal agencies outside the Defense Department should do only basic research. Administration policy was that applied research, including mining safety and health, should be left for the private sector.

Major mining legislation such as the mining safety acts of 1969 and 1977 has caused major impact on mining research. Both of these laws authorized immediate, large increases in the funding for federal mining health and safety research. Other possible future legislation that could affect mining could be environmental (e.g. global warming) or significant changes in the 1872 federal mining law. Any legislation having impact on the economic conditions of mining could also eventually affect the direction of mining research.

Regulatory proposals and changes by MSHA can have very direct effect on research priorities. The regulatory changes usually result in part from advances in technology, some of which may have resulted from NIOSH research. The regulatory changes in turn can create needs for new research. For example, changes in the regulations for noise and diesel particulate in recent years have had major effects on the direction of NIOSH mining research in these areas. Stricter regulations have increased the priority of research on control technology needed to enable compliance with the noise and diesel particulate regulations. As a result, NIOSH has greatly increased the staffing and discretionary funding assigned to these research areas since the new regulations were first proposed.

The economic conditions of the mining industry depend primarily on supply and demand for the product as well as the cost of producing the product. Supply and demand depend on national and world economic conditions. Metals are traded world-wide and prices of metals determine whether metal mining can be done profitably in the U.S. Mines limit or expand production and employment based on swings in the commodity prices. The price of coal and the economic health of the coal industry is affected by the supply of competing energy sources, especially natural gas. Any major change in the regulation and acceptance of nuclear energy for electricity generation could have long-term implications for the demand for U.S. coal production. Production costs can be affected by regulatory and technology changes, among other factors. The economic strength of the industry affects mining employment and the ability of the industry to employ more costly health and safety control technologies.

Long-term research planning is generally based on the assumption of stable funding for the program. Unexpected demands on the federal budget put pressure on other existing federal programs, including NIOSH research. These budget pressures can be caused by any weakness of the U.S. economy and resulting declines in federal revenues. Increased spending due to war or major disasters may increase budget deficits and the need for reductions in existing programs. Sometimes the Congress reacts to budget deficits by general across-the-board cuts in most federal programs. This has the effect of eroding the discretionary funds available for research.

Some of the most significant changes in mining in the past few decades include the shift from underground to surface coal mining and toward longwall mining of underground coal, the increase in underground stone operations, and the increase in independent contractors. These shifts in mining methods have resulted in large increases in production and decreases in mining employment, while the shifts to underground stone introduced new safety and health challenges for workers in that sector. The shift to independent contractors as well as other demographic changes has created new demands on training and other interventions. Other new technologies developed outside of mining find application in the industry. Sometimes these new technologies may be used to help control existing health and safety hazards, but they also may create new hazards. Developments in electronics and computer technology have been incorporated in mining, affecting both productivity and the nature of some of the mining hazards, as well as technology for controlling hazards.

Major mining disasters such as the Farmington coal mine explosion in 1968 and the Sunshine Mine fire in 1972 led to the Federal Coal Mine Health and Safety Act of 1969 and the Federal Mine Safety and Health Amendments Act of 1977. Major mine disasters are fortunately much less prevalent than in past decades, but if they do occur, they could lead to shifts in research priorities depending on the nature and cause of the disasters. The most recent example of this is the mine explosion at the Jim Walter mine in 2001, which focused attention on a wide range of emerging technical deficits that could be addressed through NIOSH research. This had a significant impact on the direction of disaster prevention research within the NIOSH mining program.

The ability to conduct effective mining safety and health research depends heavily on gaining access to mine sites and having the full cooperation of the mine operator. In many cases the in-mine research can be burdensome on the operators, despite the best efforts of the researchers, due to interference with normal maintenance, supply, or production operations, and it sometimes requires significant contributions of time and materials. Accordingly, most projects require a significant commitment from the operators. Routinely, many operators are proactive and make such a commitment to NIOSH mining research. Proposed or recently enacted legislation often serves to increase the interest in cooperating on NIOSH projects. In the end, the involvement of labor, industry, and manufacturers is generally necessary to execute the research program.

Translation of the research findings into practice is influenced by many of the external factors described previously. The value of the findings to solve real-world problems, as viewed by labor, industry, and other stakeholders, must be high enough to capture their interest. If the findings fill knowledge or technology gaps related to compliance with new regulations, then stakeholder participation tends to be very high. Economic conditions within the industry affect the number of new initiatives that NIOSH can launch in partnership with the industry and manufacturers, and they affect the degree of participation by the stakeholders. The degree to which MSHA utilizes NIOSH findings in developing regulations or in recommending compliance assistance initiatives affects the translation of NIOSH research products.

Although external factors are outside of the control of NIOSH, we have taken steps to minimize their impact on our ability to serve our customers and stakeholders. These include:

- Developing research program priorities to ensure that highest priority work is continued during periods of decreasing budgets;
- Working in partnership with customers/stakeholders from project conception to translation to ensure the relevance and quality of the work, to improve resource utilization, and to facilitate translation of the findings into practice;
- Maintaining flexible project planning processes to accommodate changing economic conditions and interests to ensure that opportunities are not missed and work is not continued if critical manufacturer or industry support is required;
- Working with MSHA to plan high-priority efforts that will provide timely input into its regulatory processes and collaborating with the agency on technology transfer efforts that will expedite the introduction and adoption of NIOSH products;
- Emphasizing quality and timely "customer service" to earn the trust and support of the mining program´s customers and stakeholders, and serving as the "honest broker" in the execution of our mission to minimize the effects of political shifts on the program.

Over the past five years, the most influential external factors were the budget swings and the changes in mining regulations. The decline in discretionary funding limited our ability to respond to customer needs across all aspects of industry, although the highest priority areas were well served. Changes in regulations served to focus attention on important areas, and resulted in significant shifts in our research program. As a consequence of this, significant advances have been accomplished in a timely manner. The least influential factor was political shifts. In total, the external factors have resulted in a net positive effect on the Mining Program.

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2.6 Partnerships

Partnerships are integral to the NIOSH Mining Program. They facilitate advances in the safety and health of U.S. mine workers. Input from customers and stakeholder groups, which have inherent knowledge and concern about the health and safety of miners, helps in setting research priorities. Collaborative research with our partners provides in-kind contributions, such as equipment and test mine sites, to extend our research dollars in conducting research. The partners often add expertise or specialized experience to the research team, which is beneficial to the research experiments and analysis and interpretation of the results. This added expertise enhances the research program and also allows for more rapid transfer of knowledge and products to the mining industry. Some of the partners that provide input are:

Labor:

- United Mine Workers of America (UMWA)
- United Steelworkers of America (USWA)
- International Union of Operating Engineers (IUOE)

Industry:

- Bituminous Coal Operators´ Association (BCOA)
- National Mining Association (NMA)
- National Stone, Sand and Gravel Association (NSSGA)
- Industrial Minerals Association-North America (IMA-NA)
- Northwest Mining Association (NWMA)

In addition, a number of state organizations, universities, manufacturers, and government agencies participate in research partnerships and provide important input to our research priorities.

Our partnerships can be grouped into three categories. Some examples of these partnerships are presented below in each category.

1. Partnerships with important customers and stakeholders to identify research needs and transfer research findings.

Noise Partnership - Noise-induced hearing loss (NIHL) moved to the forefront of health-related issues within the mining industry in the late 1990s. This culminated with the passage of a new noise rule in 1999 (30 CFR 62) that was enforced by the Mine Safety and Health Administration (MSHA) starting in 2000. Because of the new rule, a Noise Partnership was formed by NIOSH. The partnership included the UMWA, BCOA, NMA, MSHA, and several mining equipment manufacturers and suppliers. The partnership is providing opportunities for collaborative research with stakeholders (mine operators, labor officials, equipment manufacturers, regulatory officials, etc.) related to the Hearing Loss Prevention Program at NIOSH´s Pittsburgh Research Laboratory (PRL). The goal of the program is to reduce noise exposures to the nation´s miners through research efforts associated with worker noise exposure and related sources, noise control technologies, worker empowerment and education, and improved hearing protection devices. The partnership is expediting progress toward achieving the goals of the program.

Diesel Partnerships - In January 2001, MSHA promulgated two rules regulating the exposure of underground coal miners (30 CFR 72) and metal/nonmetal miners (30 CFR 57) to diesel particulate matter (DPM). Labor and industry were concerned with the ability of current control technologies to reduce DPM concentrations in mine air below those mandated by these regulations.

In early 2000, in anticipation of the proposed rulemaking, the UMWA, BCOA, NMA, and NIOSH formed the Coal Diesel Partnership. Although not an official member of the partnership, MSHA worked closely with the partnership to advance the state of technology through both lab and in-mine testing of control technologies. NIOSH´s role was to provide the partners with a scientifically sound evaluation of diesel emission control technologies in underground coal mines.

All parties involved in the partnership bring something of value to the effort. Industry, through the BCOA and NMA, has made mines available to NIOSH for testing control technologies. This has often required investing time, money, and effort into preparing controlled test sites ventilated with fresh air. Industry has also independently conducted testing of various available control technologies and provided test findings to the partnership. In addition, industry has purchased a number of control technologies for testing done under the partnership. The UMWA has worked closely with NIOSH in locating acceptable mine test sites and obtaining cooperation from miners in conducting the in-mine testing. Knowledgeable diesel experts from both labor and industry have worked with NIOSH to put together test protocols, locate potential control technologies, and review and analyze test results. MSHA has assisted in underground testing and conducted tests of control technologies at its Approval and Certification Center in Triadelphia, WV.

All parties in the Coal Diesel Partnership have benefited by reducing individual costs, avoiding duplication of effort, and being able to evaluate a relatively large number of diesel control technologies in a short period of time. In the effort to disseminate emission control information to the industry, the partnership sponsored an open industry workshop on the state of the art of diesel emission control technologies in coal mines. The partnership efforts continue with preparations for evaluating various control technologies at NIOSH´s Lake Lynn Experimental Mine. A committee was recently appointed to work with engine, vehicle, and aftertreatment manufacturers in overcoming barriers to the introduction of clean engine technology into coal mines.

In early 2002, the success of the Coal Diesel Partnership prompted the formation of a Metal/Nonmetal Diesel Partnership. The goal was to address various issues related to implementing diesel control technologies in metal/nonmetal mines. Members of this partnership are the USWA, NMA, NSSGA, the MARG Diesel Coalition, IMA-NA, and NIOSH. Although not officially a member of the partnership, MSHA has actively participated in all partnership activities. The Metal/Nonmetal Diesel Partnership, similar to its coal counterpart, has proved that this kind of partnership is efficient in addressing complex health and safety issues. Work has been accomplished that benefits all involved parties while sharing costs and avoiding duplication of efforts. Industry and labor have worked closely with NIOSH in locating mine test sites, reviewing test protocols and test results, conducting underground testing of control technologies, and sponsoring two diesel emission control technology workshops. One accomplishment was a series of studies in an operating metal/nonmetal mine to evaluate several control technologies. Additional studies are planned in the near future. Work under the partnership resulted in findings that helped MSHA decide to use elemental carbon rather than total carbon as the surrogate for total DPM.

Comprehensive information on selecting and implementing diesel particulate filter systems has been supplied to the industry through a Web-based diesel filter selection guide available from both the NIOSH and MSHA websites. NIOSH is hosting a diesel list server that allows free exchange of information on diesel emissions and controls.

Both the Coal and the Metal/Nonmetal Diesel Partnerships demonstrate how labor, industry, and government can benefit from working together toward a common goal - reducing the exposure of underground miners to diesel engine emissions.

2. Partnerships with manufacturers and mining companies to conduct research and develop products.

Personal Dust Monitor Partnership - The NIOSH Pittsburgh Research Laboratory, in partnership with the UMWA, BCOA, and NMA, has been working to develop a personal dust monitor (PDM) that will provide real-time dust exposure data to miners. This partnership has also had assistance from MSHA. The actual development was done through a research contract with Rupprecht & Patashnick Co., Inc. (now Thermo Electron Corp.), whose commitment to this effort has been important to its success. The concept was to develop a person-wearable dust monitor that provides both real-time and end-of-shift dust exposure data, empowering both miners and management to take action to prevent overexposures to respirable dust.

The evolution of this new dust monitoring technology is a product of this partnership effort. From the start of the partnership in early 1999, there was agreement among all partnership members as to the conceptual design of the PDM and its intended fundamental capabilities. There has also been a commitment on the part of all partnership members to work toward the development of a technology that will make a difference in improving the health of U.S. coal miners. Each member of the partnership has contributed to advancing the development of the PDM to its current status. The BCOA and NMA have made mines available to NIOSH for testing of prototype PDM units. The UMWA has provided the support of its mining membership by cooperating in the conduct of underground testing and providing miner feedback on daily use of the PDM units. NIOSH has committed financial and personnel efforts to the design, development, and testing of the PDM concept. MSHA has provided assistance in facilitating intrinsic safety testing and approval and has participated in underground testing. All partners in this effort have taken an active role in the review of lab and in-mine test protocols, review of PDM performance results, and numerous meetings to discuss design improvements to the PDM to make it more mine-worthy and user-friendly. The rapid advance in PDM technology exemplifies how labor, industry, and government can work together in partnership to improve safety and health in the mining industry.

Bridger Coal Co. Partnership - Work-related musculoskeletal disorders (MSDs) have long been identified as a problem within the mining industry. These disorders result from exposure to MSD risk factors. Studies have shown that at least 35% of mine workers were potentially exposed to overload conditions affecting the neck, back, forearms, arms, shoulders, fingers, and hands.

A recently completed NIOSH project involved partnering with Bridger Coal Co. to implement an ongoing, effective process to reduce exposure to work-related MSD risk factors at the Jim Bridger surface coal mine in Wyoming. NIOSH´s role was to guide and direct Bridger in customizing and implementing a sound ergonomics process that the company can build upon

and continue to benefit from for years to come. The main objective was to develop an ergonomics process that emphasized employee participation. First, a company ergonomics committee was established. NIOSH then gave awareness training to all Bridger Coal employees that focused on recognizing MSD risk factors and how to take action by reporting risk factors to the ergonomics committee. During the first 3 years of using the process, the committee implemented more than 20 job improvements. Instead of waiting for an injury or illness to occur before making changes, Bridger Coal now relies on this employee-based participative process to implement interventions that promote the well-being and safety of its employees. In addition to responding to employee reports of risk factors, the committee is also applying its ergonomics knowledge and awareness to other processes, such as purchasing equipment, implementing new procedures, and developing new training. Work under this partnership has shown that establishing a comprehensive ergonomics process is the best way to reduce injury and the cost of injury, as well as to improve work performance.

Proximity Warning Technology Collaboration - In addition to the more structured partnerships, the mining program has dozens of research and development collaborations involving various combinations of mining companies, equipment manufacturers, labor organizations, universities, and other state and federal agencies.

An example of research involving a number of collaborators is the study of proximity warning systems to reduce serious injuries and fatalities that can be attributed to the lack of visibility around large off-highway mining equipment. These accidents account for 12% of all surface mine fatalities. In 1998, MSHA proposed rules requiring some type of sensor-based collision warning system and cameras to monitor blind areas around mining equipment. At that time, no sensor-based technology had been thoroughly tested on large, off-highway mining equipment, and cameras had been applied only to a limited extent. NIOSH proposed that a test program be initiated for off-the-shelf collision warning systems to see how they performed on mining equipment prior to the finalization of any rules.

Since then, NIOSH has provided regular updates to MSHA regarding available proximity warning systems and their effectiveness in the surface mining environment. NIOSH has also provided information for MSHA training materials and an MSHA web page describing available systems. In August of 2005, NIOSH partnered with MSHA in organizing an open industry briefing on proximity warning systems that was attended by 120 mining professionals representing industry, equipment manufacturers, sensor manufacturers, and other research organizations. NIOSH and MSHA have successfully worked together to understand the applications and limitations of proximity warning systems on mining equipment, providing a rational background for regulatory action.

Another collaborator in this work is Phelps Dodge, Inc., which has provided access to equipment and facilities for the past 5 years at its Morenci, AZ, copper mine. Various proximity warning technologies have been tested for months at a time at this location, providing necessary information on the limitations and strengths of the systems. Feedback from truck drivers, alarm data, and video footage from the cameras mounted on the trucks has provided measures for effectiveness. The company has used NIOSH test results to make decisions regarding which technologies will be implemented on its fleet of trucks at all mining properties.

Collaborative work with the Colorado School of Mines has provided the means to study high-tech innovative solutions to proximity warning. Its work in underground load-haul-dump automation led to the development of a computer-assisted stereovision system that could detect the location and shape of a muck pile. The system could also distinguish between workers and other objects in the environment. NIOSH proposed that this system be tested for use in proximity warning for surface mining equipment, and a prototype system was built and tested in a quarry. These proof-of-concept tests showed potential for providing a system that could detect obstacles and provide a view of blind areas using only cameras. A startup company was formed by the university researchers and is further developing this and related technologies.

NIOSH also worked with Trimble, Inc., to develop a proximity warning system based on the global positioning system (GPS). Surface mines already use GPS to track and dispatch mobile equipment. NIOSH researchers proposed adding a safety function to existing dispatch systems that would allow each truck driver to know the location of nearby obstacles, equipment, and passenger vehicles. By working with Trimble, the cost to develop the system was minimal because all the components and functionality were already implemented in its mining dispatch system. A prototype system was successfully tested on a dump truck, a dozer, and two light vehicles at Phelps Dodge Morenci, Inc.

Preco Electronics, Inc., worked with NIOSH to test its radar-based proximity warning system at a surface mine. Test results showed that the original radar system needed to be modified to provide an adequate detection area around large trucks. NIOSH worked with Preco to define the detection characteristics needed, and the company is now marketing a heavy-duty system that uses multiple antennas to detect obstacles at the front and rear of large trucks and other equipment. NIOSH tests also resulted in recommendations that passive sensor technologies should be used in combination with camera systems so the source of all warning alarms could be verified by the driver. Preco is now marketing a combined radar and camera system.

NIOSH researchers were asked to demonstrate their test procedures for a committee of the International Standards Organization that was developing ISO standard 16001 - "Earth-Moving Machinery - Hazard Detection and Visual Aids - Performance Requirements and Tests." The NIOSH procedures were used to define tests for determining the detection characteristics of radar and radio transponder-based systems. NIOSH researchers are participating on the ISO committee to further develop this and other safety-related standards for heavy equipment.

3. Partnerships with organizations to exchange safety and health information and technology and to conduct research in areas of mutual benefit.

Global Mining Research Alliance - The global mining industry presents some of the most complex and demanding scientific, engineering, and technical challenges in the world today as it attempts to meet resource needs in a cost-effective and environmentally sustainable manner while improving the safety and health of its workers. To help meet these challenges, several mining research organizations throughout the world have joined together to form the Global Mining Research Alliance (GMRA). This collaboration aims to become the supplier of choice for mining research solutions and knowledge in the international mining and resources industry. The partners forming the alliance are:

- Canada Centre for Mineral and Energy Technology, Mining and Mineral Sciences Laboratories (CANMET-MMSL)

- Council for Scientific and Industrial Research (CSIR) Miningtek (Republic of South Africa)
- Commonwealth Scientific and Industrial Research Organisation (CSIRO) Exploration and Mining (Australia)
- National Institute for Occupational Safety and Health (NIOSH) (United States)

The GMRA collaboratively pools together the above organizations´ mining research expertise and lab facilities. It undertakes cooperative research designed to benefit the industry in technologies associated with mineral exploration and resource management, extractive technologies, ground control, occupational health and safety, equipment automation, mineral processing, and the environment. Its customers are domestic and multinational mining corporations, industry associations, governments, multilateral agencies, and industry stakeholders. The principal objectives of GMRA include (1) improving the work environment for mine workers by researching and developing technologies that lead to sustainable industry practice, (2) sharing expertise and facilities among the GMRA partners, (3) providing economic leverage to funding by reducing duplication and coordinating research efforts in order to increase the probability of success, and (4) providing improved opportunities for career development through staff exchanges between the GMRA partners.

Council for Scientific and Industrial Research of South Africa - During the past 3 decades, the South African coal mining industry has experienced a series of explosions leading to a considerable loss of life. Over the past 4-5 years, research was done to develop a bagged stone dust barrier to prevent a coal dust explosion from propagating. In South African coal mines, multiple-entry mining methods are used, but little was known of how explosions propagate under these conditions. It was essential to determine whether or not bagged stone dust barriers can effectively suppress coal dust explosions in room-and-pillar sections. The Council for Scientific and Industrial Research (CSIR) of South Africa requested technical assistance in the full-scale testing of these passive barriers to suppress dust explosions in coal mines. NIOSH´s Lake Lynn Experimental Mine (LLEM) was the only facility in the world that could perform the required full-scale evaluations in a multiple-entry mining configuration. The evaluations were successfully completed in the LLEM during 1999-2000. Two barrier designs were evaluated: the distributed barrier configuration and the concentrated barrier configuration. From the full-scale experimental mine test results, it was concluded that both bagged barrier designs were effective in stopping coal dust explosions in the multiple entries of the LLEM. Based on the results of these tests, the South Africans have implemented these barriers to protect miners from underground explosions. Further tests are planned with rock dust barriers that contain a small explosive charge, which is triggered by an approaching flame front to disperse the rock dust and extinguish the explosion.

2.7 Stakeholders and Customers

The mining research program collaborates and works closely with a broad spectrum of the mining community. The stakeholder and customer list is extensive, including industry, labor, academia, government agencies, equipment manufacturers and professional organizations both domestic and international. These organizations are often times research partners, as described in the previous section, as well as users of our technology and scientific findings, peer reviewers, recipients of research grants and contracts and providers of equipment, technology or knowledge for advancing research in the mining community. The following list of stakeholders and customers is not intended to be exhaustive but instead is indicative of the wide-range of organizations that are served by the mining health and safety research program.

Academia

- Carnegie Mellon University
- Colorado School of Mines
- Montana Tech
- Purdue University
- Southern Illinois University
- The Pennsylvania State University
- University of Arizona
- University of Cincinnati
- University of Kentucky
- University of Minnesota
- University of Missouri-Rolla
- University of North Carolina
- University of Pittsburgh
- University of Utah
- University of Washington
- Virginia Polytechnic Institute and State University
- West Virginia University

Equipment Manufacturers

- ABC Industries
- Advanced Resources International
- Air Sun Auto
- American Commercial Inc.
- American Mine Door
- Bergstrom
- Blue Circle Cement, Inc.
- Burrell Mining Products
- Caterpillar, Inc.
- Clean Air Filter
- CTS Cement Manufacturing Corp.
- DBT America Inc.
- Draeger

- Dynamic Systems Inc.
- Efficient Mining Systems
- Excel Mining Systems
- Geokon, Inc.
- Geosteering
- Heintzmann Corporation
- Hilti, Inc.
- J. H. Fletcher and Company
- Jennmar Corporation
- Joy Mining Machinery
- Metso/Nordberg
- Mine Safety Appliances
- Minova
- Preco Electronics, Inc.
- Red Dot Corporation
- RM Wilson Co.
- SKC Company, Inc.
- SSA Marine
- Strata Products USA
- Sub-Technical Inc.
- Sy-Klone International, Ltd.
- Thermo Electron Corporation (Rupprecht and Patashnick Co., Inc.)
- Thiessen Team USA
- Transtek, Inc.
- Triune, Inc.
- US Foam Technologies, Inc.
- Visionaire
- Wampum Hardware
- Wynn Environmental Company

Government (Federal and State)

- Arizona State Mine Inspectors Office
- Department of Energy
- Mine Safety and Health Administration (MSHA)
- Montana Bureau of Mines and Geology
- Occupational Safety and Health Administration (OSHA)
- Office of Surface Mining
- Pennsylvania Department of Environmental Protection Bureau of Deep Mine Safety
- Virginia Department of Mines Minerals and Energy

Industry

- Arizona Rock Products Association
- Bituminous Coal Operators Association
- California Construction Materials Association
- Industrial Minerals Association-North America
- MARG Diesel Coalition

- National Limestone Association
- National Mining Association
- National Stone, Sand and Gravel Association
- National Water Well Drillers Association
- Nevada Mining Association
- Northwest Mining Association
- Pennsylvania Coal Association
- Washington Construction Materials Association
- West Virginia Coal Association
- Western Underground Miners Association

International

- Australian Environmental Health Services Pty. Ltd.
- CANMET, Canada
- Construction, Forestry, Mining, and Energy Union (Australia)
- CSIR Mining Technology, South Africa
- CSIRO, Australia
- DBT, Germany
- Imperial College, London, UK.
- SIMTARS, Queensland, Australia
- University of Queensland, Australia

Labor

- International Brotherhood of Electrical Workers (IBEW)
- International Union of Operating Engineers (IUOE)
- Iron Workers International Union
- United Mine Workers of America (UMWA)
- United Steel Workers of America (USWA)

Mine Operators

- Alliance Coal
- Amfire Mining Company
- Anker Energy Corp.
- Apollo Gold
- Arch Coal, Inc
- Badger Mining
- Barrick Goldstrike Mines, Inc.
- BHP San Juan Coal Company
- Black Beauty Coal Company
- Bridger Coal Company
- Central Premix Company
- Cleveland-Cliffs Iron Company
- Coeur d'Alene Mines Corp.
- Consol Energy
- Deer Creek Coal Company

- Doe Run Company
- Drummond Company, Inc.
- Endless Mountain Stone Company
- Energy West Inc.
- Florida Rock
- Foundation Coal Company
- Freeman United Coal Company
- Graymont Western, Inc.
- Hanson Aggregates
- Hecla Mining Company
- Henderson Mine
- Insland Asphalt and Rock Products
- Jim Walter Resources
- Joliet Sand and Gravel Company
- Kennecott Energy
- Lafarge Aggregate Materials
- Laurel Aggregates
- Leslie Resources
- Luck Stone
- Luzenac America, Inc.
- Martin-Marietta Aggregates
- Massey Energy Company
- Monterey Coal Company
- Morton Salt
- Murray Energy Corp.
- Newmont Mining Corp.
- P&M Mining
- Peabody Energy
- Phelps-Dodge
- Placer Dome, Inc.
- Powder River Coal Company
- Queenstake Resources
- Rio Tinto Borax
- Rogers Group
- Rohrer´s Quarry
- Sahara Sands
- Shafer Brothers Construction, Inc.
- Sidney Coal
- Specialty Minerals
- Springfield Pike Mine
- Stillwater Mining Company
- Thunder Basin Coal Company
- Tilcon New York, Inc./Old Castle Minerals
- TJS Mining
- Twentymile Coal Co.
- U.S. Silica Co.
- Unimin Corp.
- Vulcan Materials Co.
- West Elk Coal Co.

Professional Associations

- American Association of Aerosol Research
- American Industrial Hygiene Association
- American Society of Agricultural Engineers
- Central Mine Rescue Association
- Institute of Electrical and Electronics Engineers
- Institute of Makers of Explosives
- International Society of Explosives Engineers
- International Society of Mine Safety Professionals
- Joseph A. Holmes Safety Association
- National Ground Water Association
- National Mine Rescue Association
- National Safety Council
- Pittsburgh Coal Mining Institute of America
- Society for Mining, Metallurgy, and Exploration, Inc.
- U.S. Mine Rescue Association

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2.8 International Collaborations

As a result of research accomplishments by the NIOSH Mining Program, the worldwide mining engineering and scientific community has recognized our unique expertise, capabilities, and facilities. The following table summarizes collaborative activities between NIOSH mining researchers and various organizations around the world since 1996.

47 collaborations

Country	Activity	Start Year	End Year	Strategic Goal
Australia; Canada; South Africa	The Global Mining Research Alliance (GMRA) is a collaboration that aims to become the supplier of choice for mining research solutions and knowledge in the international mining and resources industry. The partners forming the alliance are the Canada Centre for Mineral and Energy Technology, Mining and Mineral Sciences Laboratories (CANMET-MMSL); the Council for Scientific and Industrial Research (CSIR) Miningtek (Republic of South Africa); the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Exploration and Mining (Australia); and the National Institute for Occupational Safety and Health (NIOSH) (United States). GMRA undertakes cooperative research designed to benefit the industry in technologies associated with mineral exploration and resource management, extractive technologies, ground control, occupational health and safety, equipment automation, mineral processing, and the environment. The main objectives of GMRA include (1) improving the work environment for mine workers by researching and developing technologies that lead to sustainable industry practice, (2) sharing expertise and facilities among the GMRA partners, (3) providing economic leverage to funding by reducing duplication and coordinating research efforts in order to increase the probability of success, and (4) providing improved opportunities for career development through staff exchanges between GMRA partners.	2005	Present	All
Canada	NIOSH PRL diesel researchers have been collaborating with the Canadian Diesel Emission Evaluation Program (DEEP) by providing technical expertise on underground sampling and have shared in the findings.	1999	Present	Respiratory diseases
South Africa	NIOSH has been collaborating with the Council for Scientific and Industrial Research (CSIR) to conduct research on reducing excessive exposure to noise for rock drill operators by developing low-cost retrofit engineering noise controls.	2000	Present	Hearing loss
Chile	Two senior researchers are serving on a committee to investigate silica dust control in Chile.	2005	Present	Respiratory diseases

Country	Activity	Start Year	End Year	Strategic Goal
Australia; Canada; Denmark; Indonesia; Iran; Ireland; Israel; Mexico; New Zealand; South Africa; United Kingdom	The NIOSH-developed Hearing Loss Simulator has been used in 11 countries around the world.	2005	Present	Hearing loss
All	A NIOSH researcher is a member of the International Organization for Standardization´s (ISO) Earth-Moving Machinery Work Group, which is developing standards for hazard detection and warning systems for blind areas near mining machinery. The researcher also acts as a subject matter expert for the development of ISO standards related to machine safety. ISO is a global network of the national standards bodies of more than 140 countries located in all regions of the world.	2002	Present	Traumatic injuries
Czech Republic	A NIOSH researcher is on the review board of a Czech grant agency that reviews submittals for projects in rock mechanics instrumentation and numerical modeling of underground mines. This work started in 2002; three proposals have been reviewed to date.	2002	Present	Ground control
South Africa	NIOSH is scheduled to carry out additional tests to evaluate triggered rock dust barriers for explosion protection for the Safety in Mines Research Advisory Committee (SIMRAC) and CSIR Miningtek.	2006	2006	Mine disasters
India	A senior researcher has been invited to present a workshop in India on silica dust control.	2006	2006	Respiratory diseases
Australia	A senior researcher participated in laboratory and field trials of the NIOSH diesel detective tailpipe sampler under a Memorandum of Understanding with BHP-Billiton/AEHS, Mineral Resources of New South Wales.	2002	2005	Respiratory diseases
Poland	A NIOSH researcher was invited to present a paper at the KOMTECH Sixth International Scientific and Technical Conference in Zakopane, Poland, on "Comparing Estimated Low-Back Loads From Control Interventions for Underground Coal Mine Roof Bolter Operators." The researcher also met with representatives of the KOMAG Mining Mechanization Center in Gliwice, Poland, to discuss common research efforts to eliminate traumatic injuries in the mining workplace. The visit to KOMAG included a tour of its facilities and discussions about research activities at KOMAG and PRL.	2005	2005	Cumulative injuries

Country	Activity	Start Year	End Year	Strategic Goal
Chile	A senior researcher was an invited guest lecturer at two prominent educational institutions in Chile: Technical University Federico Santa María, Valparaiso, and Universidad de Concepción, Concepción. Representatives from both universities had heard his presentation at the IEEE Industry Applications Conference in Hong Kong in October 2005. Both universities have strong undergraduate and graduate engineering programs and believed that the following presentations would greatly benefit students and the Chilean mining industry: "NIOSH Best Practice Recommendations for the Functional Safety of Programmable Electronic Mining Systems," "Emerging Technology Research at the NIOSH Pittsburgh Research Laboratory," and "An Overview of Wireless Sensor Technologies for Mining Applications."	2005	2005	Traumatic injuries
United Kingdom	NIOSH collaborated on a joint project with researchers from Imperial College in London to study postexplosion coal dust samples. The work was funded by the British Coal Utilisation Research Association.	2004	2005	Mine disasters
South Africa	NIOSH participated in a SIMRAC project to evaluate roof bolt support systems used by the South African coal industry.	2005	2005	Ground control
Canada	Researchers from the Canada Centre for Mineral and Energy Technology (CANMET) collaborated with NIOSH scientists to characterize weak rock masses in underground mines. This work resulted in the publication, "Influence of Intermediate Principal Stress on Rock Mass Quality."	2005	2005	Ground control
Australia	NIOSH researchers collaborated with mine personnel of the Xstrata Zinc-George Fisher Mine, Mount Isa, Queensland, on the use of split-set rock bolts to monitor rock movement in underground mines.	2005	2005	Ground control
Australia	NIOSH participated in an ACARP project to develop guidelines for support of ribs in underground coal mines. This resulted in the Analysis and Design of Rib Support (ADRS) software package.	2001	2005	Ground control
Canada	NIOSH, the Ontario Mines and Aggregates Safety and Health Association, Inco, and CANMET shared research findings relative to protecting mine rescue workers in hot environments and developed research protocols to develop and test mine rescue procedures in hot Canadian mines.	2004	2005	Surveillance and training

Country	Activity	Start Year	End Year	Strategic Goal
Canada	NIOSH researchers worked with Neodym Technologies, Inc., Vancouver, British Columbia, to adapt the company´s stationary hydrogen sensor technologies to a platform suitable for use in a safety control system on underground mine mobile equipment. Transferring this temperature-compensating combustible gas system to a mobile platform and integrating it into a programmable controller that manages a vehicle´s hydrogen fuel supply allowed NIOSH´s Zero Emissions Utility Solution (ZEUS) vehicle to be safely operated under the variable environmental conditions found in U.S. underground mines.	2003	2004	Surveillance and training
Venezuela	A NIOSH researcher worked with engineers and safety staff at Hecla Mining´s La Camorra Mine in Venezuela to provide copies of all underground training videos. The collaboration resulted in translation of three videos into Spanish for mine employees.	2002	2004	Surveillance and training
Australia	Researchers from NIOSH and the University of Queensland collaborated on studies of backfill, cavability of rock, cemented rock fill for ground support, and overbreak due to blasting.	2004	2004	Ground control
Canada	Analysts from the Ontario Ministry of Labour collaborated with NIOSH researchers to generate statistics on health and safety in mining, specifically, information related to the analysis of mine disasters.	2004	2004	Ground control
Canada	NIOSH researchers continued collaborative work with Inco of Sudbury, Ontario, pertaining to weak rock, assessments of shotcrete, and the effectiveness of ground support.	2002	2004	Ground control
Canada	Personnel from Placer Dome's Musselwhite Mine in Ontario collaborated with NIOSH researchers to assess weak ground, ground support, and cemented backfill in weak ground. Results of the work were published in the proceedings of the Canadian Institute of Mining, Metallurgy and Petroleum´s (CIM) 2004 annual meeting.	2002	2004	Ground control
Germany	A NIOSH researcher was coauthor with a German colleague of a book chapter on "Eigenschaften Brennbarer Stäube" in Handbuch des Explosionsschutzes, published in German in 2000. The chapter and handbook were later translated into English in 2004 as "Properties of Combustible Dusts" in the Handbook of Explosion Prevention and Protection.	2000	2004	Mine disasters
Australia	NIOSH researchers collaborated with Minova Australia to evaluate an innovative, flexible brattice stopping design against 2- and 5-psi explosion overpressures within NIOSH´s Lake Lynn Experimental Mine. Based on the results of these evaluations, this Flexi-Stop stopping is now being used in some Australian underground coal mines.	2003	2003	Mine disasters
South Africa	NIOSH participated in a SIMRAC/Miningtek project to transfer the Coal Mine Roof Rating (CMRR) to the South African coal industry.	2002	2002	Ground control

Country	Activity	Start Year	End Year	Strategic Goal
Canada	NIOSH participated in the Underground Coal Mine Safety Research Collaboration project entitled "Standardisation of Geological and Geomechanical Assessment at Underground Coal Mines in Canada," which involved transfer of ALPS, Analysis of Retreat Mining Pillar Stability (ARMPS), the Coal Mine Roof Rating (CMRR), and horizontal stress control technologies.	1999	2001	Ground control
Mexico	NIOSH received a request for technical assistance from Mexico´s National Institute of Public Health (Instituto Nacional de Salud Pública (INSP)) to assess mercury exposures at reprocessing plants in Zacatecas. NIOSH and INSP researchers spent a week assessing the potential for occupational exposure to mercury at four plants that reprocess old mine tailings that contain a significant amount of mercury.	2001	2001	Surveillance and training
Switzerland	NIOSH collaborated with SIG Rocktools AG to conduct research to reduce excessive noise exposure to rock drill operators.	2000	2001	Hearing loss
South Africa	A Fulbright scholar from the University of Pretoria, Republic of South Africa, worked with NIOSH scientists for 3 months as a guest researcher to assist in developing a device called a Shox Box. The device incorporates a global positioning system to display the locations and amplitude of mechanical jolts experienced by operators of haulage trucks. To date, 102 Shox Boxes have been produced and used in industry. The device was developed under a Cooperative Research and Development Agreement between NIOSH and Phelps Dodge´s Morenci Mine.	2001	2001	Cumulative injuries
Australia	Under the sponsorship of the New South Wales Department of Mineral Resources, a NIOSH researcher met with mine safety officials and mine equipment manufacturers to discuss obtaining case study material and accident data for programmable electronic mining systems. He was the keynote speaker at the 11th Annual Electrical Engineering Safety Seminar held in Penrith, New South Wales. He conducted a workshop on "NIOSH Best Practice Recommendations for Programmable Electronic Mining Systems," both in Penrith and Brisbane. The workshop helped establish a world leadership position for NIOSH in the area of programmable electronic mining equipment safety. In Brisbane, he was hosted by the University of Queensland Mineral Industry Safety and Health Center and the Queensland Department of Natural Resources and Mining. His presentations were used by the university in its Mining Risk Analysis course work.	2001	2001	Traumatic injuries
United Kingdom	A senior researcher assisted in evaluating a prototype NIOSH dust dosimeter in 10 U.K. coal mines under a Letter of Understanding with the U.K. Health and Safety Executive.	1999	2001	Respiratory diseases

Country	Activity	Start Year	End Year	Strategic Goal
South Africa	NIOSH collaborated with the Council for Scientific and Industrial Research (CSIR) to evaluate barriers used to suppress coal dust explosions. The passive barrier design consisted of a series of strategically placed bags of stone dust that were suspended from the mine roof. Based on the successful conclusion of this joint project, these explosion barriers are now being used to protect miners from underground explosions in the Republic of South Africa. This work was conducted in NIOSH´s Lake Lynn Experimental Mine and was fully funded by CSIR.	1999	2000	Mine disasters
Poland	NIOSH cosponsored an international seminar on "Seals and Barriers as a Means of Protection Against Fires and Explosions in Mines" (SEALBARR ´99) held in Katowice, Poland. This 2-day U.S.-Poland seminar was held to promote international technology transfer of mine seals and barriers for controlling mine explosions.	1999	1999	Mine disasters
Poland	Two senior researchers cooperated with researchers from KOMAG Mining Mechanization Center in Gliwice, Poland, to evaluate the dust generation potential for various coals collected from mines in the United States and Poland. In addition, a comparison of the dust control technologies used on longwall mining operations in both countries was completed.	1995	1999	Respiratory diseases
Ecuador	As a result of a request for technical assistance from the Minister of Health for Ecuador, a study was conducted to assess occupational exposure to mercury in the gold mining region of Bella Rica, Ecuador. NIOSH researchers, in collaboration with researchers from George Washington University and the University of Cuenca, Ecuador, conducted an industrial hygiene study, a medical study, and an evaluation of the region's mining processes. The outcome was a technical report on this site survey, which provided the mining industry in Bella Rica with an evaluation of the extent of mercury exposures in the workplace and suggested interventions for protecting potentially exposed workers.	1999	1999	Surveillance and training
Australia	NIOSH researchers participated in a project of the Australian Coal Association Research Program (ACARP) to calibrate the Analysis of Longwall Pillar Stability (ALPS) method for Australian conditions. This resulted in the Analysis of Longwall Tailgate Serviceability (ALTS) software package.	1995	1998	Ground control
Venezuela	NIOSH researchers, in collaboration with the Center for Toxicological Investigations, University of Carabobo, Venezuela, conducted a comprehensive survey to determine if overexposure to mercury was occurring in El Callao, a gold mining area in Venezuela. The site survey consisted of the collection of personal breathing zone samples, spot urine samples, administration of a questionnaire by an occupational physician, a comprehensive evaluation of the processing techniques currently being used by the mine personnel, and recommendations for reducing exposure to mercury.	1998	1998	Surveillance and training

Country	Activity	Start Year	End Year	Strategic Goal
Panama	Two senior NIOSH researchers analyzed risk factors for low-back pain among line handlers and deck hands at the Panama Canal and made recommendations on job design changes to reduce the risk of back injury.	1998	1998	Cumulative injuries
Viet Nam	NIOSH assisted with the development and presentation of a NIOSH ergonomics workshop for the Vietnamese National Institute of Occupational and Environmental Health (NIOEH).	1998	1998	Cumulative injuries
Australia	NIOSH collaborated on two joint research projects with Australian seal manufacturers to investigate the capability of various ventilation control structures to meet or exceed the requirements of the Queensland Department of Mines and Energy´s "Approved Standard for Ventilation Control Devices." This research was conducted in NIOSH´s Lake Lynn Experimental Mine. The purpose was to evaluate the explosion resistance of various seals and stoppings and an overcast. Based on the successful conclusions to these joint projects, these ventilation structures are now being used to protect miners from underground explosions in Australia and in some U.S. mines. This research was fully funded by Tecrete Industries of New South Wales and Barclay Mowlem Construction of Queensland.	1997	1998	Mine disasters
Poland	NIOSH cosponsored a 5-day symposium with the American Society for Testing and Materials and the National Fire Protection Association (United States) and the Warsaw University of Technology and the Committee for Thermodynamics and Combustion of the Polish Academy of Sciences (Poland). The symposium presentations transferred knowledge on gas, dust, and hybrid explosion hazards and prevention techniques. The symposium was held in Schaumburg, IL, with 100 attendees from 13 countries. The 56 papers from the symposium were published in two proceedings volumes.	1998	1998	Mine disasters
Czech Republic	A NIOSH researcher was the U.S. representative for the U.S.-Czech Science and Technology Joint Fund project "Rock Mass Freezing." A method for mathematically modeling rock bolt reinforcements was developed and is now used in numerical models of underground mines in both countries.	1994	1998	Ground control
Japan	A senior researcher presented an "Overview of U.S. Research on Three Approaches to Ensuring That Coal Miners Work Safely: Management, Workplace Design, and Training" at the request of the Japan Technical Cooperation Center for Coal Resources Development.	1997	1997	Surveillance and training
Mexico	A senior researcher, at the request of the World Health Organization, taught a week-long course to mining health and safety representatives in Mexico on mining health issues and their control. He also visited several underground coal mines and provided guidance on a number of health and safety issues.	1996	1996	Respiratory diseases

Country	Activity	Start Year	End Year	Strategic Goal
Saudi Arabia	A senior researcher, at the request of the State Department, worked in Saudi Arabia for several weeks to advise the Saudis on dust control at aggregate operations, cement plants, and gold mines.	1995	1995	Respiratory diseases

Chapter 3
What has the Mining Program Accomplished?

3.1 Overview of Chapter 3

This chapter addresses the improvements to mineworker safety and health that have been realized over the past ten years, and that have resulted from the research and prevention activities of the NIOSH Mining Program. It is often difficult to establish causal relationships between research activities and tangible gains in safety or health measures, and the process is further complicated by the fact that multiple organizations or individuals have contributed to the sequence of events that has effected the desired health or safety outcome. We have organized the relationships between our research activities and the ultimate health or safety improvement into three categories of outputs, intermediate outcomes, and strategic program outcomes. Each of these will be defined here, and then additional remarks on who can rightly take credit for safety and health advancements will be offered in this introduction. Finally, the layout of this chapter is defined.

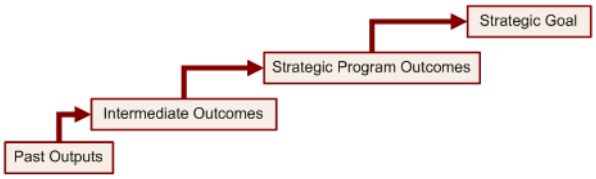
The execution of our research projects leads to defined deliverables or **outputs**. Outputs include papers published in peer-reviewed journals, articles in trade magazines, reports, workshops, and patents, among others, since 1996. Each output has intrinsic value, but only to the extent that it is translated into practice. For example, a specific technology to reduce dust entrainment may be developed and demonstrated as part of a project. Papers may be written on this technology and workshops may be conducted. These are important outputs of the research, but until they are put into practice, they cannot have much impact. The next step is therefore to identify outputs that have been applied with some measurable success.

The successful application of multiple research outputs leads to an **intermediate outcome**. Continuing with our example, suppose that as a result of the papers and workshops to promote the newly developed technology, the industry adopts it. The translation of these research outputs into practice is a necessary, but not sufficient condition, to define an intermediate outcome. The second necessary condition is that putting these into practice will contribute to the solution of a desired safety or health problem. In our example, if the adoption of the dust control technology throughout the industry also results in reduced dust exposure to workers, then a logical basis exists to believe that this will have an outcome of reducing dust diseases among mineworkers. Thus, the intermediate outcome in this example would be reducing dust exposure. We label these outcomes as intermediate to emphasize that they are, in themselves, not the final goal, but rather an intermediate step to the ultimate goal of positively impacting the safety and health measures.

The realization over time of one or more intermediate outcomes leads to a desired safety or health **strategic program outcome** - a reduction in the occupational illnesses, injuries, and fatalities related directly to one of the seven **strategic goals** of the Mining Research Plan (see Section 1.5). In our example, a reduction in dust exposure, in conjunction with other

intermediate outcomes, would be expected to lead to the strategic program outcome of a reduction in a lung disease associated with that dust. Of course, this final extension of the logic is more difficult to prove when the outcome, e.g. reducing coal worker pneumoconiosis, has a long latency period. Nonetheless, most experts would agree that a long-term reduction in exposure would have the desired outcome. The safety-based outcomes tend to be easier in this regard because the time period between the intermediate outcomes and the measurable changes in the desired outcome is shorter.

In summary, the accomplishments of the Mining Program are presented hierarchically, as follows:



Finally, there is the issue of determining the underlying causes of improvements to observable safety and health measures. At the output level, despite the often significant synergies among researchers at universities, private-sector research groups, and government agencies, it is usually straightforward to link a specific research project to a specific output. At the intermediate outcome level, however, this becomes more difficult. NIOSH outputs can be linked to measurable intermediate outcomes. However, in many cases the activities of others directly or indirectly contributed to those intermediate outcomes. In most cases, multiple intermediate outcomes are required to effect a change in the strategic outcome, and it is likely that NIOSH had involvement in only some of those. We are certain that NIOSH research and prevention activities have contributed to the measured improvements in mineworker safety and health. At the same time, we are certain that the activities of other non-NIOSH researchers have also contributed, and without the combined efforts of NIOSH and non-NIOSH researchers, these improvements would not have occurred. Moreover, the efforts of labor unions, industry groups, and enforcement agencies are absolutely essential to the process, and without their actions, little good would ever come of the research. For the purposes of this review, we have established plausible relationships between our past research activities and presently measurable changes in mineworker safety and health, and we have summarized the evidence that we believe supports these relationships. The remainder of this chapter presents those relationships and the supporting evidence.

3.2 Outcomes

This section describes the safety and health accomplishments over the past ten years for each strategic goal of the Mining Research Plan. The section begins with a list of the seven strategic goals and strategic program outcomes produced through implementation of the research results for each goal. Listed within each goal are intermediate outcomes that support the strategic program outcomes. For each intermediate outcome, there is a brief description of the problem, research and development activities, R&D outputs and transfer activities, a description of the intermediate outcome, and a list of past outputs which contributed to the intermediate outcome.

Strategic Goals	Strategic Program Outcomes
1. **Respiratory diseases -** Reduce respiratory diseases in miners by reducing health hazards in the workplace associated with coal worker pneumoconiosis, silicosis, and diesel emissions.	▸ Reducing Coal Dust Exposures Through Improved Monitoring and Control ▸ Reducing Silica Exposures in Mining Through Improved Control Technologies ▸ Reducing Exposures to Diesel Emissions Through Improved Monitoring and Control
2. **Hearing loss -** Reduce noise-induced hearing loss (NIHL) in the mining industry.	▸ Preventing Noise-induced Hearing Loss
3. **Cumulative injuries -** Reduce repetitive/cumulative musculoskeletal injuries in mine workers.	▸ Preventing Musculoskeletal Disorders
4. **Traumatic injuries -** Reduce traumatic injuries in the mining workplace.	▸ Reducing Traumatic Injuries and Fatalities in Blasting ▸ Reducing Electrically Related Traumatic Injuries ▸ Reducing Machine-related Traumatic Injuries
5. **Mine disasters -** Reduce the risk of mine disasters (fires, explosions, and inundations); and minimize the risk to, and enhance the effectiveness of, emergency responders.	▸ Preventing and Mitigating Mine Fires and Explosions
6. **Ground control -** Reduce ground failure fatalities and injuries in the mining industry.	▸ Reducing Fatalities and Injuries Due to Ground Failures
7. **Surveillance and training -** Determine the impact of changing mining conditions, new and emerging technologies, training, and the changing patterns of work on worker health and safety.	▸ Improved Training Materials and Methods to Prevent Injuries and Illnesses ▸ Reducing the Hazards of Mining's Emerging Issues

Strategic Program Outcome for Respiratory Diseases

Reducing Coal Dust Exposures Through Improved Monitoring and Control

Long-term exposure to excessive levels of respirable coal mine dust can lead to coal workers´ pneumoconiosis (CWP), a debilitating lung disease commonly known as "black lung." The last 35 years have seen major gains in the national effort to reduce CWP. The percentage of dust samples exceeding the 2 mg/m3 federal regulatory limit for continuous miner workers has dropped from 49% to 9%. For longwall workers, the percentage has dropped from 44% to 12%. Likewise, the prevalence of CWP category 1/0+ or higher has dropped from 28% to 8%.

These improvements are due in great part to the development of new dust control technology by NIOSH. Of course, new technology was not the only cause for these improvements. Strong enforcement by the Mine Safety and Health Administration (MSHA) and changing attitudes within the coal industry were vital. Nevertheless, NIOSH made a critical and essential contribution by providing the engineering control tools to make these improvements possible.

Our research has resulted in dozens of new and practical ways to control dust that are now used every day in the coal industry throughout the United States. For example, research for longwalls has identified optimum spray types and locations in cutting drums, developed directional spray systems for the longwall shearer, identified optimum operating pressures for different water spray types, demonstrated methods to control dust from crusher/stageloader units, and improved operating practices such as worker positioning and cutting practices.

MSHA has played a valuable role in promoting NIOSH-developed technology. For instance, in 1999, MSHA placed a Longwall Dust Control Toolbox on its website to guide longwall operators in their efforts to control respirable dust. Most of the control technologies shown in this toolbox were developed by NIOSH, with 28 of the 32 cited publications reporting on our research findings.

At the same time that new techniques were being developed to reduce dust, countertrends within the industry were underway. Production levels on both continuous miner and longwall sections were undergoing huge increases. Compared to 1971 levels, the 2003 shift production at continuous sections more than doubled. Longwall production increased nearly tenfold. Higher production means more dust. Nevertheless, the new dust controls being introduced were so numerous and so effective that compliance with federal dust standards continued to improve.

Although significant reductions in average worker overexposures and CWP have been achieved, shift production levels continue to increase. Thus, the task of protecting miners from respirable coal dust is far from finished. For example, today the highest production continuous miner sections are producing over 2,000 tons per shift, while the highest production longwalls routinely produce over 15,000 tons per shift. This represents about 2.5 times the average for the industry. Further improvements in control technologies are still needed, particularly for a number of high-risk occupations.

In recent years, NIOSH has developed dust control technologies that build on or supplement the controls already being used. For example, continuous miner research showed that blocking sprays, if properly used, can reduce dust levels at the operator locations. Blocking sprays create a water barrier near the cutting face, which prevents dust from rolling back to the operator locations at the

back of the machine and allows the dust to be captured by the scrubber inlets. A major continuous miner manufacturer now offers blocking sprays on its machines, and new continuous mining machines are underground with these sprays installed. NIOSH researchers also found that thinner filters were being used in flooded-bed scrubbers on continuous miners. Research showed that these thinner filters allowed 30% more dust back into the mine air. NIOSH recommended the use of thicker filters in a NIOSH *Hazard ID* flyer. MSHA requested 1,000 copies of this *Hazard ID* to distribute to mine inspectors as part of its initiative to lower silica dust exposure. MSHA has also required mine operators to use these thicker filters when dust problems exist and currently requires the industry to specifically identify these filters in dust control and ventilation plans.

In 2003, all of the dust control technologies that we developed over the years and that are currently in use in mines were published in a handbook. This handbook provides a single information source to help mine operators control dust levels. To date, this handbook has had wide acceptance based on requests and feedback from industry, labor, and regulatory agencies. The handbook is also available on the NIOSH Mining Website.

In addition to major research directed at coal dust control technology, a parallel research effort devoted to improved dust sampling has been ongoing for the past 10 years. Under the Federal Coal Mine Health and Safety Act of 1969, personal gravimetric dust samplers were specified as the instrumentation to be used to monitor compliance with federal dust regulations. These samplers use a size-selective cyclone to collect the respirable fraction of dust on a filter. The mass of dust, pump flow rate, and sampling time are used to calculate an average dust concentration for the shift. This concentration is not determined until the filter has been weighed at MSHA´s Pittsburgh lab several days after the sample is collected. This sampling process has not changed in the past 36 years. In 1999, NIOSH began developing a mass-based, continuous dust monitor that could be worn as a personal dust sampler. This personal dust monitor (PDM), built into the miner´s cap lamp system, provides a running average of dust exposure at any point in the shift, projects an end-of-shift concentration, and provides an actual end-of-shift concentration without any delay. This information will allow mine operators and workers to monitor the dust exposure during the shift. It will empower workers to make changes if it seems that their shift exposure will exceed the standard. The PDM is currently near the end of an extensive field evaluation to assess sampling accuracy, mine worthiness, reliability, and acceptance by mine workers. Results to date are very positive. The PDM is now commercially available.

In 2003, MSHA published proposed changes to its dust sampling program. In these new regulations, MSHA allowed for the use of the continuous PDM. However, industry and labor indicated in public response forums that MSHA should delay rulemaking until the PDM could be further evaluated as a compliance-grade instrument. Both industry and labor envision the PDM as having the potential to become the cornerstone for a new sampling process. Based on stakeholder input, MSHA suspended work on the proposed regulations until additional information on PDM performance is available. A NIOSH report on the latest series of underground and lab evaluations of the PDM is expected to be completed by the end of 2005.

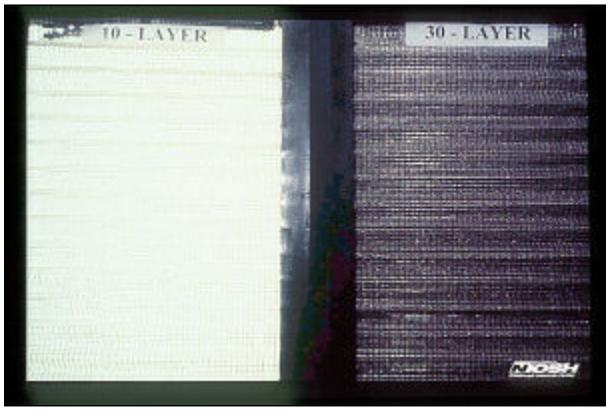
Intermediate Outcomes

- Effective Dust Collection with Flooded-Bed Scrubbers
- Handbook to Facilitate Transfer of Dust Control Technology for Mining
- New Personal Dust Monitor Empowers Miners to Reduce Their Dust Exposure
- NIOSH Establishes the Ineffectiveness of Area Dust Sampling as a Measure of Worker Exposure
- Reducing Miners' Dust Exposure Through the Use of Confining Sprays for Flooded-bed Scrubbers

Intermediate Outcome related to Reducing Coal Dust Exposures Through Improved Monitoring and Control

Effective Dust Collection with Flooded-Bed Scrubbers

Description of Problem



Difference in filter density using backlighting

NIOSH researchers found through a series of underground and lab investigations that flooded-bed scrubbers on continuous miners were not providing the level of respirable dust control (removal rates of about 90% or better) that earlier U.S. Bureau of Mines research had shown they were capable of providing. During this investigation in the mid-1990s, Pittsburgh Research Laboratory (PRL) researchers learned that equipment manufacturers were making thinner filters for the flooded-bed scrubbers in order to reduce filter back pressure. This extended the life of the filters and allowed for higher scrubber flow rates. This practice had gone unnoticed until recognized by NIOSH researchers while conducting other dust control research. It was immediately recognized that this change allowed more air to move through the scrubber with less resistance. However, there was no information on how this affected the efficiency of the scrubbers to collect respirable dust.

Research and Development Activities

PRL conducted a series of lab tests to compare the dust collection efficiencies of standard filters with those of the newer, thinner filters being supplied by manufacturers at that time. Results showed that, on average, the new thinner filters allowed 30% more respirable dust to be discharged by the scrubber back into the mine air. These new filters often had removal efficiencies of around 60%. Often, the discharge point of the scrubber is near to the continuous miner operator and the shuttle car operator. This results in an increase in dust exposure for these workers.

R&D Outputs and Transfer Activities

The results of this study were reported in a peer-reviewed journal and a conference presentation. The results were also reported in a NIOSH *Hazard ID* flyer, which was distributed to the industry. In 1997, the Mine Safety and Health Administration (MSHA) initiated a program to lower silica dust exposure and requested 1,000 copies of this *Hazard ID*. These were distributed to MSHA mine inspectors to increase their awareness of the issue. Inspectors were also asked to pass on this information to mine operators.

Description of Intermediate Outcome

As a result of these findings, MSHA has required mine operators to go back to the thicker filters when problems with silica control are encountered. MSHA also began requiring mine operators to specify the use of the thicker filters in their dust control and ventilation plans.

Greater awareness of scrubber performance and increased use of thicker filters has contributed to improved dust control in continuous miner operations and has reduced dust exposure at continuous miner faces.

Outputs

5 Outputs

Title	Year	Output Type	Strategic Goal
Laboratory Evaluation of Quartz Dust Capture of Irrigated-filter Collection Systems for Continuous Miners Colinet-JF; McClelland-JJ; Erhard-LA; Jankowski-RA | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 9313	1990	Publication	Respiratory diseases
NIOSH Hazard ID - Exposure to Silica Dust on Continuous Mining Operations Using Flooded-Bed Scrubbers Colinet-JF; Flesch-JP | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 97-147, 1997 Aug :1-2	1997	Publication	Respiratory diseases
Performance Evaluation of Irrigated Filters McClelland-JJ; Colinet-JF | Trans Soc Min Metal Explor, Vol 290. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc; :1828-1832	1992	Publication	Respiratory diseases
Respirable Dust Control Technology Utilised in Underground Coal Mines in the United States Colinet-JF | In: Proceedings of the Second International Underground Coal Conference, Hebblewhite BK, Galvin JM, Broome AJ, eds. , 1999; :171-179	1999	Publication	Respiratory diseases
Silica Collection Concerns When Using Flooded-Bed Scrubbers Colinet-JF; Jankowski-RA | Mining Engineering 52(4) 2000; :49-54	2000	Publication	Respiratory diseases

Intermediate Outcome related to Reducing Coal Dust Exposures Through Improved Monitoring and Control

Handbook to Facilitate Transfer of Dust Control Technology for Mining

Description of Problem

Over the last 30 years, much successful research has been done by NIOSH and the former U.S. Bureau of Mines (USBM) to reduce dust in mines. However, no comprehensive summary of practical dust control technology for mining industry personnel had been published. The information was available, but was scattered among a variety of publications. Therefore, it was hard to put together a comprehensive dust control plan for mines that addressed all required aspects of the plan.

The handbook is a comprehensive summary of practical dust control technology for all aspects of mining

Research and Development Activities

NIOSH used all of the available information from past NIOSH and USBM research and combined the information into a Handbook for Dust Control in Mining. This 131-page handbook describes methods for controlling mineral dusts in mines. Dust control methods are described for underground coal and hard-rock mines, as well as surface mines, stone mines, and hard-rock tunnels. The information is assembled in a way that is user-friendly and according to easy-to-find topics.

R&D Outputs and Transfer Activities

The handbook was published in June 2003. We have received hundreds of requests for the handbook by labor and industry organizations worldwide, and we have handed out the handbook at training sessions and conferences. We did several things to make the handbook "Web-friendly" in order to facilitate technology transfer:

- File size was minimized to make downloads faster.
- Text and figure size were maximized for easier reading on a computer screen.
- The text was single-column (rather than double-column) for easier reading on a computer screen.
- The Adobe Acrobat bookmark feature was used to produce an on-line index. This allows the reader to instantly move to any desired location in the document, instead of tediously scrolling through a large document.

The handbook is currently available on the NIOSH Mining Website.

Description of Intermediate Outcome

A key impact is that years of useful and practical dust control technology information is now consolidated into one easily usable format. Thus, the probability of its application in the mining industry is greatly enhanced. The handbook has been widely distributed within the U.S. mining industry. It has received positive notice from many foreign mining websites. Nevertheless, the main impact comes from the technology cited within the handbook. Most of the technology was developed by NIOSH or the USBM. It continues to have lasting impact on industry practice. Some of the major successes are:

- Shearer-clearer systems on longwall shearers.
- Spray nozzle application on continuous miners and longwall shearers.
- Deep cutting with dust scrubbers on continuous miners.
- Face curtains to control longwall ventilation.
- New sampling methods to find dust sources.
- New stopping construction methods for mine entries with a large cross-section.
- Improved dust control for surface drills.
- New methods for conveyor belt dust control.
- Dust control methods for hard-rock tunnels.

Outputs

25 Outputs

Title	Year	Output Type	Strategic Goal
An Evaluation of Three Wet Dust Control Techniques for Face Drills Page-SJ | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 8596. NTIS No. PB82-177320	1982	Publication	Respiratory diseases
An Update on Stageloader Dust Control Jayaraman-NI; Jankowski-RA; Organiscak-JA | In: Proceedings of Longwall USA (Pittsburgh, PA), 1992	1992	Publication	Respiratory diseases
Atomization of Water Sprays for Quartz Dust Control Jayaraman-NI; Jankowski-RA | Appl Ind Hyg 3; :327-331	1988	Publication	Respiratory diseases
Control of Respirable Dust by Improved Water Sprays Courtney-WG; Cheng-L | In: Respirable Dust Control - Proceedings of Technology Transfer Seminars, Pittsburgh, PA, and St. Louis, MO, US Bureau of Mines, Information Circular 8753, NTIS No PB 272 910; :92-108	1977	Publication	Respiratory diseases
Dust Sources and Controls on the Six U.S. Longwall Faces Having the Most Difficulty Complying with Dust Standards Jankowski-RA; Organiscak-JA | Pittsburgh, PA: U.S. Department of the Interior, Information Circular 8957. NTIS No. PB84-142058	1983	Publication	Respiratory diseases
Evaluation of a Combined Face Ventilation System Used with a Remotely Operated Mining Machine Divers-EF; Jayaraman-NI; Custer-J | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Information Circular 8899. NTIS No. PB83-156794	1982	Publication	Respiratory diseases
Evaluation of a New Half-curtain Technique for Continuous Miner Faces Jayaraman-NI, Divers-EF, Derick-RL, Babbitt-C | In: Proceedings of the Symposium on Respirable Dust. University Park, PA: The Pennsylvania State University	1986	Publication	Respiratory diseases
Extended Advance of Continuous Miner Successfully Ventilated with a Scrubber in a Blowing Section Volkwein-JC; Thimons-ED; Halfinger-G | In: Proceedings of the Second U.S. Mine Ventilation Symposium (Reno, NV)	1985	Publication	Mine disasters
Factors Affecting Respirable Dust Generation from Longwall Roof Supports Organiscak-JA; Listak-JM; Jankowski-RA | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Information Circular 9019. NTIS No. PB85 236453	1985	Publication	Respiratory diseases
Field Assessment of Retrofitting Surface Coal Mine Equipment Cabs with Air Filtration Systems Organiscak-JA; Cecala-AB; Heitbrink-WA; Thimons-ED; Schnitz-M; Ahrenholtz-E | Proc 31st Annual Institute of Mining Health, Safety and Research, 2000, Aug 27-30 Virginia Polytechnic Institute and State University, Department of Mining and Minerals Engineering, 2000 Aug; :57-68	2000	Publication	Respiratory diseases
Foams for Dust Control Page-SJ; Volkwein-JC | Eng Min J 187(10):50-52, 54	1986	Publication	Respiratory diseases
Gas and Dust Control Kissell-FN | In: SME Mining Engineering Handbook. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc, 1992; :1004-1020	1992	Publication	Mine disasters; Respiratory diseases
Handbook for Dust Control in Mining NIOSH | NIOSH Pub No. 2003-147, IC 9465, 2003 Jun; :1-131	2003	Publication	Respiratory diseases

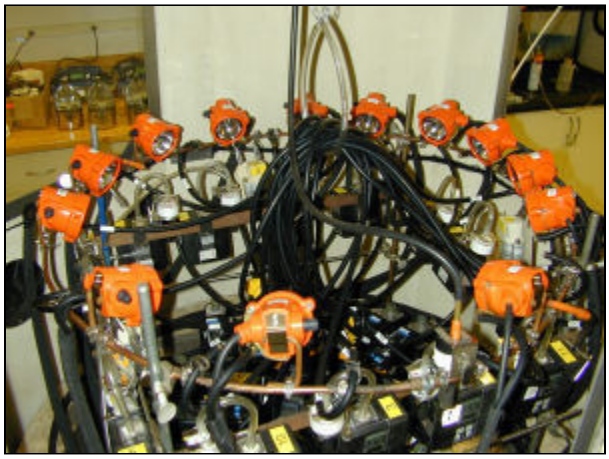
Title	Year	Output Type	Strategic Goal
How to Control Air Contaminants During Tunnel Construction Kissell-FN | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Information Circular 9439. NTIS stock number: PB96-147558, 1995	1995	Publication	All
Keystone Achieves Positive Dust Control During Dry Drilling Page-SJ; Folk-M | Eng Min J 185(9):84-85	1984	Publication	Respiratory diseases
Maintaining Filters, Bits Can Control Respirable Quartz Dust During Roof Drilling Divers-EF; Jankowski-RA | Coal Age, 1987 Feb; :57-59	1987	Publication	Respiratory diseases
Optimizing Continuous Miner Scrubbers for Dust Control in High Coal Seams Jayaraman-NI; Jankowski-RA; Whitehead-KL | In: Proceedings of New Technology in Mine Health and Safety Symposium. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc, 1992; :193-205	1992	Publication	Respiratory diseases
Silica Collection Concerns When Using Flooded-Bed Scrubbers Colinet-JF; Jankowski-RA | Mining Engineering 52(4) 2000; :49-54	2000	Publication	Respiratory diseases
Status of Dust Control Technology on U.S. Longwalls Colinet-JF; Spencer-ER; Jankowski-RA | In: Proceedings of the 6th International Mine Ventilation Congress, Ramani RV, ed., Chapter 55. Society for Mining, Metallurgy, and Exploration, Inc.: Littleton, CO, 1997; :345-351	1997	Publication	Respiratory diseases
Studies of Bit Wear and Respirable Dust Generation Organiscak-JA; Khair-AW; Ahmad-M | Trans Soc Min Eng, Vol. 298, Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.; :1874-1879	1996	Publication	Respiratory diseases
Technology news 118 - Lower Dust Exposure of Longwall Shearer Operator by Relocating the Machine Cooling Water Sprays USBM | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Technology News 118, 1981	1981	Publication	Respiratory diseases
Technology news 203 - How to Reduce Shearer Operators Dust Exposure by Using Remote Control USBM | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Technology News 203, 1984	1984	Publication	Respiratory diseases
Technology news 220 - How Twelve Continuous Miner Sections Keep Dust Levels at 0.5 mg/m3 or Less USBM | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Technology News 220, 1985	1985	Publication	Respiratory diseases
Use of Foam for Dust Control in Minerals Processing Volkwein-JC; Cecala-AB; Thimons-ED | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 8808. NTIS No. PB84-131184	1983	Publication	Respiratory diseases
Water Infusion for Coal Mine Dust Control: Three Case Studies McClelland-JA; Organiscak-JA; Jankowski-RA; Pothini-BR | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 9096. NTIS No. PB88-120514	1987	Publication	Respiratory diseases

Intermediate Outcome related to Reducing Coal Dust Exposures Through Improved Monitoring and Control

New Personal Dust Monitor Empowers Miners to Reduce Their Dust Exposure

Description of Problem

In 1996, the Secretary of Labor asked NIOSH to develop a better dust monitoring instrument for coal mining. At that time, the coal mine "personal sampler" had been in use for 30 years. It is a rugged and reasonably accurate instrument. However, because the inside filter must be weighed in a lab, there was always a delay of a week or more in getting results back to the mine operator. The miners themselves seldom had any knowledge of their dust exposure. This delay meant that miners could be exposed to excessive dust levels without having the chance to immediately correct the problem and avoid overexposures for the entire shift.



Certification of PDM accuracy in the PRL Laboratory Marple Dust Chamber

Research and Development Activities

Initial work to develop a better dust monitoring instrument focused on a machine-mounted area-sampling monitor. However, NIOSH found that this area-sampling instrument was inadequate for compliance sampling of operator dust exposure. NIOSH findings showed that there was no consistent relationship between personal sampling equipment worn by workers and area samples. (See the Intermediate Outcome entitled "NIOSH Establishes the Ineffectiveness of Area Dust Sampling as a Measure of Worker Exposure.")

The work was then redirected to develop a monitor that was small and light enough to be worn by the workers (called a personal dust monitor, or PDM), but which kept most of the functionality features of the area monitor. One of the most important of these features was the ability to read out the gravimetric dust level during the work shift and to predict the full-shift dust level if nothing changed in the mining situation. This allowed workers and mine management to immediately correct engineering dust controls to remedy high dust levels, thereby avoiding overexposure of the workers. At the end of the shift, the PDM data are downloaded into a computer and stored for future reference. The concept was to empower miners and mine management to do something about possible dust overexposures in real time. The dust monitor was built into a miner's cap lamp unit so that miners are putting on their dust monitors when they put on their cap lamps. This makes the PDM more user-friendly for the miners.

R&D Outputs and Transfer Activities

The PDM has undergone a great deal of technology transfer. It has been discussed in numerous papers, presentations, and workshops, both national and international. It has been demonstrated at recent Mine Safety and Health Administration (MSHA) dust hearings. Mockups have been provided for industry and United Mine Workers of America meetings. International PDM partnerships have been established with Australia and the Republic of South Africa. The PDM was recently given an R&D100 award as one of the nation's top 100 technical developments of the year. A PDM Coal Partnership has been established with members from industry, labor, and NIOSH to promote the PDM and to exchange information on the technology.

Description of Intermediate Outcome

In March 2003, MSHA proposed new rules on how coal dust is to be measured. These proposed rules incorporated the new PDM instrument under development by NIOSH (Federal Register, Vol. 68, No. 4, pages 10805, 10807, 10809, 10826, 10827, 10874, 10875, and 10879). However, in 2003, the instrument had not been fully tested. Because of this and for other reasons, MSHA announced a postponement of the proposed dust rule (Federal Register, Vol. 68, No. 128, July 3, 2003, Proposed Rules, pages 39881-39882). Since then, additional underground testing of the latest version of the PDM has been ongoing. Findings have been highly encouraging.

The PDM is now available as a commercial product (http://www.rpco.com). Orders from mines to purchase the device have been received by the manufacturer.

Outputs

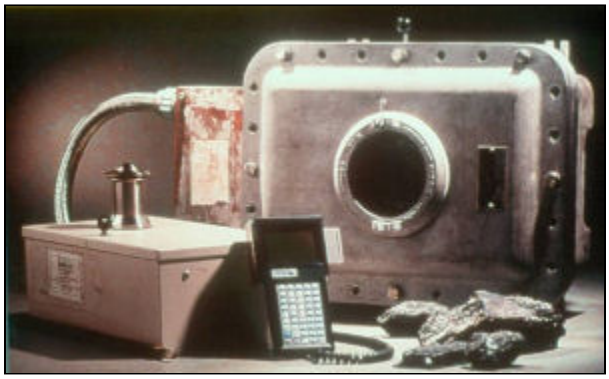
4 Outputs

Title	Year	Output Type	Strategic Goal
Analysis of Sampling Line Bias on Respirable Mass Measurement Peters-TM; Volkwein-JC | Appl Occup Environ Hyg 18(6); :458-465	2003	Publication	Respiratory diseases
Implementing a New Personal Dust Monitor as an Engineering Tool Volkwein-JC; Thimons-ED; Yanak-C; Dunham-D; Patashnick-H; Rupprecht-E | Coal Age 2004 Dec; 109(12):26-29	2004	Publication	Respiratory diseases
Performance of a New Personal Respirable Dust Monitor for Mine Use Volkwein-JC; Vinson-RP; McWilliams-LJ; Tuchman-DP; Mischler-SE | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2004-151, Report of Investigations 9663, 2004 Jun :1-25	2004	Publication	Respiratory diseases
State-of-the-Art in Monitoring Respirable Mine Aerosols Volkwein-JC; Thimons-ED; Timko-RJ; Hall-EE; Mischler-SE; Kissell-FN; Vinson-RP | In: Gillies ADS, ed. Proceedings of Eighth International Mine Ventilation Congress (Brisbane, Australia), AusIMM, Victoria, Australia, 2005; :151-156	2005	Publication	Respiratory diseases

Intermediate Outcome related to Reducing Coal Dust Exposures Through Improved Monitoring and Control

NIOSH Establishes the Ineffectiveness of Area Dust Sampling as a Measure of Worker Exposure

Description of Problem



NIOSH research showed area sampling was not indicative of worker dust exposures

In the mid-1980s, the Mine Safety and Health Administration (MSHA) initiated the development of a new kind of sampling instrument for measuring dust levels in coal mines - a machine-mounted respirable dust monitor (MMRDM). However, the MMRDM was more than a new sampling instrument. It also changed the location where samples are collected. The usual method of sampling for coal mine dust uses "personal sampling," i.e., equipment worn by the workers. The MMRDM, housed in a 160-pound box, had to be mounted in a fixed location. The general location being considered was on the mining equipment, such as fixed locations on continuous mining machines or on longwall shearers or longwall shields. Thus, it could only be used for sampling in a particular area. However, area sampling equipment does offer the benefits of providing more functionality and being less subject to possible tampering.

Developing the MMRDM was very controversial within the coal industry. The industry believed that it was likely to measure higher dust concentrations than the personal sampler. There were also serious questions about its accuracy.

Research and Development Activities

During 1998-1999, NIOSH did a number of underground studies to assess the viability of the MMRDM. Clusters of current conventional personal dust samplers were placed at locations typical of where MMRDMs might be mounted on mining equipment. Their dust concentration readings were compared with those from identical samplers worn by miners in the working face area of the mine. Results showed that there was no consistent relationship between personal sampling equipment worn by workers and area samples taken by the MMRDM on the mining machine. These data proved that the MMRDM would be inadequate for compliance sampling of operator dust exposure and gave little meaningful information about the actual dust exposure of workers.

R&D Outputs and Transfer Activities

A NIOSH report on this study was written, and the findings were first presented at MSHA headquarters. The findings were then provided to both industry and labor at a number of meetings to discuss the overall issue of improved coal dust sampling in underground coal mines. The results were also presented at national and international conferences, and published in a peer-reviewed journal.

Description of Intermediate Outcome

These findings were instrumental in getting MSHA, in the fall of 2000, to drop its 15-year long initiative to develop an MMRDM. Then, through an industry-labor-NIOSH partnership, a decision was made to turn all of the MMRDM resources toward developing a person-wearable real-time continuous dust monitor. This has resulted in the evolution of the personal dust monitor (PDM) over the past 5 years, a device that is showing great promise.

Outputs

2 Outputs

Title	Year	Output Type	Strategic Goal
Inaccuracy of Area Sampling for Measuring the Dust Exposure of Mining Machine Operators in Coal Mines Kissell-FN; Sacks-HK | Mining Engineering, 54(2), 2002 Feb; :33-39	2002	Publication	Respiratory diseases
Test Report on the Machine-Mounted Continuous Respirable Dust Monitor Kissell-FN; Thimons-ED | Proc Seventh International Mine Ventilation Congress, 2001, (Krakow, Poland); :253-260	2001	Publication	Respiratory diseases

Intermediate Outcome related to Reducing Coal Dust Exposures Through Improved Monitoring and Control

Reducing Miners' Dust Exposure Through the Use of Confining Sprays for Flooded-bed Scrubbers

Description of Problem

Side sprays positioned on each side of the frame of the continuous mining machine

Some flooded-bed scrubbers on continuous mining machines have poor inlet dust capture efficiencies. This results in higher dust levels for workers at the face of the mine. High inlet dust capture efficiency means that the scrubber captures a high proportion of the dust generated by the miner cutting the coal. Most continuous miners have a flooded-bed scrubber that pulls dust-laden air through multiple inlets located on the underside of the cutting boom. Dust is then scrubbed out of the air by passing the air through a filter that is continuously wetted by water sprays. The cleaned air is then discharged at the rear of the continuous miner. As coal is cut and loaded, a dust cloud forms beneath the cutting boom. An efficiently designed ventilation and scrubber system will result in the capture of most of the dust cloud by the scrubber inlets. If the water spray system and ventilation system are properly designed, the dust cloud will be confined near the scrubber inlets, leading to high inlet dust capture efficiency.

Unfortunately, in many continuous mining operations, forward air velocities are minimal. This allows the dust cloud to bypass the inlets and move in an outby direction toward the miner operator. The problem is exaggerated in higher-seam operations where the cutting boom confinement is less and the open area over the miner is greater.

Research and Development Activities

NIOSH research explored alternative methods to improve scrubber inlet dust capture efficiency at low face air velocities. Field studies in 1999 showed that strategically placed water sprays (confining sprays) could confine dust beneath the cutting boom, leading to improved capture of the dust cloud by the scrubber inlets. Placed near the hinge point of the cutting boom, these sprays induce additional airflow along the chassis of the continuous mining machine to limit outby movement of the dust cloud and to allow sufficient time for the dust cloud to be captured

by the scrubber inlets. NIOSH lab testing of this concept allowed for further improvements and further confirmed that a well-designed confining spray system could greatly increase dust capture by scrubber systems. The resulting benefit is lower dust exposures for miners in the face area.

R&D Outputs and Transfer Activities

NIOSH researchers distributed these findings through a number of forums. The research was published in a peer-reviewed journal and presented at several major mining conferences. The information was also presented to the United Mine Workers of America at training sessions for their mine safety representatives.

Description of Intermediate Outcome

A major continuous mining machine manufacturer, at the request of several mine operators, will now provide blocking spray systems on its continuous mining machines when requested. This technology has been accepted by the industry. Dozens of continuous miners now have such sprays as part of their standard spray system, either provided as original equipment or installed by the mine.

Outputs

1 Output

Title	Year	Output Type	Strategic Goal
Using Water Sprays to Improve Performance of a Flooded-Bed Dust Scrubber Goodman-GV | Applied Occupational and Environmental Hygiene; 15(7), 2000 Jul; 550-560	2000	Publication	Respiratory diseases

Strategic Program Outcome for Respiratory Diseases

Reducing Silica Exposures in Mining Through Improved Control Technologies

In the past 15 years, significant gains in fighting silicosis have been realized across the mining industry, as shown below:

	Percent of samples exceeding permissible exposure limit	
	1990-1994	2000-2004
Coal	27	17
Metal	26	17
Nonmetal	27	19
Stone	22	11
Sand and gravel	18	11

These gains are due in large part to the development of new dust control technology by NIOSH. Of course, new technology was not solely responsible for these improvements. Strong enforcement by the Mine Safety and Health Administration (MSHA) and changing attitudes within the mining industry were vital. Nevertheless, NIOSH made a critical contribution by providing many of the engineering control tools that made these gains possible.

Research on silica controls has involved two unique challenges that made it different from coal dust research. First, a wide variety of industries had a silica problem. This ruled out "one technology fits all" solutions. The second challenge was the low dust levels that had to be attained. It is not unusual to have a mixed dust permissible exposure limit (PEL) of 0.5 mg/m3 or less. These levels can be hard to meet, especially in underground mining.

Over the years, NIOSH has worked to stay ahead of the problem in various ways. MSHA routinely analyzes inspector samples for silica content. NIOSH periodically reviews the MSHA data to identify occupations/areas of excessive silica exposure and refocuses control research in these areas. In this way, the highest exposure occupations in mining are addressed by NIOSH research.

For example, in underground coal mining, occupations that are involved with drilling into rock surrounding the coal seam are typically at the highest silica exposure risk. For roof bolter operators, 25% of samples exceeded the PEL from 1990 to 2004. NIOSH research has shown that roof bolter operators get exposed to silica dust that is released by the roof bolting machine. However, most of their exposure comes from working downwind of the continuous mining machine. Research to provide a clean air source for bolter operators when working downwind of the continuous mining machine has led to the development of a canopy air curtain system. This air curtain is mounted to the underside of the bolter canopies and is above the bolter operator while drilling is ongoing. The air curtain filters a portion of the air entering the bolter entry and blows the cleaned air down over the breathing zone of the bolter operator. Lab testing showed that a 60% reduction in dust (silica) levels could be achieved beneath the air curtain. Results of subsequent underground testing have been promising. A major manufacturer of roof bolters has requested to work with NIOSH to further refine this system for commercialization on its machines.

Another high-risk occupation is that of highwall drill operators at surface mines. During 1990-2004, 36% of samples from these workers exceeded the PEL. To reduce dust for these workers, our research has identified deficiencies in the "Rotoclone" type of dust collector on drills, improved the efficiency and established maintenance procedures for dry collectors, and reduced dust emissions from secondary sources. Significant research has also been done over the last few years to improve the protection given by enclosed cabs on mobile mining equipment. Intervention studies have shown that appropriate filtration systems along with improving cab sealing can reduce dust levels in the cab by 90% or more. Key implementation and operating parameters were identified in this cab research and compiled into a video that shows these parameters. MSHA has placed this video on its website as a tool for mine workers. In addition, NIOSH personnel have worked with a filter manufacturer to develop a new methodology for field testing cab filtration systems for leakage. This test can be done in less than 30 minutes in the field, and a patent application has been filed. This technology will allow mine personnel and mine inspectors to quickly and accurately evaluate the dust (silica) protection provided by cabs.

In processing mills, during 1990-1994, 38% of bagging operator samples exceeded the PEL. As a result of these high exposures, NIOSH conducted research that led to the development of an improved nozzle design for loading bags, a bag and belt cleaner that removes dust from the outside of the bags, an overhead air supply island (OASIS) that provides filtered airflow for workers, and a total mill ventilation system that reduces ambient dust levels throughout a plant. These technologies have been widely accepted and implemented throughout the industry. The bag-filling nozzle has become the standard technology used by the industry, while two different manufacturers are building the bag-cleaning system. These control technologies have been summarized in a compilation of publications on minerals processing dust control that has been widely distributed. In 2002, the Occupational Safety and Health Administration placed this compilation of reports on its website for companies seeking to improve silica dust control. A major manufacturer recently requested copies of this compilation and, at its own expense, had it translated into Spanish for its operations in Mexico.

NIOSH has also developed a new method for cleaning dust from workers´ clothes. A worker´s exposure can increase by as much as 1 mg/m3 from dust liberated by soiled work clothes. For workers in silica sand plants, this means that their silica exposure, just from soiled work clothing, is 10 times over the allowable limit. Currently, MSHA requires that workers use a vacuum to remove dust from their clothing. This method is time-consuming, difficult, and inefficient. Working in partnership with a silica sand plant, NIOSH developed and tested a clothes-cleaning system that uses compressed air nozzles to blow dust from workers´ clothes in a cleaning booth. The worker is required to wear a respirator, goggles, and hearing protection during the process. Field testing at the silica plant showed that the clothes-cleaning booth was 10 times faster and 50% more efficient in removing dust from soiled clothes compared to the vacuuming method. Using compressed air for clothes cleaning is not currently accepted by MSHA. However, the silica sand producer has received a petition for modification with MSHA in order to use this method in its U.S. plants. The company is also pursuing installation of these cleaning booths in its plants abroad. Several other companies are now preparing petitions for modification to allow them to implement the system in their operations.

Intermediate Outcomes

- Compilation of Minerals Processing Publications Assists Industry with Implementing Effective Dust Control Technologies
- Engineering Control Technologies Reduce Drill Operator Dust Exposure
- Improvements in Mobile Equipment Cabs to Reduce Dust Exposure
- New Clothes-Cleaning Method Reduces Worker Silica Exposure

Intermediate Outcome related to Reducing Silica Exposures in Mining Through Improved Control Technologies

Compilation of Minerals Processing Publications Assists Industry with Implementing Effective Dust Control Technologies

Description of Problem

In mineral processing plants, workers do many different job functions and tasks that expose them to high concentrations of respirable dust. When the product being processed at these operations contains silica, the health hazard to workers can be even more serious since allowable silica exposures are 20 times lower than respirable coal dust levels. A significant problem for the industry has been the lack of a single source of information that provides practical control solutions to lower respirable dust exposures to these workers.

The OASIS system provides filtered air for plant worker

Research and Development Activities

NIOSH has developed many practical dust control technologies that have been recognized by the minerals processing industry as effective for lowering workers' respirable dust exposures. Some examples of these are the dual-bag nozzle system and the overhead air supply island system (OASIS). These were developed to lower the respirable dust exposure of workers performing bag-loading processes. A bag and belt cleaning device and automated and semiautomated palletizing systems were developed and/or tested by NIOSH to lower the respirable dust exposures of workers performing the bag-stacking process. NIOSH also designed the total mill ventilation system to lower the respirable dust exposure to all workers throughout an entire mineral processing plant.

In the past, information on dust control technology for minerals processing, most of which was developed by NIOSH or the former U.S. Bureau of Mines (USBM), was available only by reviewing a vast array of publications. These included various conference proceedings papers, journal articles, and NIOSH and USBM publications. NIOSH has since combined the various individual reports and papers written over the years into a single compilation. The dust control technology contained within this compilation has been accepted by the industry to successfully lower respirable dust exposures to workers performing various job functions. By combining this varied information on NIOSH-developed and tested control technologies into a single compilation, NIOSH provided the industry with a convenient, single source of information to lower respirable

dust exposures to its workers. While years of research effort went into developing the control technologies presented in the compilation, its actual preparation required minimal work other than organizing the information into the most user-friendly format. As new findings on practical and economically viable controls result from NIOSH research, the relevant published reports are added to the compilation. In general, the compilation of publications is updated every 2 to 3 years, depending on stakeholder need.

R&D Outputs and Transfer Activities

At least six of the control technologies described in the compilation have been developed into commercial products by manufacturers and are available to the industry. Most of the NIOSH-developed techniques listed in this compilation are being used by the industry and are considered by the industry to be practical and economically viable dust control technologies. To facilitate technology transfer, NIOSH researchers, when giving presentations at conferences, workshops, and industry meetings, make attendees aware of this compilation of reports and distribute it to interested customers. NIOSH also makes copies of the compilation available to industry associations and labor unions. A minimum of 500 copies have been distributed to industry-related individuals. No information is available on how many copies have been reproduced by individuals outside of NIOSH or how many copies have been accessed through the Web.

Description of Intermediate Outcome

Fifty to sixty copies of this compilation of publications are normally requested annually by industrial health and safety personnel. In 2002, the Occupational Safety and Health Administration (OSHA) posted it on its website (http://www.osha.gov/SLTC/silicacrystalline/dust/). Unimin Corp., the largest U.S. silica sand producer with operations throughout the world, has been distributing this compilation to its health and safety personnel throughout the corporation. In an effort to effectively distribute this information to its Spanish-speaking operations throughout the world, Unimin has recently decided to have the compilation translated into Spanish at the company's own expense.

At the 1997 National Conference to Eliminate Silicosis held in Washington DC, the plant manager from U.S. Silica's Mill Creek Facility discussed engineering controls used in his facility to reduce respirable dust exposures to workers. Of the dozen dust control techniques that he presented, eight were developed by NIOSH or the USBM and are included in the minerals processing compilation of publications. Since this conference, other dust controls have been developed and tested, and the relevant published papers describing them have been added to the compilation.

More than 100,000 individuals work in minerals processing operations throughout the United States. The control technologies presented in this compilation can reduce exposures to respirable dust and silica from 30% to 90%. Thus, the potential health impact of the information contained in the compilation is evident.

Outputs

46 Outputs

Title	Year	Output Type	Strategic Goal
Acoustical Considerations in the Design of Minerals Processing Plants Burks-JA; Rider-JP; Cecala-AB | In: Proceedings of the 1998 National Conference on Noise Control Engineering (Noise-Con 98), 1998; :443-448	1998	Publication	Hearing loss; Respiratory diseases
Adding Foam to Control Dust in Minerals Processing Volkwein-JC; Cecala-AB; Thimons-ED | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 8808	1983	Publication	Respiratory diseases
Automation to Control Silica Dust During Pallet Loading Cecala-AB; Covelli-A | Min Eng 43(12):1440-1443	1991	Publication	Respiratory diseases
Automation to Control Silica Dust During Pallet Loading Process Cecala-AB; Covelli-A | SME preprint 90-28. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc; :1-5	1990	Publication	Respiratory diseases
Bag and Belt Cleaner Reduces Employee Dust Exposure Cecala-AB; Timko-RJ; Prokop-AD | Rock Prod 100 (3),1997 Mar; :41-43	1997	Publication	Respiratory diseases
Closing the Door on Dust - Dust Exposure of Bag Operator and Stackers Compared for Commercial Bag Valves Cecala-AB; Muldoon-T | Pit quarry 78(11); :36-37	1986	Publication	Respiratory diseases
Dust Control in Coal Prep and Mineral Processing Plants Divers-EF; Cecala-AB | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Information Circular 9248	1990	Publication	Respiratory diseases
Dust control in Coal Preparation and Mineral Processing Plants Cecala-AB; Divers-EF | In: Proceedings of 1990 Joint Power Generation Conference	1990	Publication	Respiratory diseases
Dust Reduction Capabilities of Five Commercial Bag Valves Cecala-AB; Covelli-A; Thimons-ED | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines Information Circular 9068	1986	Publication	Respiratory diseases
Evaluation of a Local Exhaust Ventilation System for Controlling Refractory Ceramic Fibers During Disc Sanding Dunn-KH; Shulman-SA; Cecala-AB; Venturin-DE | J Occup Environ Hyg 2004. 2004 Oct 1(10):D107-111	2004	Publication	Mine disasters
General Ventilation Reduces Mill Dust Concentrations Cecala-AB; Mucha-R | Pit quarry 84(1):48-53	1991	Publication	Respiratory diseases
Impact of Background Sources on Dust Exposure of Bag Machine Operator Cecala-AB; Thimons-ED | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Information Circular 9089	1986	Publication	Respiratory diseases
Improved Dust Control for Bag Handlers Cecala-AB; Zimmer-JA; Smith-B; Viles-S | Rock Products 2000 Apr 103(4); :46-49	2000	Publication	Respiratory diseases
Industrial Hygiene from Mining Research: Three Cost-Effective Dust Control Techniques for Mineral Processing Operations Cecala-AB | Appl Ind Hyg J 3(8); :23-25	1988	Publication	Respiratory diseases
Lowering Respirable Dust Exposures at Mineral Processing Facilities Cecala-AB; Timko-RJ; Thimons-ED | In: Proceedings of the Eighth U.S. Mine Ventilation Symposium, Tien JC, ed., Rolla, MO: University of Missouri-Rolla Press,1999; :221-227	1999	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
Lowering Respirable Dust Exposures at Mineral Processing Facilities Cecala-AB; Timko-RJ; Thimons-ED | In: Proceedings of 104th Annual Northwest Mining Association Conference (Spokane, WA, December 1998)	1998	Publication	Respiratory diseases
Methods to Lower Dust Exposures at Mineral Processing Operations Cecala-AB; Daniel-JH; Thimons-ED | Appl Occupational and Environmental Hygiene 11(7), 1996; :854-859	1996	Publication (guidelines)	Respiratory diseases
Methods to Lower Dust Exposures at Mineral Processing Operations Cecala-AB; Thimons-ED | In: Proceedings of National Stone Association's 1997 Environmental Safety and Health Forum, 1997; :231-249	1997	Publication (guidelines)	Respiratory diseases
Methods to Lower the Dust Exposure of Bag Machine Operators and Bag Stackers Cecala-AB; Timko-RJ; Thimons-ED | Applied Occupational Environmental Hygiene 2000 Oct; 15(10):751-765	2000	Publication	Respiratory diseases
Moisture Application for Dust Control Volkwein-JC; Cecala-AB; Thimons-ED | Appl Ind Hyg J 4(8):198-200	1989	Publication	Respiratory diseases
New Bag Nozzle System Reduces Dust From Fluidized Air Bag Machines Cecala-AB; Volkwein-JC; Thimons-ED | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 8886	1984	Publication	Respiratory diseases
New Bag Nozzle System Reduces Dust Generated During Bag Filling Cecala-AB; Muldoon-T | Rock Prod Jul; :32-33	1985	Publication	Respiratory diseases
New Dual-Bag Nozzle System Cecala-AB; Thimons-ED | Ceram Eng Sci Proc 10(1-2); :36-41	1989	Publication	Respiratory diseases
NIOSH Hazard Controls 31: Dust Protection for Bag Stackers NIOSH | Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, HC 31, DHHS (NIOSH) Publication No. 2001-142, 2001 Jul :1-4	2001	Publication	Respiratory diseases
Pallet Loading Dust Control System Cecala-AB; Covelli-A | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 9197	1988	Publication	Respiratory diseases
Reducing Bag Operator's Dust Exposure in Mineral Processing Plants Cecala-AB; Volkwein-JC; Daniel-JH | Appl Ind Hyg J 3(1); :23-27	1988	Publication	Respiratory diseases
Reducing Bag Operator's Dust Exposure in Mineral Processing Plants Cecala-AB; Volkwein-JC; Daniel-JH | In: Proceedings of the Seventh International Pneumoconioses Conference (Pittsburgh, PA, August 23-26, 1988). Part 2. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 90-108; :996-1000	1990	Publication	Respiratory diseases
Reducing Dust Exposure of Workers During Bag Stacking in Enclosed Vehicles Cecala-AB; Covelli-A; Thimons-ED | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Information Circular 9148	1987	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
Reducing Respirable Dust Concentrations at Mineral Processing Facilities Using Total Mill Ventilation System Cecala-AB; Klinowski-GW; Thimons-ED | SME preprint 94-27. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc; :1-5	1994	Publication	Respiratory diseases
Reducing Respirable Dust Concentrations at Mineral Processing Facilities Using Total Mill Ventilation Systems Cecala-AB; Thimons-ED; Klinowski-GW; | Mining Engineering 47(6), 1995; :575-576	1995	Publication	All
Reducing Respirable Dust Concentrations at Mineral Processing Facilities Using Total Mill Ventilation Systems Cecala-AB; Klinowski-GW; Thimons-ED | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, RI 9469, 1993 Jan; :1-11	1993	Publication	Respiratory diseases
Reducing Respirable Dust Levels During Bag Conveying and Stacking Using Bag and Belt Cleaner Device Cecala-AB; Timko-RJ; Prokop-AE | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 9596. NTIS stock number: PB96-135470	1995	Publication	All
Reducing Silica Exposure in Aggregate Operations Cecala-AB; Organiscak-JA; Page-SJ; Thimons-ED | Aggregates Manger 2005 Jan; :24-28	2002	Publication (guidelines)	Respiratory diseases
Reducing Workers Dust Exposure During Bag Stacking in Enclosed Vehicles Cecala-AB; Covelli-A; Thimons-ED | Am Ind Hyg Assoc J 50(2); :99-104	1989	Publication	Respiratory diseases
Respirable Dust Evaluation of Two Portland Cement Operations: Part 1 of 2 Cecala-AB; Timko-RJ; Zimmer-JA; Thimons-ED | Cement Americas 2000 Jan/Feb; :20-23	2000	Publication	Respiratory diseases
Respirable Dust Evaluation of Two Portland Cement Operations: Part 2 of 2 Cecala-AB; Timko-RJ; Zimmer-JA; Thimons-ED | Cement Americas 2000 Mar/Apr; :28-30	2000	Publication	Respiratory diseases
Significant Dust Exposures from Background Sources Cecala-AB; Thimons-ED | Pit quarry 79(12); :46-51	1987	Publication	Respiratory diseases
Some Factors Impacting Bag Operator's Dust Exposures Cecala-AB; Thimons-ED | Pit quarry 85(5):38-40	1992	Publication	Respiratory diseases
Steam Reduces Dust Levels at Mineral Processing Plant Cecala-AB; Volkwein JC; Thimons-ED | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 8935, 1985	1985	Publication	Respiratory diseases
Supplementing Your Dust Control Equipment with Whole-Plant Ventilation Cecala-AB | Powder and Bulk Eng, 12(1), 1998 Jan; :19-32	1998	Publication	Respiratory diseases
Technology news 207 - New Bag Nozzle System Reduces Dust During Bagging Operations USBM | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Technology News 207, 1984	1984	Publication	Respiratory diseases
Technology news 240 - Reduce Dust Exposure During Bag Filling and Stacking USBM | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Technology News 240, 1986	1986	Publication	Respiratory diseases
Technology news 299 - Reduce Bagging Machine Operator's Dust Exposure by Controlling Background Dust Sources USBM | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Technology News 299, 1988	1988	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
Technology news 328 - New Pallet Loading System Lowers Worker's Dust Exposure and Improves Bag Stacking Process USBM | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Technology News 328, 1989	1989	Publication	Respiratory diseases
Technology News 437 - Total Mill Ventilation System for Mineral Processing Facilities USBM | US Bureau of Mines, Technology News 437, 1994 May; :1-2	1994	Publication	Mine disasters
Tips for Reducing Dust from Secondary Sources During Bagging Cecala-AB; Thimons-ED | Powder and Bulk Eng 7(5):77-84	1993	Publication	Respiratory diseases

Intermediate Outcome related to Reducing Silica Exposures in Mining Through Improved Control Technologies

Engineering Control Technologies Reduce Drill Operator Dust Exposure

Description of Problem

Visible dust reduction using a wet drilling technique to drill overburden blast holes

Dust exposures at surface mines often exceed allowable levels, particularly the exposure of drill operators. During 1985-1992, 77% of drill operator silica dust samples at surface mines exceeded the permissible exposure limit. This serious overexposure to silica indicated the need for vigorous research to reduce dust at surface mine drilling operations to reduce the exposures of drill operators and helpers to acceptable levels. To make the research findings acceptable to the industry, it was necessary to develop control technologies that were economically viable for the industry to implement.

Research and Development Activities

NIOSH has conducted several projects to develop technologies to reduce dust at surface mine drill sites. These include studies to (1) measure the dust collection efficiency of the commonly used "Rotoclone" dust collector, (2) establish the optimum water flow rates for wet drilling, (3) establish the dust reductions obtained with better maintenance of dry collectors, (4) improve the dust capture efficiency of the dust collection system, (5) reduce the secondary dust emissions from the dust collection system, and (6) identify the impact of dust collection system malfunctions and to allow mine operators to evaluate the performance of drill dust collection systems. To the greatest extent possible, all of this research was carried out in partnership with equipment manufacturers and mining companies to facilitate the eventual transfer of the developed technologies to the industry.

R&D Outputs and Transfer Activities

Research results were transferred through peer-reviewed publications, trade journals, Technology News flyers, and conference presentations. NIOSH produced an educational pamphlet entitled "Silica...It's Not Just Dust." This pamphlet won the U.S. Public Health Service Engineering Literary Award in 1998 and helped to educate drillers about the hazards of silica dust. NIOSH is requested annually by the United Mine Workers of America to present surface mine research results to mine personnel at the Mine Safety and Health Academy near Beckley, WV. In addition, NIOSH personnel are routinely requested to give presentations to surface mine personnel in MSHA regions, particularly where silica exposures are highest.

Description of Intermediate Outcome

Dust samples exceeding the exposure limit dropped from 77% during 1985-1992 to 31% during 1996-2000. NIOSH research was an important contributor to this reduction. For example, NIOSH showed that Rotoclone dust collectors, a commonly used device, were not satisfactorily controlling operator exposure and that simple improvements could be made to reduce dust levels around the drill rigs. These results were cited by Marvin Nichols, then the Administrator for Coal Mine Safety and Health in MSHA, in an agency memorandum regarding procedures for assessing compliance with 30 CFR 72.620. MSHA now prohibits Rotoclone collectors at surface coal mines. MSHA also used NIOSH research results in a 1998 court case for civil penalty proceedings against a mining company (MSHA v. Hobet Mining, docket Nos. WEVA 96-170, 185, 178; 97-33. August 31, 1998).

Outputs

24 Outputs

Title	Year	Output Type	Strategic Goal
Assessment of Airborne Dust Generated From Small Truck-Mounted Rock Drills Organiscak-JA; Page-SJ | USBM, RI 9616. NTIS stock number: PB96-155098, 1995 :1-11	1995	Publication	Respiratory diseases
Characteristics of Fugitive Dust Generated from Unpaved Mine Haulage Roads Organiscak-JA; Reed-WR | Int J Surface Min Reclam Environ 18(4)2004; :236-252	2004	Publication	Respiratory diseases
Current NIOSH Dust Control Research for Noncoal Surface Mines Cecala-AB; Organiscak-JA; Page-SJ; Heitbrink-WA; Thimons-ED | Proc National Stone, Sand & Gravel Association Environment, Safety & Health Forum 2001 Sept Arlington, VA: National Stone, Sand & Gravel Association, 2001; :87-100	2001	Publication	Respiratory diseases
Development of a Dust Collector Inlet Hood for Enhanced Surface Mine Drill Dust Capture Organiscak-JA; Page-SJ | Int J Surface Min Reclam Environ 19(1):12-28	2005	Publication	Respiratory diseases
Dust Underfoot: Enclosed Cab Floor Heaters Can Significantly Increase Operator's Respirable Dust Exposure Cecala-AB; Organiscak-JA; Heitbrink-WA | Rock Products 2001 Apr; 104(4):39-44	2001	Publication	Respiratory diseases
Evaluation of Dust Exposure to Truck Drivers Following the Lead Haul Truck Reed-WR; Organiscak-JA | SME preprint 05-10. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2005; :1-9	2005	Publication	Respiratory diseases
Field Assessment of Control Techniques and Long-Term Dust Variability for Surface Coal Mine Rock Drills and Bulldozers Organiscak-JA; Page-SJ | International Journal of Surface Min Reclam Environ, 13 1999; :165-172	1999	Publication	Respiratory diseases
Handbook for Dust Control in Mining NIOSH | NIOSH Pub No. 2003-147, IC 9465, 2003 Jun; :1-131	2003	Publication	Respiratory diseases
New Approach Controls Dust at the Collector Dump Point: NIOSH Finds a Simple, Cost-Effective Solution for Reducing Dust for Blasthole Drills Reed-WR; Organiscak-JA; Page-SJ | Eng Min J 204(7), 2004; :29-31	2004	Publication	Respiratory diseases
New Approach Controls Dust at the Collector Dump Point: NIOSH Finds a Simple, Cost-Effective Solution for Reducing Dust for Blasthole Drills Reed-WR; Organiscak-JA; Page-SJ | Coal Age 2004 109(6), 2004 Jun; :20-22	2004	Publication	Respiratory diseases
NIOSH Hazard Controls 27 - New Shroud Design Controls Silica Dust from Surface Mine and Construction Blast Hole Drills Page-SJ; Organiscak-JA; Flesch-JP; Hagedorn-RT | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 98-150, 1998 Nov; : 1-4	1998	Publication	Respiratory diseases
NIOSH/Industry Collaborative Efforts Show Improved Mining Equipment Cab Dust Protection Organiscak-JA; Cecala-AB; Thimons-ED; Heitbrink-WA; Schmitz-M; Ahrenholtz-E | In: Yernberg WR, ed. Transactions of Society for Mining, Metallurgy, and Explorations, Inc., Vol. 314. Littleton, CO: Society for Mining, Metallurgy, and Explorations, Inc., 2003; :145-152	2003	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
Reducing Enclosed Cab Drill Operator's Respirable Dust Exposure at a Surface Coal Operation Using a Retrofitted Filtration and Pressurization System Cecala-AB; Organiscak-JA; Heitbrink-WA; Zimmer-JA; Fisher-T; Gresh-RE, et al. | In: Yernberg WR, ed. Transactions of Society for Mining, Metallurgy, and Explorations, Inc. Vol. 314. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc; :31-36	2003	Publication	Respiratory diseases
Reducing Silica Exposure in Aggregate Operations Cecala-AB; Organiscak-JA; Page-SJ; Thimons-ED | Aggregates Manger 2005 Jan; :24-28	2002	Publication (guidelines)	Respiratory diseases
Retrofit Options for Better Dust Control Chekan-GJ; Colinet-JF | Aggregates Manag 8(9); :9-12	2003	Publication (guidelines)	Respiratory diseases
Semiempirical Model for Predicting Surface Coal Mine Drill Respirable Dust Emissions Page-SJ; Organiscak-JA | Int J Surface Min Reclam Environ 18(1), 2004; :42-59	2004	Publication	Respiratory diseases
Silica...It's Not Just Dust MSHA, OSHA, NIOSH | Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, HC27, DHHS (NIOSH) Publication No. 97-118	1997	Publication	Respiratory diseases
Static Pressure Requirements for Ventilated Enclosures Heitbrink-WA; Thimons-ED; Organiscak-JA;, Cecala-AR; Schmitz-M; Ahrenholtz-E | In: Progress in Modern Ventilation. Vol 2. Proceedings of the Ventilation 2000 - 6th International Symposium on Ventilation for Contaminant Control [Helsinki, Finland, June 4-7, 2000). Helsinki, Finland: Finnish Institute of Occupational Health; :97-99	2000	Publication	Respiratory diseases
Taming the Dust Devil: an Evaluation of Improved Dust Controls for Surface Coal Mine Drills Using Rotoclone Collectors Page-SJ; Organiscak-JA | Eng Min J 196(11); :30-31	1995	Publication	Respiratory diseases
Technology News 447 - Dust Collector Discharge Shroud Reduces Dust Exposure to Drill Operators at Surface Coal Mines USBM | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Technology News 447, 1995	1995	Publication	Respiratory diseases
Technology News 485 - Improved Cab Air Inlet Location Reduces Dust Levels and Air Filter Loading Rates NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 485, 2001 Feb :1-2	2001	Publication	Respiratory diseases
Technology News 487 - Sweeping Compound Application Reduces Dust From Soiled Floors Within Enclosed Operator Cabs NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 487, 2001 Mar :1-2	2001	Publication	Respiratory diseases
The Effects of Low Quartz Mass Loading and Spatial Variability on the Quartz Analysis of Surface Coal Mine Dust Samples Page-S; Organiscak-J; Mal-T | Appl Occup Environ Hyg 16(9), 2001 Sept; :910-923	2001	Publication	Respiratory diseases
Validation of a Dust Dispersion Model for Haul Trucks Reed-WR | Trans Soc Min Metal Explor. Vol. 316. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc; :163-170	2004	Publication	Respiratory diseases

Intermediate Outcome related to Reducing Silica Exposures in Mining Through Improved Control Technologies

Improvements in Mobile Equipment Cabs to Reduce Dust Exposure

Description of Problem

Cabs on mobile equipment at surface mines, particularly older equipment, provide little, if any, dust protection. Many cabs are not properly designed for dust control in the first place. As the cabs age, the seals around the doors and at locations where controls enter the body of the cab degrade. This allows dusty air to enter the cab. In addition, for a cab to provide meaningful dust protection, positive air pressurization within the cab is needed. Few older cabs, and many new cabs, cannot maintain this positive air pressurization. Mobile equipment (such as drills, graders, loaders, dozers, and trucks) operate at surface mines and construction sites throughout the United States. Workers in the cabs are often overexposed to respirable dust and silica. For example, data from the Mine Safety and Health Administration (MSHA) have shown a 9% silicosis rate in central Pennsylvania surface coal miners. Many of these miners work in cabs.

Cab filtration and pressurization systems prevent dust from penetrating cabs reducing respirable dust exposure

Research and Development Activities

NIOSH began collaborating with MSHA, mine operators, and equipment manufacturers to find the most cost-effective ways to improve dust protection in cabs. While most of this work was done at actual field sites, some of it included lab studies at the Pittsburgh Research Laboratory and at cooperator facilities. In nine NIOSH field demos, economical and viable ways to improve dust protection for workers in enclosed cabs have been shown. NIOSH researchers, in partnership with mining companies and equipment suppliers of filtration systems and assisted by MSHA, showed that cabs providing almost no dust protection could show major improvements when simple changes were made to the cab. The two most important factors needed to achieve low dust levels were an efficient air filtration system (high-efficiency intake and recirculation filters) and an effectively sealed (tight) cab for positive inside cab pressurization. In most cases, the overall cost of the improvements was less than $5,000. In addition, the introduction of efficient filtration systems on the cabs was usually accompanied by putting good air conditioning and heating systems on at the same time. Miners are thus more comfortable in their cabs and are more apt to keep the cab doors closed. This further protects them from outside dust. Results of the field demos showed that a 90% reduction in respirable dust could

be achieved if proper cab filtration was applied and air leaks in the cab were reasonably sealed by replacing door seals and patching up holes in the body of the cab. In most cases, the improvements yielded a cab average silica dust level below 100 µg/m^3 (the silica or quartz permissible exposure limit) at moderate to high outside dust levels.

R&D Outputs and Transfer Activities

NIOSH published these findings in peer-reviewed journals, trade journals, and conference proceedings. Trade journals and conferences were selected to reach the appropriate target audience. Technical presentations were made at conferences and at mine corporate safety and health meetings A video that gives guidelines for effectively protecting cabs was also produced. The video is now available from the MSHA Catalog of Training Products for the Mining Industry (http://www.msha.gov/TRAINING/prodintr.htm). Hundreds of copies of the video have been distributed to mining companies around the world. Major unions, such as the United Steelworkers of America and the International Union of Operating Engineers, have requested copies of the video. Trade organizations such as the Industrial Minerals Association-North America and the National Stone, Sand & Gravel Association, have also asked for the video.

Description of Intermediate Outcome

One project collaborator, a filter supplier, saw an aftermarket develop for the use of its retrofit intake filtration pressurization systems for mining and related (construction) equipment cabs. While NIOSH has not been able to get any sales numbers, the supplier continues to offer the systems after several years and continues to work with NIOSH in further improving cab dust control.

MSHA dust sampling data from surface mines now show a meaningful reduction in the fraction of workers overexposed to silica. From 1991 to 2004, drill operator exposures fell by 30%, bulldozer operators by 46%, scraper operators by 75%, refuse truck drivers by 75%, and front-end loader operators by 33%. The overall reduction was 40%. While we do not have a good feel for how many cabs have been changed because of this research, we believe, based on industry and labor interest in the findings, that improved cabs account for some of the improvement. Although engineering controls developed through NIOSH research have clearly played a role in this reduction, the education of workers and the enforcement of dust standards have also been essential. This cab research, along with other NIOSH research on surface mine dust control, have provided industry, labor, and MSHA with control technologies that have contributed to this reduction. Surface coal miners and heavy construction workers can all benefit from this NIOSH-developed cab technology.

Outputs

11 Outputs

Title	Year	Output Type	Strategic Goal
An Evaluation of Cab Filtration and Pressurization Systems: Two Case Studies Chekan-GJ; Cecala-AB; Colinet-JF | In: Proceedings of the Environment, Safety & Health Forum and Expo (Phoenix, AZ, Sept. 22-24, 2003). Alexandria, VA: National Stone, Sand & Gravel Association, 2003; :114-129	2003	Publication	Respiratory diseases
Current NIOSH Dust Control Research for Noncoal Surface Mines Cecala-AB; Organiscak-JA; Page-SJ; Heitbrink-WA; Thimons-ED | Proc National Stone, Sand & Gravel Association Environment, Safety & Health Forum 2001 Sept Arlington, VA: National Stone, Sand & Gravel Association, 2001; :87-100	2001	Publication	Respiratory diseases
Dust Underfoot: Enclosed Cab Floor Heaters Can Significantly Increase Operator's Respirable Dust Exposure Cecala-AB; Organiscak-JA; Heitbrink-WA | Rock Products 2001 Apr; 104(4):39-44	2001	Publication	Respiratory diseases
Filtered Recirculation: A Critical Component to Maintaining Acceptable Air Quality in Enclosed Cabs for Surface Mining Equipment Cecala-AB; Zimmer-JA | In: Ganguli R, Bandopadhyay S, eds. Mine ventilation: Proceedings of the 10th U.S./North American Mine Ventilation Symposium (Anchorage, AK, May 16-19, 2004). Leiden, Netherlands: Balkema, 2004 May; :377-387	2004	Publication	Respiratory diseases
NIOSH/Industry Collaborative Efforts Show Improved Mining Equipment Cab Dust Protection Organiscak-JA; Cecala-AB; Thimons-ED; Heitbrink-WA; Schmitz-M; Ahrenholtz-E | In: Yernberg WR, ed. Transactions of Society for Mining, Metallurgy, and Explorations, Inc., Vol. 314. Littleton, CO: Society for Mining, Metallurgy, and Explorations, Inc., 2003; :145-152	2003	Publication	Respiratory diseases
Reducing Enclosed Cab Drill Operator's Respirable Dust Exposure at a Surface Coal Operation Using a Retrofitted Filtration and Pressurization System Cecala-AB; Organiscak-JA; Heitbrink-WA; Zimmer-JA; Fisher-T; Gresh-RE, et al. | In: Yernberg WR, ed. Transactions of Society for Mining, Metallurgy, and Explorations, Inc. Vol. 314. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc; :31-36	2003	Publication	Respiratory diseases
Reducing Enclosed Cab Drill Operator's Respirable Dust Exposure with Effective Filtration and Pressurization Techniques Cecala-AB; Organiscak-JA; Zimmer-JA; Heitbrink-WA; Moyer-ES; Schmitz-M; Ahrenholtz-E; Coppock-CC; Andrews-EH | Journal of Occupational Environmental Hygiene 2(1)2005; :54-63	2005	Publication	Respiratory diseases
Reducing Silica Exposure in Aggregate Operations Cecala-AB; Organiscak-JA; Page-SJ; Thimons-ED | Aggregates Manger 2005 Jan; :24-28	2002	Publication (guidelines)	Respiratory diseases
Retrofit Options for Better Dust Control Chekan-GJ; Colinet-JF | Aggregates Manag 8(9); :9-12	2003	Publication (guidelines)	Respiratory diseases
Technology News 487 - Sweeping Compound Application Reduces Dust From Soiled Floors Within Enclosed Operator Cabs NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 487, 2001 Mar :1-2	2001	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
Reducing Dust Inside Enclosed Cabs NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. Videocassette	2002	Video	Respiratory diseases

Intermediate Outcome related to Reducing Silica Exposures in Mining Through Improved Control Technologies

New Clothes-Cleaning Method Reduces Worker Silica Exposure

Description of Problem

NIOSH researcher demonstrates the efficiency of the clothes cleaning process

Soiled work clothing can be a significant source of dust exposure for workers in many industries. For example, at one silica sand plant, a U.S. Bureau of Mines study documented a tenfold increase in worker respirable dust exposure from soiled clothing while workers did their normal duties. Respirable dust levels measured in this study were so high that workers would be overexposed to the 8-hour federal silica standard in less than 2 hours. The most effective way to eliminate this dust source is to have workers clean or change their work clothing. Changing work clothing during a shift is generally not practical. Cleaning of work clothing can be difficult, and, if not done properly, can actually increase dust exposures. Currently, the Mine Safety and Health Administration (MSHA) requires that worker clothing be cleaned by using a vacuuming method. This method is cumbersome and not very efficient.

Research and Development Activities

A cooperative research effort was established between Unimin Corp. and NIOSH to develop a better method to clean dust-soiled work clothing while it is still being worn. The result was a new clothes-cleaning process. To perform this new cleaning method, a worker enters a booth wearing a respirator, goggles, and hearing protection and activates an air spray manifold containing 26 vertically spaced air nozzles. As the individual rotates one or two times in front of the air spray manifold, compressed air from the nozzles blows the dust from the worker's clothing. Since the booth is under negative pressure, the dust removed from the worker's clothing is ducted away to a baghouse dust collector, discharged into the atmosphere outside the plant, or passed through a HEPA filter located on the booth and then discharged back into the plant.

Results have shown that this clothes-cleaning process is 20 times faster and removes about 40% more dust than the currently approved MSHA vacuuming method. The average cleaning time with this new process is normally less than 20 seconds. Workers found the method easy to use and very efficient.

R&D Outputs and Transfer Activities

NIOSH has transferred this information through peer-reviewed and trade journal articles. Presentations have been made at numerous conferences. In addition, NIOSH researchers have made presentations at safety and health meetings of individual companies and at industry organization meetings such as the Industrial Minerals Association-North America. NIOSH has also produced a video and instructional manual that describes the clothes-cleaning process. This video has been widely distributed throughout the U.S. minerals processing industry and is available for viewing on the NIOSH Mining Website.

Description of Intermediate Outcome

When initially developed, the new clothes-cleaning process was not approved by MSHA for use in U.S. operations. A petition for modification to allow the use of this cleaning process was submitted by Unimin Corp. and approved in June 2005. Other companies wishing to use this method need only file a similar petition to get approval. At this time, several other companies are preparing petitions for modification. The next time MSHA changes the federal regulations, it is expected that it will modify the standard to allow the use of this improved clothes-cleaning method.

Two private companies have started manufacturing the clothes-cleaning system: S. K. Bowling Co. and Superior Construction and Repair Co. In addition, there has been interest in this clothes-cleaning method in many different industries outside of mining and in many different countries, including Canada, Mexico, Australia, and Belgium. Unimin is currently making plans to incorporate it into several of its Canadian operations.

Outputs

3 Outputs

Title	Year	Output Type	Strategic Goal
Dusting Off: NIOSH Develops a New Method to Clean Dust-Soiled Work Clothes Pollock DE, Cecala AB, O'Brien AD, Zimmer JA, Howell JL | Rock Prod 108(3), 2005; :30-34	2005	Publication	Respiratory diseases
Technology News 509 - A New Method to Clean Dust From Soiled Work Clothes Cecala-AB; Pollock-DE | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH Publication No. 2005-136, Technology News 509, 2005 May; :1-2	2005	Publication	Respiratory diseases
Clothes Cleaning Process NIOSH | NIOSH 2004 Jan; :Video (VHS format)	2005	Video	Respiratory diseases

Strategic Program Outcome for Respiratory Diseases

Reducing Exposures to Diesel Emissions Through Improved Monitoring and Control

Substantial evidence has shown that underground miners are routinely exposed to very high concentrations of diesel particulate matter (DPM), much higher than for any other occupation. In 1998, the Mine Safety and Health Administration (MSHA) proposed two diesel rules - one for coal mining, the other for metal/nonmetal mining. The coal rule set a staged implementation limit on DPM emission ending at 2.5 g/hr for heavy-duty equipment and can be met by the use of MSHA-approved filters based on the diesel emission characteristics of the engines involved. The metal rule set an interim concentration limit of 400 $\mu g/m^3$ of total carbon and a final concentration limit of 160 $\mu g/m^3$ of total carbon scheduled to go into effect in January 2006.

In early 1999, with both MSHA and the American Conference of Governmental Industrial Hygienists setting limits on DPM, NIOSH convened a committee with the intent of determining a realistic exposure limit for DPM in mining. Although it was decided that an exposure limit for DPM was premature, NIOSH was, however, able to estimate a minimum DPM level achievable by using clean engines and ceramic filter technologies. This analysis was placed into the MSHA rule hearing record and published in *Mining Engineering* magazine in 2001.

Later in 1999, a coal diesel partnership was formally established among union, industry, and NIOSH. Its goal is to work together to address technology to control diesel emissions in coal mines. The partners requested that NIOSH provide a review of available technology. This was presented to the partnership in 2000 and published as NIOSH Information Circular 9462 in 2002. That same year, the metal/nonmetal industry, observing the coal partnership successes, requested that NIOSH establish a similar metal/nonmetal partnership to address diesel issues of concern in its own industry.

NIOSH researchers have greatly facilitated the implementation of diesel control technologies into both coal and metal/nonmetal mines:

- NIOSH researchers worked in conjunction with the Canadian Diesel Emissions Evaluation Program (DEEP), a consortium of Canadian industry, academics, government, and labor. NIOSH participated in an isolated zone study to determine exhaust particulate filter performance and took the initiative to conduct the world's first examination of the size distribution of diesel exhaust particles downwind of an operating vehicle. NIOSH found that the nanoparticle concentration actually increased with the use of filters, many of which were 98% efficient in removing larger particles. Based on this experience, NIOSH was able to suggest and conduct isolated zone experiments in coal and metal mines that obtained definitive assessments of the effects of engine tuning for altitude, pleated-element filters, ceramic filters, and fuels. Findings from these efforts were transferred to the U.S. mining industry through reports, conference presentations, and workshops.
- The metal/nonmetal industry contested the metal rule. In an agreement with MSHA, it demanded that NIOSH be involved in determining the proper compliance surrogate for DPM exposures in metal mines. The contested rule had incorporated the commercial version of the U.S. Bureau of Mines (USBM) diesel sampler to separate out

carbon-bearing dusts from diesel soot and used total carbon (TC) as the DPM surrogate. NIOSH worked with MSHA and the manufacturer to improve the reliability and accuracy of the commercialized version of the USBM diesel sampler. It is now the MSHA-required sampler for sampling DPM in metal/nonmetal mines. NIOSH research was instrumental in changing the surrogate from TC to elemental carbon (EC). Using EC overcame the problem of sampling interference from oil mist, carbonaceous ores, or tobacco smoke, all of which can be present in metal/nonmetal mines. NIOSH was tasked with reviewing the results of a study at 31 mines, which was agreed to under a litigation agreement between MSHA, industry, and labor. NIOSH analyzed all samples from the study, and reviewed and commented on the study results.

- Uncertainty from the metal/nonmetal industry over the real-world performance of diesel control technology resulted in two NIOSH studies in a western metal mine in 2003 and 2004. The studies verified that ceramic filters could reduce EC by 98% under actual production scenarios, biodiesel blends could reduce EC by over 40%, water fuel emulsions reduced EC by more than 80%, and differences among No. 1, No. 2, and ultralow sulfur fuels were negligible. Also, excess NO_2 was observed when platinum-catalyzed systems were used.
- In late 2002, MSHA requested NIOSH assistance in producing an industry guideline for the selection of diesel filters. NIOSH took the lead and produced a highly acclaimed Diesel Particulate Filter Selection Guide in early 2003. The guide is Web-based and leads a novice through the process of selecting the proper system for equipment requiring filters. It starts with organizational and engine maintenance/condition prerequisites and continues all the way through filter selection criteria and operational limitations. It is posted on both the MSHA and NIOSH websites.
- In 2003, NIOSH, working through the abovementioned partnerships, hosted workshops for control of diesel emissions at coal and metal/nonmetal mines. The workshops were held at several locations and transferred the latest diesel emission control technologies, Canadian experiences, and engine maintenance practices to the U.S. mining industry.
- NIOSH, working together with a private company, has developed an exhaust cooling system that reduces the diesel exhaust temperature entering high-temperature pleated-element filters, which are widely used in the coal mining industry. The cooler exhaust from this device prevents unintended ignition of the diesel soot accumulations in the filter (filter fires) that can result from uncooled exhaust.
- NIOSH is working with a diesel ceramic filter manufacturer to develop a passive (self-regenerating) filter that will regenerate at lower-duty cycle temperatures without creating an increase in tailpipe emissions and workplace concentrations of NO_2 in the mines. Successful curtailment of excessive NO_2 of this system would allow the application of passive filter technology on a wider range of underground equipment in underground mines.

As a result of NIOSH efforts, the coal and metal/nonmetal industries, labor, and MSHA have pertinent and useful results based on solid research and have a continuing resource for unbiased and factual information about technology to control diesel emissions. Better and more technology is now being implemented that will reduce miners´ exposures to diesel exhaust contaminants.

Intermediate Outcomes

- New Size-Selective Sampler for Diesel Compliance Measurements
- NIOSH Research Results in a Revised Final Rule on the Interim DPM Standard for Underground Metal/Nonmetal Mines
- NIOSH Research Supports Diesel Rule Implementation

Intermediate Outcome related to Reducing Exposures to Diesel Emissions Through Improved Monitoring and Control

New Size-Selective Sampler for Diesel Compliance Measurements

Description of Problem

More than 30,000 underground mine workers are exposed to excessively high levels of diesel particulate matter (DPM). DPM has been declared as a possible cancer-causing agent by NIOSH and others. In 1998, the Mine Safety and Health Administration (MSHA) proposed a new rule to regulate the exposure of underground metal/nonmetal miners to DPM. The agency planned to use measurements of total carbon (TC) as a surrogate for DPM. However, before the rule could be finalized, MSHA needed to solve the problem of TC interference from carbon-containing ore dust.

SKC size selective sampler

Years earlier, the U.S. Bureau of Mines (USBM) had developed a size-selective sampler that had potential to solve this TC interference problem. The sampler, developed to separate coal mine dust from DPM, prevented 90% of coal dust from being collected on the sampling media. MSHA asked NIOSH to verify that the sampler would also work for metal/nonmetal mine dusts and then develop a commercial version.

Research and Development Activities

NIOSH contracted with SKC Corp. to develop a commercial version of the USBM sampler and with the University of Minnesota to test it. In-mine and lab testing of the USBM sampler verified that the sampler would, in fact, eliminate metal/nonmetal mine dusts as desired. Subsequent NIOSH lab and field experience with the commercial version, developed in consort with MSHA, revealed that the samplers produced irregularly shaped deposit areas on the filters. NIOSH conducted research and found an innovative solution to the problem. Upon recommendations from NIOSH and MSHA, SKC replaced the crimped aluminum shield holding the filter media with a flat gasket. This resulted in precise circular deposit areas. SKC also incorporated a NIOSH recommendation to increase the filter diameter for a better fit and to include a second filter to serve as a field blank. NIOSH did extensive testing of the new commercial version to ensure its reliability and repeatability.

R&D Outputs and Transfer Activities

NIOSH, MSHA, and SKC worked as a team on this research. This joint effort greatly facilitated the transfer of the technology. Industry and labor were kept informed of progress throughout this effort. All of this stakeholder interaction made acceptance of this technology for measuring DPM in underground metal/nonmetal mines easy to achieve. The results of this research were also published in a peer-reviewed journal and have been presented at a number of technical conferences.

Description of Intermediate Outcome

The modified sampler is now a commercial product from SKC, Inc. It has become the MSHA-required sampler for measuring diesel particulate in metal/nonmetal mines (Federal Register, Vol. 67, No. 39, February 27, 2002, Rules and Regulations, p. 9180). It now represents the state of the art in measuring DPM in underground metal/nonmetal mines.

Outputs

6 Outputs

Title	Year	Output Type	Strategic Goal
A Cost-Effective Personal Diesel Exhaust Aerosol Sampler McCartney-TC; Cantrell-BK | In: Diesels in underground mines - measurement and control of particulate emissions. Proceedings of the Bureau of Mines Information and Technology Transfer Seminar, Minneapolis, MN, September 29-30, 1992. Minneapolis, MN: U.S. Department of the Interior, Bureau of Mines, Information Circular 9324; :24-30	1992	Publication	Respiratory diseases
Development of Personal Diesel Aerosol Sampler Design and Performance Criteria Cantrell-BK; Rubow-KL | Min Eng 43(2); :231-236	1991	Publication	Respiratory diseases
Evaluation of the SKC® DPM Cassette for Monitoring Diesel Particulate Matter in Coal Mines Noll-JD; Birch-E | J Environ Monit 2004 Dec; 6(12):973-978	2004	Publication	Respiratory diseases
Measurement of Coal Dust and Diesel Exhaust Aerosols in Underground Mines Rubow-KL; Cantrell-BK; Marple-VA | In: Proceedings of the Seventh International Pneumoconioses Conference (Pittsburgh, PA, August 23-26, 1988). Part 1. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 90-108; :645-65	1990	Publication	Respiratory diseases
Sampling Results of the Improved SKC® Diesel Particulate Matter Cassette Noll-JD; Timko-RJ; McWilliams-LJ; Hall-P; Haney-R | Journal of Occupational and Environmental Hygiene, 2(1), 2005 Jan; :29-37	2005	Publication	Respiratory diseases
Submicrometer Elemental Carbon as a Selective Measure of Diesel Particulate Matter in Coal Mines Birch-ME; Noll-JD | J Environ Monit 2004 Oct; 6(10), 2004 Oct; :799-806	2004	Publication	Respiratory diseases

Intermediate Outcome related to Reducing Exposures to Diesel Emissions Through Improved Monitoring and Control

NIOSH Research Results in a Revised Final Rule on the Interim DPM Standard for Underground Metal/Nonmetal Mines

Description of Problem

In January 2001, the Mine Safety and Health Administration (MSHA) promulgated a rule regulating underground metal and nonmetal miners' exposure to diesel particulate matter (DPM). The rule specified that compliance would be determined by sampling a surrogate for DPM. The surrogate was to be the concentration of total carbon (TC) measured by using a size-selective impactor sampler. Total carbon is the sum of organic carbon (OC) and elemental carbon (EC). Mining industry officials claimed that sources of OC in the mine other than DPM, such as carbonaceous ore dust, tobacco smoke, and oil mist from drills, would falsely elevate TC above that attributable to DPM. They therefore challenged the rule. The resulting settlement agreement among industry, labor, and MSHA specified that a metal/nonmetal mine study would be conducted in a variety of mines around the country. NIOSH was to be involved in the study, evaluate the data, and review and comment on the final report of the study.

Research and Development Activities

Working together, NIOSH, MSHA, and industry developed a protocol to investigate possible non-DPM sources of OC in underground metal/nonmetal mines and to evaluate the impact of those interferences on TC measurement. The mine study verified that drill oil mist and cigarette smoke could be significant sources of OC. Some sources of OC could be eliminated or corrected out. The impactor sampler eliminated mineral dust from the filter sample, and vapor-phase OC could be corrected for by applying a second filter. However, the study also concluded that the non-DPM contributions to OC from oil mist and cigarette smoke could not be avoided, nor could an appropriate correction factor be applied to account for these OC sources. Based on the research findings, the earlier (1997) position of NIOSH was verified - EC was a better surrogate for DPM than TC since the only source of EC was DPM.

R&D Outputs and Transfer Activities

Since this research effort was conducted closely with industry, labor, and MSHA, the transfer of findings was easy to achieve. Findings have been presented at workshops and partnership meetings attended by personnel from MSHA, industry, and labor. They have also been published in a peer-reviewed journal.

Description of Intermediate Outcome

As a result of this NIOSH research, MSHA, industry, and labor agreed to change the compliance surrogate for the DPM interim standard to EC, with EC being 77% of TC (Federal Register, Vol. 68, No. 157, August 14, 2003, Proposed Rules, page 48668). In addition, as the January 2006 final rule approaches, the findings of this research are being examined inasmuch as the final rule was originally written in terms of TC, not EC, as the surrogate for DPM. MSHA has already approached NIOSH for help in dealing with this issue.

Outputs

2 Outputs

Title	Year	Output Type	Strategic Goal
Diesel Exhaust Aerosol: Review of Occupational Exposure Cantrell-BK; Watts-WF Jr | Appl Occup Env Hyg 12(12), 1997; :1019-1027	1997	Publication	Respiratory diseases
Sampling Results of the Improved SKC® Diesel Particulate Matter Cassette Noll-JD; Timko-RJ; McWilliams-LJ; Hall-P; Haney-R | Journal of Occupational and Environmental Hygiene, 2(1), 2005 Jan; :29-37	2005	Publication	Respiratory diseases

Intermediate Outcome related to Reducing Exposures to Diesel Emissions Through Improved Monitoring and Control

NIOSH Research Supports Diesel Rule Implementation

Description of Problem

A diesel powered load haul dump vehicle in isolated zone study

In January 2001, the Mine Safety and Health Administration (MSHA) promulgated a new rule that regulates the exposure of metal/nonmetal miners to diesel particulate matter (DPM). However, the mining industry doubted whether the diesel emission control technology existed to meet the new rule. Many of the proposed controls had only been tested in labs. The industry asked NIOSH to conduct underground studies to determine the effectiveness of diesel emissions controls under more realistic conditions and to determine if any other adverse health or safety impacts could result from their application. NIOSH agreed to perform in situ testing only if the control technology could be tested in isolation.

Research and Development Activities

Stillwater Mining Co.'s Nye Mine in Montana offered the use of a long drift ventilated by fresh air to conduct the studies. A single vehicle ran a representative and repeatable duty cycle within this isolated drift as air contaminant measurements were obtained. Comparisons were made between air contaminant concentrations when the vehicle was operated with no control technology versus when the control technology was used. The effects of the following technologies were measured:

1. two blends of yellow grease biodiesel fuel,
2. two blends of soy-based biodiesel fuel,
3. cold and warm weather formulations of a water-fuel emulsion,
4. No. 1 versus No. 2 diesel fuel,
5. an ultralow sulfur No. 2 fuel,
6. a diesel oxidation catalyst,
7. platinum-catalyzed particulate filters,
8. a fuel-borne catalyzed particulate filter, and
9. high-temperature disposable pleated-element filters from two manufacturers.

These studies were done in two individual sets of tests during 2003-2004. Contaminants measured were CO_2, CO, NO, NO_2, and particulate matter (including total particle mass, elemental carbon, total carbon, and size distribution and number).

The findings confirmed that reductions in contaminant concentrations reported in lab studies were achievable when applied to real equipment operated under simulated production cycles. The study also confirmed an increase in NO_2 caused by platinum-catalyzed ceramic filters designed to facilitate the passive regeneration at lower-duty cycle temperatures. The elevated NO_2 emissions indicated a possible health hazard associated with the use of these filters in underground mines.

R&D Outputs and Transfer Activities

The research was done under a Metal/Nonmetal Diesel Partnership consisting of NIOSH, MSHA, industry, and labor. Working with the partnership greatly facilitated the transfer of the technology to NIOSH customers. Stakeholders participated in the mine site testing. NIOSH issued reports to the partnership detailing the research findings. Information from the studies is being published in several journals and presented at several conferences. The research results were also presented at numerous workshops and partnership meetings attended by representatives of industry, labor, and government.

Description of Intermediate Outcome

Prior to these studies, enforcement, labor, and mine operators were certain of the effectiveness of various control options in the real world. Mines were reluctant to commit to using controls with unproven effectiveness. Such concerns are no longer an issue. In the recasting of the interim diesel rule for metal/nonmetal mines, MSHA referenced the 2003 NIOSH/Stillwater study report as part of the evidence that available technologies are capable of reducing DPM. The report, entitled "The Effectiveness of Selected Technologies in Controlling Diesel Emissions in an Underground Mine: Isolated Zone Study at Stillwater Mining Company's Nye Mine," is on MSHA's website at http://www.msha.gov/01-995/dpmdocs/stillwater.pdf. The information obtained from this research has given industry an increased level of confidence that the technology to reduce worker exposure to DPM is available and works. This research did not address long-term implementation issues associated with using these technologies. Research to address long-term issues is currently being planned by NIOSH and is expected to begin in late 2005.

Outputs

15 Outputs

Title	Year	Output Type	Strategic Goal
Characterization of Diesel Aerosols in an Underground Metal Mine Bugarski-AD | In: Mayer A, ed. Proceedings of the Eighth International ETH-Conference on Nanoparticle Measurement (Zurich, Switzerland, August 16-18, 2004), 2004; :1-2	2004	Publication	Respiratory diseases
Characterization of Diesel Particulate Matter (DPM) and Potential Health Effects Associated with Exposure to the DPM in Underground Mines Bugarski-AD; Gautam-M | In: Proceedings of the Mining Diesel Emissions Conference (Markham, Ontario, Canada)	2000	Publication	Respiratory diseases
Diesel Exhaust Control Technology: a Review Schnakenberg-GH; Bugarski-AD | In: Proceedings of the Mining Diesel Emissions Conference (Markham, Ontario, Canada)	2001	Publication	Respiratory diseases
Effects of Alternative Fuels on Concentrations of Nanometer and Ultrafine Particles in Underground Mine Bugarski-AD; Mischler-S; Schnakenberg-GH Jr | In: Proceedings of the Ninth ETH Conference on Combustion-Generated Nanoparticles (Aug. 15-17, 2005; Zurich, Switzerland)	2005	Publication	Respiratory diseases
Estimate of Technically Feasible DPM Levels for Underground Metal and Nonmetal Mines Schnakenberg-GH Jr | Min Eng, 53(9), Sep 2001:45-51	2001	Publication	Respiratory diseases
Evaluation of Diesel Particulate Filter Systems and Biodiesel Blends in an Underground Mine Bugarski-A; Schnakenberg-GH Jr; Noll-JD; Mischler-S; Crum-MW; Anderson-R | SME preprint 04-24. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2004; :1-13	2004	Publication	Respiratory diseases
Evaluation of Diesel Particulate Filter Systems and Biodiesel Blends in an Underground Mine Bugarski-A; Schnakenberg-GH Jr; Noll-JD; Mischler-S; Crum-MW; Anderson-R | Trans Soc Min Metal Explor. Vol 318. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.; :27-35	2005	Publication	Respiratory diseases
Field Evaluation of Diesel Particulate Filters: Size-Selective Measurements of Aerosols in Mine Air and Engine Exhaust Bugarski-AD; Schnakenberg-GH Jr | In: Proceedings of the Mining Diesel Emissions Conference (Markham, Ontario, Canada)	2001	Publication	Respiratory diseases
Metal and Nonmetal Diesel Particulate Filter Selection Guide Schnakenberg-GH; Bugarski-AD; Angel-J; Saseen-G | Web document, http://www.msha.gov/nioshmnmfilterselectionguide/dpmfilterguide.htm	2005	Web document	Respiratory diseases
Review of Technology Available to the Underground Mining Industry for Control of Diesel Emissions Schnakenberg-GH Jr; Bugarski-AD | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2002-154, Information Circular 9462, 2002 Aug :1-51	2002	Publication	Respiratory diseases
Testing Diesel Emission Control Techniques Schnakenberg-GH Jr; Bugarski-AD | In: Proceedings of the Diesel Particulate in Mining Conference (Yeppoon, Queensland, Australia)	2004	Publication	Respiratory diseases
Testing of Diesel Emissions Control Technologies in Isolated Zone Bugarski-AD; Schnakenberg-GH Jr | In: Proceedings of the Mining Diesel Emissions Conference (Markham, Ontario, Canada)	2003	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
The Effectiveness of Selected Technologies in Controlling Diesel Emissions in an Underground Mine: Isolated Zone Study at Stillwater Mining Company's Nye Mine Bugarski-AD; Schnakenberg-GH; Noll-JD; Mischler-S; Patts-L; Hummer-J, et al. | Final report to Metal/Nonmetal Diesel Partnership, Jan 5, 2004, http://www.msha.gov/01-995/dpmdocs/stillwater.pdf	2004	Publication	Respiratory diseases
Workshop on Diesel Emissions Control Technologies in Coal Mines NIOSH | NIOSH-sponsored workshop, Louisville, KY (July 30, 2003)	2003	Workshop, Seminar, or OIB	Respiratory diseases
Workshop on Diesel Emissions Control Technologies in Metal/Nonmetal Mines NIOSH | NIOSH-sponsored workshop, Cincinnati, OH (February 27, 2003), Salt Lake City, UT (March 4, 2003)	2003	Workshop, Seminar, or OIB	Respiratory diseases

Strategic Program Outcome for Hearing Loss

Preventing Noise-induced Hearing Loss

Noise-induced hearing loss (NIHL) is the most common job-related illness in the United States today. NIHL is a top priority area in the National Occupational Research Agenda (NORA). It is especially common among miners. A NIOSH analysis of more than 60,000 audiograms showed that by age 51 about 90% of the coal miners and 49% of metal/nonmetal miners had a hearing impairment. By contrast, only 10% of the nonoccupational noise-exposed population had a hearing impairment by age 51. A 2005 analysis of changes in noise exposure showed that the renewed emphasis on hearing loss prevention has already had a substantial impact. There has been a 40% reduction in the average coal miner´s noise dose from 1997 to 2003. The rate of decline in exposures increased around 2000 when a new federal noise regulation took effect. Around the same time, our Hearing Loss Prevention Branch became fully staffed. The program is playing a major role in reducing NIHL in the U.S. mining industry.

When NIHL became a prominent mining health issue in the late 1990s, a new noise rule was passed in 1999 (30 CFR 62) to be enforced by the Mine Safety and Health Administration. Before 1998, there were fewer than three employees in the Mining Program working on noise issues. The Mining Program quickly increased its hearing loss prevention staff and has had more than 20 employees working on the problem every year since 2001. It now has core expertise in a variety of physical and social sciences so that it can fully support the other partners. These include industry groups, labor organizations, equipment manufacturers, and the mine workers themselves.

The Hearing Loss Prevention Program is following a two-phase strategy for maximum impact on the national hearing loss problem. In the first phase, the program provided scientific input to the new regulatory and voluntary industry efforts to curb NIHL. During this phase, the program established its scientific credibility as the best source for unbiased information about effective interventions. In the second phase, the program began generating proven techniques that would directly affect noise exposures and subsequent hearing loss.

Phase 2 is now well underway. Initially, this involved field tests of effective engineering controls and worker empowerment techniques that had proven effective in controlled settings. For instance, noise reduction coatings for a continuous mining machine conveyor have proven to be effective in lab and field trials. Also, NIOSH testing facilities identified that drilling systems originally developed to control dust also have a significant noise reduction benefit. On the behavioral side of prevention, a hearing loss simulator was developed to motivate workers to take a more active role in protecting their own hearing. These and other interventions are being promoted and disseminated to all applicable sectors of the industry and workforce through technical communication and social marketing. The impact of these and other successful interventions will be followed through long-term evaluations to confirm that workers are being exposed to less noise and that fewer of them will develop a hearing loss, thereby enhancing the quality of life of the nation´s miners.

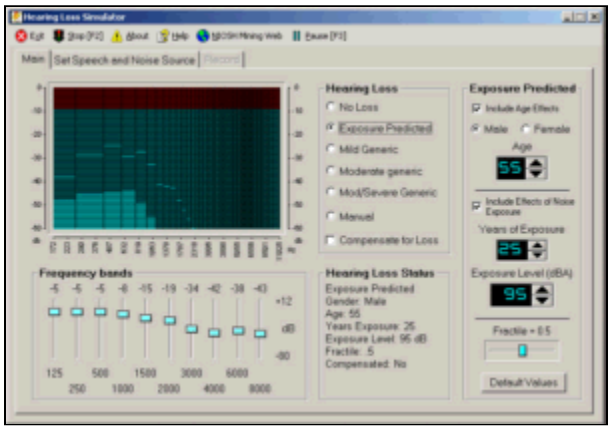
Intermediate Outcomes

- Motivating Prevention Behaviors with the NIOSH Hearing Loss Simulator
- Noise Reduction of Roof Bolting Machines Using Wet and Mist Drilling
- Reducing Noise on Continuous Mining Machines Using Coated Flight Bars

Intermediate Outcome related to Preventing Noise-induced Hearing Loss

Motivating Prevention Behaviors with the NIOSH Hearing Loss Simulator

Description of Problem



Screen shot of the Hearing Loss Simulator

Virtually every strategy for preventing hearing loss requires significant human effort. Engineering controls must be developed, implemented, and maintained. Administrative controls have to be designed, then adopted by workers who may have to adopt unfamiliar ways of working. Hearing protectors need to be provided and worn correctly. When these human efforts fall short, workers can receive hazardous noise exposures. For instance, even when hearing protectors are required, usage rates at or below 50% are typically reported. Operators of noisy equipment often leave their cab doors open, which increases their noise exposure by 9 decibels or more. These and other examples of inadequate prevention show a need for improved awareness and motivation.

Research and Development Activities

A NIOSH team developed the Hearing Loss Simulator to demonstrate that hearing loss is both a likely and severe consequence of noise exposure. The simulator is a Windows-based computer program that allows a trainer or user to "dial in" varying amounts of noise exposure to demonstrate the predicted damage to hearing. The predictions are based on the empirically validated models contained in the ANSI (American National Standards Institute) S3.44 standard. The software shows a graph of the frequencies or pitches most affected by noise. The graph shows the typical "notch" in the high frequencies for a noise-damaged worker. More importantly, the simulator provides an auditory demo of noise-induced hearing loss (NIHL). It contains prerecorded spoken messages to which the trainer can add background noises. These include a variety of mining, construction, and shop machinery. The noise makes the spoken message harder to understand. This further emphasizes the severity of NIHL. Trainees are usually workers, but can also be family members or managers who need to understand the effects of hazardous noise. By leading trainees through a series of scenarios, the simulator shows how NIHL can greatly affect communication, recognition of safety signals, and quality of life. A team of NIOSH behavioral scientists and software designers guided the simulator's development from an early prototype to a full-featured software package containing supporting documentation and training guidelines. The simulator was very successful when evaluated by coal miners, quarry workers, and technical support staff. For instance, 58 miners in a reaction study gave very positive responses to the simulator as a training tool. An evaluation of attitude and knowledge change for 89 miners and support staff showed significant increases in knowledge of hearing loss prevention and in intentions to take more effective action to preserve their hearing.

R&D Outputs and Transfer Activities

After these evaluations, NIOSH released the simulator to the public on CD-ROM. A distribution and tracking system was set up in October 2004. The simulator is also being distributed through the NIOSH website. Project staff are doing demos for health and safety practitioners throughout the United States in conjunction with the Noise Partnership and other industry and labor organizations.

Description of Intermediate Outcome

The simulator is being used as a training and motivational tool for preventing NIHL by stakeholders throughout the world. More than 300 requests for the simulator on CD-ROM have been received from stakeholders across the United States and other countries, including Mexico, Israel, Indonesia, and Canada. These include university audiology departments, state safety and health agencies, company training offices, independent industrial hygiene trainers, and military installations. In addition:

- Lee Hager of Sonomax (a producer of hearing protectors and a member of the National Hearing Conservation Association) has been using the simulator in training seminars. His audience consists mainly of audiologists, industrial hygienists, and occupational hearing conservationists. Seminar attendees have since requested the simulator for use in their own training and clinical practices.
- The simulator is a required component of a doctoral level hearing conservation course at Central Michigan University.
- The Better Hearing Institute has requested access to the simulator as part of its on-line hearing loss training materials at www.betterhearing.org. The institute is a not-for-profit organization that disseminates hearing loss prevention and treatment information to the general public.
- The Mine Safety and Health Administration (MSHA) is including the simulator in its workshops and seminars on hearing loss prevention for mine inspectors, miners, and technical support staff. The agency is also adding it to its catalog of training products.
- John Langton, the Deputy Administrator for Coal Mine Safety and Health for MSHA, recognized the simulator in his address to the Mining Hearing Loss Prevention Workshop in Charleston, WV, on June 21, 2005. He stated, "Today, tools such as...NIOSH's hearing loss simulator and MSHA's noise control guides are examples of valuable resources."
- Timothy Swisher of Employee Health, Inc. (recently named as the second most active provider of certification training for occupational hearing conservationists), is using the simulator in his popular certification classes.
- State agencies in Arizona, California, Colorado, Illinois, Missouri, New Hampshire, and Pennsylvania have asked to use the simulator.
- The Joseph A. Holmes Safety Association, the largest and oldest mining safety and health organization in the United States with more than 4,000 chapters, devoted a page on its website promoting the simulator in March 2005. The page had been accessed 749 times as of August 4, 2005.

- Rob Brauch of Larson Davis, Inc. (a leading manufacturer of noise control instruments), requested the simulator. He stated, "I present at many safety and health conferences and professional development courses around the world and would like to use this very effective tool to raise the awareness of the attendees about the effects of hearing loss."
- The simulator was featured in an article in the May 2005 issue of American Longwall Magazine. The article, entitled "NIOSH Simulator Music to the Ears," highlighted the simulator's usefulness in motivating hearing loss prevention and provided information on how to obtain a free copy.

Outputs

4 Outputs

Title	Year	Output Type	Strategic Goal
Communicating the Same Message with Different Media: An Example from Hearing Loss Prevention Randolph-RF; Kohler-JL; Byrne-DC | In: Peters R, ed. Strategies for Improving Miners' Training. Pittsburgh, PA, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2002-156, Information Circular 9463, 2002 Sep :45-54	2002	Publication	Hearing loss; Surveillance and training
What Does a Hearing Loss Sound Like? NIOSH | Web document, www.cdc.gov/niosh/mining/topics/hearingloss/hlsoundslike.htm	2005	Web document	Hearing loss
Hearing Loss Simulator (HLSim) NIOSH | Version 2.2.0.26; Windows software; CD-ROM and downloadable (http://www.cdc.gov/niosh/mining/products/educationalsoftware.htm)	2004	Software	Hearing loss
Mining Hearing Loss Prevention Workshop NIOSH | Hosted by NIOSH-PRL, Charleston, WV; June 21-22, 2005	2005	Workshop, Seminar, or OIB	Hearing loss

Intermediate Outcome related to Preventing Noise-induced Hearing Loss

Noise Reduction of Roof Bolting Machines Using Wet and Mist Drilling

Description of Problem

Mist system on a roof bolting machine

Adding water to a drilling process on a coal mine roof bolting machine can reduce the drilling noise. However, it can lead to other problems, such as wet and slippery mine floors. It can also create an uncomfortable work environment for the drillers who are exposed to the water coming out of the drill holes. Coal noise data for 2000-2003 from the Mine Safety and Health Administration (MSHA) show that roof bolting machine operators are the second most common type of underground coal equipment operator whose noise dose exceeds 100%. Further, MSHA Program Information Bulletin P04-18 states that wet drilling (where compatible with the geology and mining method) is a technically and administratively achievable engineering control to reduce a miner's noise exposure and that mist drilling offers promise in reducing overexposure. Roof bolting machines are used in underground coal mines to drill vertical holes in the roof of the mine and then insert 3 foot to 8 foot bolts into the holes. This helps secure the mine roof and prevent dangerous roof falls. Drilling into hard rock in a confined space generally results in significant noise exposure for the drill operators. There is a need to evaluate the benefits of wet drilling on roof bolting machines and to evaluate mist drilling, which requires much less water than conventional wet drilling, but may, if properly used, give the same benefits in reducing noise.

Research and Development Activities

The NIOSH Pittsburgh Research Laboratory has the facilities and personnel to evaluate engineering controls via sound power level testing. NIOSH has documented that, given similar drilling configurations and drilling media, wet and mist drilling processes produce less noise than similar tests done under vacuum conditions. This is most apparent in the one-third octave band center frequencies of 1,000 Hz or greater. The water damps noise in these frequency bands, reducing the sound power level emission. NIOSH has been testing various wet and mist drilling systems in its acoustic test chamber to optimize and evaluate these drilling technologies. As the technologies are optimized for given mining conditions, they are then tested at mine field sites to confirm the findings in the real-world environment.

R&D Outputs and Transfer Activities

Results have been disseminated to the public via a conference paper entitled "A Sound Power Level Study of a Roof Bolter." NIOSH has also been transferring the research findings to labor, industry, equipment manufacturers, and MSHA through meetings of the Coal Mine Noise Partnership and through a partnership workshop designed to make the industry aware of various engineering noise controls. In addition, NIOSH has worked closely with equipment manufacturers to ensure ready acceptance of the findings.

Description of Intermediate Outcome

When compatible with mining conditions, wet drilling is generally an effective engineering control to reduce noise exposure to roof bolting machine operators. NIOSH research has shown that the sound pressure level at the operator position attributable to the roof bolting machine is almost always reduced when wet drilling is used. Research has also shown that wet drilling enhances performance, i.e., penetration rate. Depending on the compressive strength of the drill media, lab and field testing suggest reductions of 2 to 7 dB(A) at the bolter operator's position. Roof bolting machines equipped for wet drilling are currently available from J.H. Fletcher & Co., the leading U.S. manufacturer of roof bolting machines. Fletcher has worked closely with NIOSH in developing wet drilling technology.

Mist systems, developed by Joy Mining Machinery (U.S. Patent #5,875,858, Mist System - Joy Mining Machinery) and tested by NIOSH as a retrofit for J.H. Fletcher & Co. roof bolting machines, are currently in use in several mines. The big advantage to the mist drilling system is that it has the same benefit as wet drilling, but uses much less water. This creates a better work environment for the miner and puts less water on the mine floor. In mines where wet drilling creates a problem, mist drilling offers a viable alternative.

Outputs

4 Outputs

Title	Year	Output Type	Strategic Goal
A Sound Power Level Study of a Roof Bolter Peterson-JS; Kovalchik-PG; Matetic-RJ | SME Preprint No. 05-72, 2005 SME Conference, Salt Lake City, Utah, 2005; :8 pp	2005	Publication	Hearing loss
Mist System - Technologically Achievable, Administratively Achievable, and Promising Noise Controls (30 CFR Part 62) NIOSH | Information Bulletin P04-18, 2005 (http://www.msha.gov/regs/complian/PIB/2004/pib04-18.pdf)	2005	Publication (guidelines)	Hearing loss
Wet Drilling - Technologically Achievable, Administratively Achievable, and Promising Noise Controls (30 CFR Part 62) NIOSH | Information Bulletin P04-18, 2005 (http://www.msha.gov/regs/complian/PIB/2004/pib04-18.pdf)	2005	Publication (guidelines)	Hearing loss
Mining Hearing Loss Prevention Workshop NIOSH | Hosted by NIOSH-PRL, Charleston, WV; June 21-22, 2005	2005	Workshop, Seminar, or OIB	Hearing loss

Intermediate Outcome related to Preventing Noise-induced Hearing Loss

Reducing Noise on Continuous Mining Machines Using Coated Flight Bars

Description of Problem

Coated flight bars on a continuous mining machine

Data from the Mine Safety and Health Administration (MSHA) show that the continuous mining machine is first among all equipment in underground coal mining whose operators exceed 100% noise dosage. Continuous miners are large underground machines that cut coal at the working face of the mine. They gather up the cut coal and transport it via an onboard conveyor to the back of the machine. Here, it is loaded onto either another conveyor or a piece of mining equipment designed to carry the coal away from the working face. One of the main noise sources on a continuous mining machine is the onboard conveyor. This consists of a chain with flight bars that drags the coal along the base of the conveyor system. The metal chain and flight bars in contact with the metal base and the coal itself contribute greatly to the noise exposure of workers at the face. Continuous miner operators stand near the chain conveyor, especially at the back of the machine, and receive a great part of their noise exposure from the conveyor.

Research and Development Activities

NIOSH addressed this issue by developing a chain conveyor with coated flights as a noise control for reducing the sound power emissions of continuous mining machines. By coating the flight bars with a heavy-duty, highly durable plastic, the metal-to-metal and metal-to-coal contact is reduced. This reduces the noise levels. NIOSH designed, developed, and lab tested this control in partnership with labor (United Mine Workers of America), industry (National Mining Association, Bituminous Coal Operators' Association), manufacturers (Joy Mining Machinery, C.U.E., Inc.), and Mine Safety and Health Administration (MSHA) stakeholders. The coated flight bars have proven to withstand the harsh mining environment and achieve a total noise exposure reduction of 7 dB(A) at the operator position. In many cases, this reduction can bring the machine operator into compliance with current regulations.

R&D Outputs and Transfer Activities

The coated flight bar chain conveyor is currently being made and sold by Joy Manufacturing, Inc., which produces over 80% of the continuous mining machines in the United States. Also, this control is now being used in at least two U.S. operating coal mines and a mine in South Africa. Currently, NIOSH is conducting a study to show how effective this control is in reducing the noise exposure of continuous mining machine operators under a variety of conditions. NIOSH has transferred the findings of this research to interested industry parties through journal articles,

conference proceedings, conference presentations, industry/labor workshops, and industry/labor/NIOSH partnership meetings. Technology transfer efforts such as workshops, conference presentations, and journal articles are selected based on their ability to reach the target audience for the research.

Description of Intermediate Outcome

The acceptance of this technology as an effective noise control by members the Coal Mining Noise Partnership (United Mine Workers of America, MSHA, National Mining Association, and the Bituminous Coal Operators' Association) is evidence of the potential impact of this control. The Coal Partnership represents the workers, the mining companies, the mining machine manufacturers, and the regulatory/enforcement arm of the government for coal mining. Several mine operators at two coal mine sites have stated that they now observe a clear reduction in the noise level of the continuous mining machine. Also, the mine workers have noted that the control is easy to implement and very durable. MSHA cited this as a "promising" noise control in Program Information Bulletin P04-18, "Technologically Achievable, Administratively Achievable, and Promising Noise Controls (30 CFR Part 62)."

Outputs

5 Outputs

Title	Year	Output Type	Strategic Goal
A Noise Control for Continuous Miners Kovalchik-PG; Johnson-M; Burdisso-R; Duda-F; Durr-M | Tenth International Meeting on Low-Frequency Noise and Vibration and its Control (Sept. 11-13, 2002; York, United Kingdom)	2002	Publication	Hearing loss
Coated Flight Bars - Technologically Achievable, Administratively Achievable, and Promising Noise Controls (30 CFR Part 62) NIOSH | Information Bulletin P04-18, 2005 (http://www.msha.gov/regs/complian/PIB/2004/pib04-18.pdf)	2005	Publication (guidelines)	Hearing loss
Estimated Sound Power Radiated by Surfaces on a Continuous Miner Tail Section Using Vibration Measurements Yantek-DS | NOISE-CON 2003. Ames, IA: Institute of Noise Control Engineering of the USA, 2003 Jun; :1-9	2003	Publication	Hearing loss
Evaluation of Engineering Noise Controls for a Continuous Miner Conveyer System Durr-TM; Kovalchik-P; Kwait-E | NOISE-CON. Ames, IA: Institute of Noise Control Engineering of the USA, 2003 Jun; :1-11	2003	Publication	Hearing loss
Mining Hearing Loss Prevention Workshop NIOSH | Hosted by NIOSH-PRL, Charleston, WV; June 21-22, 2005	2005	Workshop, Seminar, or OIB	Hearing loss

Strategic Program Outcome for Cumulative Injuries

Preventing Musculoskeletal Disorders

Mining is one of the most physically demanding occupations. It is also one of the most dangerous in terms of exposure to ergonomic hazards. Musculoskeletal disorders (MSDs) resulting from repetitive manual work have long been identified as a significant and costly problem for the mining industry. Strain and sprain injuries account for 24.0% and 25.2%, respectively, of all reported injuries for underground coal mining. They account for 19.4% and 20.4%, respectively, of all injuries for underground metal/nonmetal mining. In 2003, the Mine Safety and Health Administration (MSHA) reported that 44% of all illnesses were joint, tendon, or muscle inflammation. Using a new process integration and interventions development approach in mining, NIOSH contributed to a 34% overall reduction in lost workdays due to repetitive-type injuries during 1998-2004. This approach focuses on incorporating the ergonomics process in existing safety and health programs of the mining companies and empowering the workers to proactively develop injury prevention solutions to their tasks.

Although the need for intervention and prevention is great, the underground mine environment poses unique barriers to implementing many standard ergonomic "fixes." The mining workplace is a very dynamic work environment. This dynamic nature requires that workers be made aware of risk factors and take early actions to reduce their injury risk. However, mining companies rarely spend the resources to educate workers on ergonomic interventions despite recent evidence that ergonomic considerations can have significant impact in reducing the risk of both MSDs and traumatic injuries. This impact is documented in other industries that voluntarily implemented interventions despite lack of any established ergonomic regulations, standards, and methodology prescribing how that science should be applied in a workplace.

Recent major accomplishments pertain to (1) whole-body vibration and (2) development of ergonomic processes through partnerships with mines. Previous studies have shown that operators of heavy mobile equipment are afflicted by musculoskeletal injuries of the arms, shoulders, neck, and lower back. From this review, it is shown that whole-body vibration (WBV) and the postural requirements of work (both static and awkward postures) are important risk factors that contribute to MSDs among equipment operators. Despite this, very little research has been done to systematically characterize the exposure to these ergonomic hazards. Quantifying vibration and postural requirements in practical settings is needed for a better understanding of the exposure levels present in different equipment while performing various tasks. Furthermore, it is important to evaluate postural instability caused by exposure to WBV and evaluate the availability of proper egress for preventing falls among operators of mobile equipment. As such, our research evaluates exposure to WBV, awkward posture, postural stability, and improper egress from equipment among operators of mobile equipment.

For an ergonomics process to be accepted and effective, it requires working with mining companies, associations, and regulatory agencies (MSHA and the Occupational Safety and Health Administration (OSHA)) in a holistic approach. Science-based education and interventions have led to a rising awareness among mining companies of the benefits of a proactive process addressing MSD risk factors. For example, successful education of 280 management and labor employees and implementation of a proactive ergonomics program at Bridger Coal Co. have resulted in reduced injuries and more than 22 ergonomic interventions in use at the company´s mine. Using results from the Bridger experience, researchers have been able to educate mines such as Badger Mining, Vulcan

Materials, Specialty Minerals, Unimin, and Morton Salt in the importance of the abovementioned new approach, which relies on an employee participation process to implement interventions that promote their health and safety at work. This success has led to the request by many mining companies (e.g., U.S. Borax, U.S. Silica, Consol) and organizations (e.g., Industrial Minerals Association (IMA), National Stone, Sand & Gravel Association (NSSGA), United Mine Workers of America (UMWA)) for similar guidance from NIOSH. Currently, three aggregate companies (Vulcan Materials, Hansen, and Luckstone) and two industrial sand companies (Unimin and Badger Mining), as well as two of the largest mining associations (IMA and NSSGA), have joined our effort to develop methods and education that ensure successful integration of ergonomics into their current safety and health programs.

Although several interventions have been developed in the past, the documentation of their effectiveness and use has not been recorded. A new approach of thorough documentation and measurement of usability and effectiveness is our focus as the programs grows over the next decade. NIOSH is attempting to address the lack of ergonomics education, process implementation, surveillance systems, and science-based interventions in mining. In that effort, a significant investment has been made to grow and focus MSD prevention research within the NIOSH Mining Program during recent years. The new MSD Prevention Team is composed of certified professional ergonomists, industrial and mining engineers, training specialists, physiologists, bioengineers, and engineering technicians. A multidisciplinary approach to bringing safety, health, and productivity is afforded through this diverse team and through cooperation with other Mining Program teams, such as training, machine safety, and electrical safety.

Our MSD prevention research has both field and lab components. Field research determines priority problems through direct observations and physical measurements. The physical requirements of any job are not easily measured in the workplace. Lab experiments provide opportunities to study MSD risk factors in a controlled environment. The results add to the science and knowledge base of ergonomics. Recently, a NIOSH researcher conducted studies that defined the physiological demand of performing lifting tasks while the back is in flexion. This study showed that the angle of flexion has a significant effect on resultant low-back pain and injury. Considering the restricted postures used by miners while doing their jobs, the impact of this study is far-reaching. This research directly relates to the importance of the design of physical tasks performed in mining and has contributed to a preliminary assessment tool designed to determine the prevalence of low-back pain as it relates to typical mining tasks.

Other functions of the lab studies are to simulate mining tasks and equipment, determine physical effort, and test possible interventions for better job and equipment design. For example, NIOSH developed an improved low-seam shuttle car seat that reduces worker exposure to damaging jarring and jolting. The seat is now available from Joy Mining Machinery, the largest equipment manufacturer of shuttle cars, and is being ordered by mining companies for both new and retrofit orders. Researchers examine the effects of the mining environment, workforce age, and equipment and tool design on the jobs performed by mine workers. Currently, experiments on ingress/egress of equipment, scaling bar, and roof bolter screening studies are being done in our state-of-the-art labs. These include three physical capabilities labs (strength, vibration, and motion analysis) and a human performance research mine, which simulates an underground mining environment. These new labs are equipped with current technologies, including telemetric electromyography, an infrared motion analysis system, a lumbar motion monitor, force plates, and goniometers. Major equipment

manufacturers (Joy, Jeffrey, and Voest-Alpine), universities (Purdue University, University of Pittsburgh, University of Wisconsin, and University of Cincinnati), and mining associations (IMA, NSSGA, and UMWA) are partners in the studies. Interventions are developed, tested, then taken to the field. This comprehensive methodology allows researchers to prioritize, study, and solve the most pressing and costly health and safety problems in the mining industry. Science-based interventions are then shared with the mining industry. The main goal is to reduce risk factors with a high probability of leading to MSDs and lost work.

Because the team is small compared to the required resources for directly addressing the needs of each mining company, leveraging large mining associations and partnering with mine companies, universities, and government agencies will help to integrate the ergonomics process into their existing health and safety programs. Our proactive approach to reduce risk factors on the job instead of waiting for an injury to occur is catching on fast in the mining industry. In view of the current predominantly older workforce, the mining industry is in a unique position to make use of their experience and knowledge to help design better mining methods, tools, equipment, and processes for a new generation of miners. The intermediate- and long-term impacts of our MSD injury prevention research is expected to be visible and significant. As the costs of MSD injuries continue to rise, reduction of risk factors becomes critical to the effective and efficient use of the mining industry´s most valuable asset - its workforce.

Intermediate Outcomes

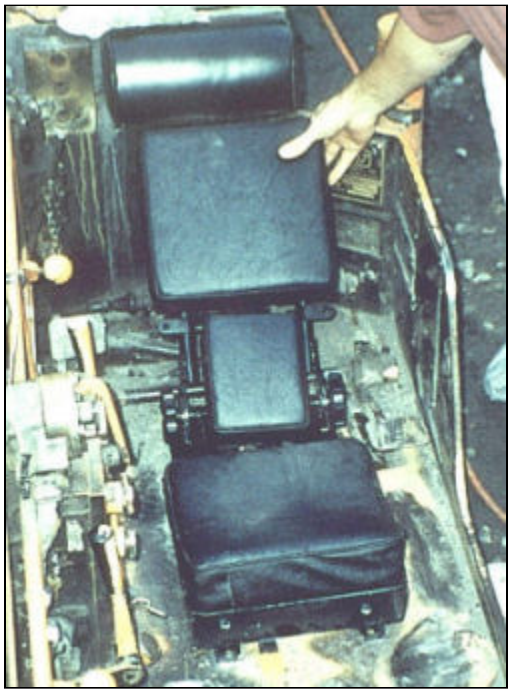
- Improved Seat Design for Low-Seam Shuttle Cars
- Reducing Work-related Musculoskeletal Disorders in Mining - Collaborations with Bridger Coal Company

Intermediate Outcome related to Preventing Musculoskeletal Disorders

Improved Seat Design for Low-Seam Shuttle Cars

Description of Problem

Research has shown that up to one-third of equipment operators in underground coal mines experience adverse levels of exposure to whole-body vibration (WBV). Major sources of WBV exposure are shuttle cars. Operators are exposed to vehicle jarring/jolting when the shuttle car travels over rough mine floor characterized by numerous bumps, ruts, and potholes. The problem is especially acute in low-seam coal mines, where seat suspension systems are hard to implement because of space restrictions.



Low seam shuttle car seat intervention for reducing jarring and jolting injuries

Research and Development Activities

NIOSH developed and tested an improved seat design for low-seam shuttle cars at cooperating mines in West Virginia and Kentucky. The seat accommodates a broader segment of the population because it is more adjustable and easier to use. It also features viscoelastic foam to reduce the risk of vehicle jolting and jarring injuries, as well as an adjustable lumbar pad needed to support the lower back while in a reclined seated position.

R&D Outputs and Transfer Activities

Joy Mining Machinery, Inc., has applied our research results for an improved seat design on low-seam shuttle car haulage. The enhanced seat design (use of viscoelastic foams and adjustable lumbar) became standard on all Joy 21SC shuttle cars as of August 2001.

Description of Intermediate Outcome

Joy Mining Machinery includes the improved seat design in its current product line. The company independently tested the new design and confirmed the results of the NIOSH study. Results from our field studies show that the vast majority of users prefer the new seat over traditional designs. The end users are pleased with the seats' ability to reduce jarring/jolting impact and to support their back and neck, as well as its adjustability. For the 21SC Model shuttle car, Joy Manufacturing has sold over 200 of the newly designed seats. They have also sold 60 replacement seats for existing 21SC Model shuttle cars in use. Approximately 150 new 10SC Model cars have been sold with the visoelastic foam padding and 100 replacement seats have been sold for the same model.

Outputs

7 Outputs

Title	Year	Output Type	Strategic Goal
Ergonomic and Existing Seat Designs Compared on Underground Mine Haulage Vehicles Mayton-A.J; Ambrose-DH; Jobes-CC; Kittusamy-NK | In: Proceedings of the Human Factors and Ergonomics Society 47th Annual Meeting (Denver, CO; Oct. 13-17, 2003). Santa Monica, CA: Human Factors and Ergonomics Society; :1256-1260	2003	Publication	Cumulative injuries; Traumatic injuries
Ergonomic Seat With Viscoelastic Foam Reduces Shock on Underground Mobile Equipment Mayton-AG; Gallagher-S; Merkel-R | In: B. Das; W. Karwoski, eds., Advances in Occupational Ergonomics and Safety II, IOS Press and Ohmsha, 1997 Jun; :177-180	1997	Publication	Cumulative injuries; Traumatic injuries
Ergonomic Seat With Viscoelastic Foam Reduces Shock on Underground Mobile Equipment Mayton-AG; Gallagher-S; Merkel-R | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin, 1998 Apr; :12-13	1998	Publication	Cumulative injuries; Traumatic injuries
Improved Seat Reduces Jarring/Jolting for Operators of Low-Coal Shuttle Cars Mayton-AG; Merkel-R; Gallagher-S | Mining Eng 51(12), 1999 Dec; :52-56	1999	Publication	Cumulative injuries; Traumatic injuries
Shock Reduction for Low-Coal Shuttle Car Operators Using Viscoelastic Seating Foam Mayton-A; Merkel-R; Gallagher-S | Society for Mining, Metallurgy, and Exploration Annual Meeting, SME preprint 98-44, Littleton, CO, Society for Mining, Metallurgy, and Exploration, Inc., 1998 Mar; :1-4	1998	Publication	Cumulative injuries; Traumatic injuries
Systematic Comparison of Different Seats on Shuttle Cars Used in Underground Coal Mines Kittusamy-NK; Mayton-AG; Jobes-CC; Ambrose-DH | Proceedings of the 32nd International Congress and Exposition on Noise Control Engineering, Jeju International Convention Center (Seogwipo, Korea; August 25-28, 2003)	2003	Publication	Cumulative injuries; Traumatic injuries
Technology News 459 - Ergonomic Seat Reduces Shock for Low-Seam Shuttle Car Operators Mayton-AG; Gallagher-S | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 459, 1997 May :1-2	1997	Publication	Cumulative injuries; Traumatic injuries

Intermediate Outcome related to Preventing Musculoskeletal Disorders

Reducing Work-related Musculoskeletal Disorders in Mining - Collaborations with Bridger Coal Company

Description of Problem

Work-related musculoskeletal disorders (MSDs) have long been identified as a significant and costly problem for the mining industry. These disorders result from exposure to MSD risk factors. Studies have shown that a sizable percentage of mine workers (at least 35%) were potentially exposed to overload conditions affecting the neck, back, forearms, arms, shoulders, fingers, and hands. The cumulative nature of MSDs suggests that older workers may be at greater risk since they have more years of exposure to physically demanding work. In addition, older workers often require a longer period of time to recover from injuries.

Intervention for reducing MSD in a dozer blade changing task at Bridger Coal

Research and Development Activities

Collaborative research with Bridger Coal Co. has led to the implementation of an ongoing, effective process to reduce exposure to work-related MSD risk factors. NIOSH's role is to guide and direct Bridger in customizing and implementing a sound ergonomics process that they can build upon and continue to benefit from for years to come. Bridger's ergonomics process has become a proactive model for other organizations to consider:

- How to integrate ergonomics into work processes to instill a proactive health and safety culture.
- How to actively encourage employee participation in reducing injury risk though science-based education and real-life applications.
- How to integrate ergonomic principles into specifications used for purchasing new equipment.

R&D Outputs and Transfer Activities

Collaborative research resulted in an organizational shift to a more proactive culture where reductions in risk factors for MSDs are the main dependent measures of safety and health success. NIOSH and Bridger personnel have coauthored publications and presentations designed to inform others about what was learned in applying ergonomics to a dynamic production process.

Description of Intermediate Outcome

Aided by NIOSH expertise, Bridger has changed its internal procedures with regard to assessing risk and examining work-related risk factors. PacifiCorp, Bridger's parent company, modified its risk assessment tools used across corporate sites to include work-related MSD risk factors.

Accordingly, Bridger has changed its internal procedures with regard to specifications and ergonomic considerations in purchasing new equipment. The company is also relying on an employee-based participative process to identify and implement ergonomic interventions that promote healthier work methods *before* injuries occur.

Bridger's ergonomics committee facilitated implementation of 22 interventions in 3 years. This resulted in reduced exposures to work-related MSD risk factors for several work tasks. About 4 years ago, Bridger began an effort to convert its surface mine to an underground operation. The ergonomics coordinator for the surface operations was assigned to apply the ergonomics process developed for the surface operation to the underground mine. Employee discomfort levels were assessed before and after (3 years) implementing the ergonomics process at the Jim Bridger Mine. The percentage of employees reporting discomfort decreased 15% over the 24- to 36-month timeframe. The specific body parts with decreased reports of discomfort included the neck, wrists, lower back, knees, ankles, and feet.

Outputs

11 Outputs

Title	Year	Output Type	Strategic Goal
Collaborative Ergonomics Field Research: An Assessment of Risk Factors at Four Mines Steiner-LJ; Bauer-ER; Cook-AH; Cornelius-KM; Gallagher-S; Rethi-LL; Rossi-EW; Turin-FC; Wiehagen-WJ | Min Eng 56(2), 2004; :41-48	2004	Publication	Cumulative injuries
Ergonomic Assessment of Musculoskeletal Risk Factors at Four Mine Sites: Underground Coal, Surface Copper, Surface Phosphate, and Underground Limestone Wiehagen-WJ; Turin-FC | NIOSH Publication No. 2004-159, Information Circular 9475, 2004 Aug :1-38	2004	Publication	Cumulative injuries
Ergonomic Issues in Mining Gallagher-S | In: Karwowski W, Marras WS, eds. The Occupational Ergonomics Handbook, Boca Raton, FL, CRC Press LLC, 1999; :1893-1915	1999	Publication	Cumulative injuries
Ergonomics Considerations for Reducing Cumulative Trauma Exposure in Underground Mining Cornelius-KM; Turin-FC | In: W. Karwowski, ed. International Encyclopedia of Ergonomics and Human Factors, 2001, Vol. III, London, United Kingdom, Taylor & Francis, Inc. 2001; :1497-1500	2001	Publication (guidelines)	Cumulative injuries
Initiating an Ergonomics Process at a Surface Coal Mine Unger-RL; Turin-FC; Wiehagen-WJ; Steiner-LJ; Cornelius-KM; Torma-Krajewski-J | In: Bockosh GR, Kohler JL, Langton JF, Novak T, McCarter MK, Biviano A, eds. Proceedings of the 33nd Annual Institute on Mining Health, Safety and Research (Aug 27-30, 2002; Roanoke, VA), Blacksburg, VA: Virginia Polytechnic Institute and State University, Department of Mining and Minerals Engineering, 2002; :39-47	2002	Publication (guidelines)	Cumulative injuries
Partnering for Successful Ergonomics: A Study of Musculoskeletal Disorders in Mining Steiner-LJ; James-P; Turin-FC | In: SME Annual Meeting (Feb 24-26, 2003; Cincinnati OH), SME preprint 03-118. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.; :1-5	2003	Publication	Cumulative injuries
Physical Strength Assessment in Ergonomics Gallagher-S; Moore-JS; Stobbe-TJ; McGlothlin-JD; Bhattacharya-A | In: Shell RL, Hall EL, eds. Handbook of Industrial Automation, New York, NY: Marcel Dekker, Inc., 2000; :797-827	2000	Publication	Cumulative injuries
Physical Strength Assessment in Ergonomics Gallagher-S; Moore-JS; Stobbe-TJ | American Industrial Hygiene Association 1998 :1-61	1998	Publication	Cumulative injuries
Recommendations for Reducing Mine Worker Cumulative Trauma Exposure Cornelius-KM; Turin-FC | In: Proceedings of the IIE Annual Research Conference. Norcross, GA: Institute of Industrial Engineers (CD-ROM), 2001	2001	Publication (guidelines)	Cumulative injuries
Using Ergonomics to Enhance Safe Production at a Surface Coal Mine: A Case Study With Powder Crews Wiehagen-W; Torma-Krajewski-J; Peterson-A; Turin-F; Unger-R | In: Proceedings of 2004 Joint Conference on Mine Safety and Health (May 23-28, 2004; Salt Lake City, UT)	2004	Publication	Cumulative injuries
What Works (and What Doesn't) in Mining Ergonomics Gallagher-S | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin Nov, 1999 Nov; :9-13	1999	Publication	Cumulative injuries

Strategic Program Outcome for Traumatic Injuries

Reducing Traumatic Injuries and Fatalities in Blasting

Over the past 25 years, the frequency of blasting-related injuries and fatalities at mining operations has dropped significantly. In 1978, 140 miners were killed or injured in U.S. blasting accidents. By 1998, this number had dropped to 22 and continued to decline to 7 in 2001. Factors contributing to increased blasting safety include the development of nonelectric initiation systems; the change from the use of cartridged explosives to bulk explosives; increased use of safer, non-nitroglycerine explosives; development of safer blasting practices; and an increase in the knowledge and professionalism of the average blaster. Industry, labor, and government all contributed to the improved safety record.

NIOSH conducted research to help eliminate injuries and fatalities resulting from blasting accidents. When high-detonation pressure (HDP-1) explosive boosters and Detaline initiation systems marketed by Explosives Technologies International (ETI) seemed to play a role in explosives accidents, the Mine Safety and Health Administration (MSHA) asked for technical assistance. Following a research project in which the accidents were simulated, NIOSH researchers identified the problem and advised the manufacturer and MSHA on how to modify the booster to make it safer.

During the 1990s there were a number of cases of carbon monoxide (CO) poisoning near blasting sites. Whether this type of accident had not occurred before the 1990s or whether it had occurred but had gone unrecognized is uncertain. The latter seems the more likely scenario. NIOSH became aware of the problem when a congressman asked for assistance in the investigation of a nonfatal CO poisoning incident in Dunmore, PA. As word of the incident and NIOSH assistance spread, requests came in from state and local officials who suspected that they might have cases of CO poisoning near blasting sites. NIOSH researchers became recognized as experts on the issue. Cases of CO poisoning near blast sites have essentially disappeared as NIOSH made blasters aware of the problem. Blasters now routinely place CO monitors in any structure at risk for CO infiltration.

The heavy equipment at all mining sites leads to the generation of quantities of waste motor oil. In past years, mines had no choice but to pay someone to dispose of this oil. Some in the industry realized that the waste motor oil could become a resource rather than a liability if it were used to make ammonium nitrate fuel oil (ANFO) blasting agent. MSHA regulations prohibited this practice because of concerns that contaminants in the oil could lead to the production of unusually sensitive, insensitive, or thermally unstable ANFO. MSHA would consider allowing mines to use the waste oil in explosives if this were approved on a case-by-case basis. Mines proposed procedures to use the waste oil in ANFO and asked for approval. There was no precedent for knowing which of these practices was safe. MSHA asked NIOSH to conduct research to evaluate the safety of waste oil-produced ANFO and help them develop safety guidelines for this practice. These guidelines were adopted by industry and are now used every time a mine uses waste oil in ANFO.

Mines in the Powder River Basin of Wyoming asked for NIOSH assistance when concerns arose about the orange or red product clouds rising from large-scale surface blasts. These blasts contained up to 8 million pounds of blasting agent. The orange to red color resulted from high concentrations of nitrogen dioxide (NO_2), a highly toxic gas, in the product cloud. NIOSH researchers met with mine safety personnel to discuss the problem and conducted in-house research to determine the

factors that lead to excessive NO_2. NIOSH advised the mines on the results of the research and recommended practices that might reduce NO_2 production. The mines and explosives suppliers adopted some of the recommendations and, in some cases, used them as the starting point for their own research to solve the problem.

NIOSH research has contributed to making blasting at mines safe and will continue to aid industry in maintaining this good safety record in the future.

Intermediate Outcomes

- Development of Guidelines for Reducing the Probability of Carbon Monoxide Poisonings Associated With Trench Blasting
- Development of Guidelines for the Safe Use of Waste Motor Oil in ANFO
- Modification of a High-Explosive Booster to Improve Safety
- Reduced NO_2 Production from Large-Scale Production Blasts at Surface Mines

Intermediate Outcome related to Reducing Traumatic Injuries and Fatalities in Blasting

Development of Guidelines for Reducing the Probability of Carbon Monoxide Poisonings Associated With Trench Blasting

Description of Problem

All explosives generate carbon monoxide (CO) to one degree or another depending on their oxygen balance. Since 1988, there have been 17 reported incidents in which explosive-generated CO moved through the ground and accumulated in a nearby underground enclosed space. As a result, there have been 30 suspected or medically verified CO poisonings and 1 fatality.

Researchers study data collected from an experimenal explosive shot at PRL

Research and Development Activities

NIOSH expertise was called upon to identify the root cause of the CO poisoning among several likely proposed scenarios. NIOSH researchers evaluated the evidence and identified poor-quality explosive formulation as a major contributing factor. During the study, NIOSH researchers also recognized a need to better educate blasters and workers as to the hazards of CO and to develop guidelines to reduce the probability of future events when blasting near occupied dwellings. Subsequently, NIOSH researchers have been called upon to assist in other explosives and mining-related investigations involving toxic fumes. These include gas migration incidents in Dunmore, PA; Kittanning, PA; Lake Mills, WI; Derry, PA; Bristow, VA; and Amherst, NY.

R&D Outputs and Transfer Activities

NIOSH published papers to alert the public and industry about the possibility of CO poisoning due to nearby blasting. NIOSH researchers have also given presentations on this topic at national conferences for the International Society of Explosives Engineers (ISEE), local ISEE chapter meetings, the Penn State Drilling and Blasting Conference, and drilling and blasting seminars sponsored by the Mine Safety and Health Administration. For each gas migration incident, NIOSH researchers met with local and state officials to educate and advise them. For example, one explosives researcher worked with the New York State Department of Transportation (NYSDOT) in Amherst, NY. In this incident, blasting for the installation of new sewer lines had produced CO that migrated into nearby homes and businesses. This caused home CO monitors to alarm. Researchers recommended a change in explosive and advised NYSDOT on CO monitoring techniques. They

also assisted NYSDOT in developing better safety requirements for blasters and steps to take to mitigate the effects of CO when detected in nearby homes. This was incorporated into the blast plan. NYSDOT also asked NIOSH to comment on the blast plan revisions, which included mitigation techniques to use in the event of high CO measured in nearby structures.

Description of Intermediate Outcome

In 2001, NIOSH *Technology News* No. 488 advised blasters to place CO monitors in basements of homes and businesses near blasting sites. Many blasters now routinely employ this practice. Since 2001 there have been no reported blasting-related CO poisonings. In the two most recent known incidents of CO migrating from blasts, home CO monitors alerted residents before they became sick. Blasters are now aware of the importance of using good-quality explosives to minimize generation of CO when blasting near occupied dwellings.

Outputs

8 Outputs

Title	Year	Output Type	Strategic Goal
Blasting-Related Carbon Monoxide Migration Incident in Bristow, Virginia Harris-ML; Rowland-JH; Mainiero-RJ | In: Proceedings of the 30th Annual Conference on Explosives and Blasting Technique (New Orleans, LA, Feb. 1-4, 2004). Vol. 2. Cleveland, OH: International Society of Explosives Engineers; :319-327	2004	Publication	Traumatic injuries
CO Migration from Trench Blasting in Amherst, New York Harris-ML; Mainiero-RJ | In: Proceedings of the 30th Annual Conference on Explosives and Blasting Technique (New Orleans, LA, Feb. 1-4, 2004). Vol. 2. Cleveland, OH: International Society of Explosives Engineers; :25-39	2004	Publication	Traumatic injuries
Fugitive Carbon-Based Gases: Blasting Related or Not Eltschlager-KK; Harris-ML; Baldassare-F | In: Proceedings of the 30th Annual Conference on Explosives and Blasting Technique (New Orleans, LA, Feb. 1-4, 2004). Vol. 1. Cleveland, OH: International Society of Explosives Engineers; :409-418	2004	Publication	Traumatic injuries
Hazard Evaluation and Technical Assistance Report, HETA-98-0020, Carbon Monoxide Intoxication and Death in a Newly Constructed Sewer Manhole NIOSH | U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA Report No. 98-0020; :1-22	1997	Publication	Traumatic injuries
NIOSH Hazard ID - Carbon Monoxide Poisoning and Death After the Use of Explosives in a Sewer Construction Project NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication 98-122, 1998 Mar	1998	Publication	Traumatic injuries
Protecting Workers From Toxic Fumes Generated by Explosives Mainiero-RJ | Tunnel Business Magazine, 1999 Dec; :15	1999	Publication	Traumatic injuries
Technology News 488 - Migration of Blasting Fumes into a Western Pennsylvania Home NIOSH | Pittsburgh, PA: US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 488, May 2001; :1-4	2001	Publication	Traumatic injuries
Toxic Fume Comparison of a Few Explosives Used in Trench Blasting Harris-ML; Sapko-MJ; Mainiero-RJ | In: Proceedings of the 29th Annual Conference on Explosives and Blasting Technique (Nashville, TN, Feb. 2-5, 2003). Vol. 2. Cleveland, OH: International Society of Explosives Engineers; :319-336	2003	Publication	Traumatic injuries

Intermediate Outcome related to Reducing Traumatic Injuries and Fatalities in Blasting

Development of Guidelines for the Safe Use of Waste Motor Oil in ANFO

Description of Problem

During the mid-1990s, several mines had asked the Mine Safety and Health Administration (MSHA) if they could dispose of waste motor oil from their heavy equipment by using it to make ammonium nitrate fuel oil (ANFO) blasting agent. MSHA regulations prohibited this practice because it was not known if it was safe.

Blasting agent, combined with waste oil, being loaded into boreholes

Research and Development Activities

MSHA asked for NIOSH assistance in determining whether this practice was safe and in developing a set of criteria that mines would have to follow to employ this practice safely. The Pittsburgh Research Laboratory conducted research to determine the temperature at which waste oil became too viscous to properly coat ammonium nitrate prills, developed a field test that blasters could use to ensure that their waste oil was properly mixing with ammonium nitrate, and evaluated the thermal stability of ANFO produced with waste oil. At MSHA's request, NIOSH assisted mines in developing safe procedures for the use of waste oil in ANFO.

R&D Outputs and Transfer Activities

NIOSH researchers and MSHA personnel developed a set of safe practices for the use of waste oil in explosives. MSHA required that any mine using waste oil in explosives had to follow these practices. Through publications and presentations at conferences, NIOSH informed blasters of these safe practices.

Description of Intermediate Outcome

The use of waste motor oil in ANFO has now become an accepted industry practice. The NIOSH-developed guidelines were adopted by the Institute of Makers of Explosives. Mines save the cost of disposal of waste motor oil, decrease their need for fuel oil, and turn waste motor oil into a usable resource rather than a waste product that requires disposal.

Outputs

2 Outputs

Title	Year	Output Type	Strategic Goal
Low Temperature Limits for Mixing Recycled Oil, Diesel Fuel, and Ammonium Nitrate to Make ANFO-Type Blasting Agents Ruhe-TC; Bajpayee-TS | In: Proceedings of the 22nd Annual Conference on Explosives and Blasting Technique (Orlando, FL, Feb. 4-8, 1996). Vol. 2. Cleveland, OH: International Society of Explosives Engineers, 1996; :232-243	1996	Publication	Traumatic injuries
Thermal Stability of ANFO Made with Recycled Oil Ruhe-TC; Bajpayee-TS | In: Proceedings of the 25th Annual Conference on Explosives and Blasting Technique (Nashville, TN, Feb. 7-10, 1999). Vol. 2. Cleveland, OH: International Society of Explosives Engineers, 1999 Feb; :263-271	1999	Publication	Traumatic injuries

Intermediate Outcome related to Reducing Traumatic Injuries and Fatalities in Blasting

Modification of a High-Explosive Booster to Improve Safety

Description of Problem

During 1996-1999, there were three blasting accidents involving a single type of detonator and booster. In one case, the detonator and booster detonated in the blaster's hands during assembly. The other two cases involved booster/detonator assemblies that initiated by impact at the bottom of a blasthole. Two blasters were killed and one injured in the three accidents.

High-explosive boosters ready to be lowered into a blasthole

Research and Development Activities

The Mine Safety and Health Administration asked explosives researchers at the Pittsburgh Research Laboratory (PRL) to assist in the investigation of these accidents. A borehole from the surface to the Bruceton Research Coal Mine was used to simulate a typical blasthole at a mine. Simulated boosters with detonators were dropped down the borehole to simulate two of the accidents. Impact geometry was varied to understand how the boosters may have detonated accidentally. Drop weight impact tests were conducted on the boosters and detonators to identify any unusual sensitivity to impact. Tests were conducted at Lake Lynn Laboratory to simulate what might happen if the detonator gets stuck in the booster and a blaster tries to pry it out with a knife. The findings showed that the accidents most likely occurred because the detonator well in the booster was partially plugged with foreign material such that a detonator could not be fully inserted, placing the detonator in a more exposed and hazardous position.

R&D Outputs and Transfer Activities

In 2000, PRL explosives researchers met with the manufacturer and the company's consultant. NIOSH researchers recommended that the booster be modified to incorporate a piece of tape over the detonator well to keep out foreign material.

Description of Intermediate Outcome

The manufacturer modified the specifications for its boosters according to NIOSH recommendations. Since the modification was made, there have been no further accidents involving this type of detonator and booster.

Outputs

3 Outputs

Title	Year	Output Type	Strategic Goal
MSHA Report, Summary of Explosive Testing Conducted Relative to the Accident at Material Service Quarry, Romeoville, IL Rowland-JH III; Mainiero-RJ	1999	Publication	Traumatic injuries
MSHA Report, Summary of Explosive Testing Conducted Relative to the Accident at Trapper Mining Inc., Craig CO Mainiero-RJ; Mytrysak-CA	1999	Publication	Traumatic injuries
MSHA Report, Summary of Testing Conducted Relative to Miller Quarry Accident Mainiero-RJ	1996	Publication	Traumatic injuries

Intermediate Outcome related to Reducing Traumatic Injuries and Fatalities in Blasting

Reduced NO_2 Production from Large-Scale Production Blasts at Surface Mines

Description of Problem

Over the past 10 years, large surface mines have been plagued by large orange or red product clouds produced by their large-scale blasting operations. The orange or red color of the cloud indicates high concentrations of nitrogen dioxide (NO_2), a highly toxic gas. There has been increasing concern over the effect of the NO_2 in the blasting product clouds on workers and neighbors.

Orange cloud produced by blasting at a surface coal mine

Research and Development Activities

On May 25, 2000, NIOSH researchers met with members of the Wyoming Mining Association (WMA) Red Smoke Committee to discuss how our research might help them to monitor and minimize the occurrence of blasting product clouds containing excessive concentrations of NO_2. The committee asked NIOSH for help in developing a plan to monitor NO_2 at its mines. A 3-year research project at the Pittsburgh Research Laboratory (PRL) was initiated to determine the causes for excessive NO_2 production in blasting. The research identified key factors that influenced the quantities of toxic fumes produced by various blasting agents.

R&D Outputs and Transfer Activities

PRL explosives researchers explained that they had used a variety of instrumentation to measure NO_2: a wet chemistry method, a chemiluminescence analyzer, a fixed electrochemical cell-based system, and portable electrochemical cell-based systems. NIOSH researchers also told WMA personnel that research had shown that excessive NO_2 production could be related to poor confinement, poor explosive formulation, and water contamination of the explosive. NIOSH recommended methods and strategies to reduce NO_2 production and minimize the potential for miner exposure.

Description of Intermediate Outcome

The gas monitoring protocol recommended by NIOSH researchers was incorporated into Thunder Basin Coal Co.'s action plan submitted to the Wyoming Department of Environmental Quality on April 7, 2000. It was also incorporated into the WMA's Powder River Basin Short-Term Exposure NO_2 Study. The mines in the Powder River Basin incorporated NIOSH research results into their blasting plans. These included lining blastholes and shooting with 100% emulsion blasting agent rather than ANFO/emulsion blends.

Outputs

4 Outputs

Title	Year	Output Type	Strategic Goal
Chemical and Physical Factors that Influence N0x Production During Blasting: Exploratory Study Sapko-M; Rowland-J; Mainiero-R; Zlochower-I | In: Proceedings of the 28th Annual Conference on Explosives and Blasting Technique (Las Vegas, NV, Feb. 10-13, 2002). Vol. 2. Cleveland, OH: International Society of Explosives Engineers, 2002 Feb; :317-330	2002	Publication	Surveillance and training; Traumatic injuries
Factors Affecting ANFO Fumes Production Rowland-JH, III; Mainiero-RJ | In: Proceedings of the 26th Annual Conference on Explosives and Blasting Technique (Anaheim, CA, Feb. 13-16, 2000). Vol. 1. Cleveland, OH: International Society of Explosives Engineers, 2000 Feb; :163-174	2000	Publication	Traumatic injuries
Factors Affecting Fumes Production of an Emulsion and ANFO/Emulsion Blends Rowland-JH III; Mainiero-R; Hurd-DA Jr. | Proc 27th Ann Conf Explos Blasting Tech. Vol. II. Cleveland, OH: International Society of Explosives Engineers, 2001; :133-141	2001	Publication	Traumatic injuries
Wyoming Mining Association seminar Mainiero-RJ | Assisted Wyoming Mining Association in preparing seminar for industry experts and federal regulators, including the US EPA, on blasting techniques and nitrous oxide gases (Jan 2000)	2000	Workshop, Seminar, or OIB	Traumatic injuries

Strategic Program Outcome for Traumatic Injuries

Reducing Electrically Related Traumatic Injuries

Data from the Mine Safety and Health Administration (MSHA) show that from 1990 to 2004 fatal electrical accidents decreased by 50%, lost workday electrical accidents decreased by 75%, and lost workdays decreased by 60%. Nevertheless, electrical accidents remained the fourth leading cause of on-the-job death in mining. The goal of the NIOSH electrical safety research program is to forge innovative solutions to existing and emerging problems in mine electrical safety. Research has focused on a variety of topics, including trailing cables, motors, trolley systems, ground fault protection, intrinsic safety, explosion-proof enclosures, overhead power lines, and lasers. For example, several aspects of electrical safety research have contributed to new and proposed changes in mining safety law that will dramatically increase high-voltage electrical safety and expedite new technology into the marketplace. Other electrical safety research is leading toward new safety standards for equipment that operates near high-voltage power lines.

Demand for larger, more powerful mining equipment stimulated the need for increased voltages for coal mine face machinery. Several NIOSH studies showed that higher voltages were feasible. The resultant research reports provided technical information to MSHA that was used to help formulate new regulations. These regulations went into effect on May 10, 2002, and allowed the use of high-voltage longwall machines in coal mines. The reports also contributed to the formulation of proposed new regulations for high-voltage continuous miners. These are now in the formal rulemaking process.

MSHA data show that nearly one-fifth of mine electrical deaths occur when workers contact overhead power lines. Research to protect workers from overhead power line electrocution led to one patent and stimulated two U.S. manufacturers to introduce stand-alone power line contact alarms.

Laser technology has become common in several fields, e.g., surveying and level detection. The use of lasers in potentially hazardous underground atmospheres was recognized as a new area of concern. Research was done to measure the risk of igniting flammable atmospheres by radiation from optical equipment. American National Standards Institute and International Electrotechnical Commission standards are now in process, based in part on NIOSH laser ignition research. These standards will result in safety guidelines for the safe use of lasers in gassy and dusty atmospheres.

These and other contributions of the NIOSH electrical safety research program have led to improved electrical safety for the U.S. mining workforce.

Intermediate Outcomes

- Contact Warning Alarm System to Reduce Overhead Power Line Injuries
- Electrical Safety Training to Reduce Overhead Power Line Injuries
- MSHA High-voltage Longwall Regulations
- Proposed MSHA Regulation to Improve High-voltage Continuous Miner Electrical Safety
- Research Guidelines Based on an Analysis of Occupational Electrical Injuries
- Using Lasers in Potentially Flammable Environments: Recommendations on Safer Limits

Intermediate Outcome related to Reducing Electrically Related Traumatic Injuries

Contact Warning Alarm System to Reduce Overhead Power Line Injuries

Description of Problem

High-voltage power line contact by a crane hoist cable

During the 1990s, about 20% of all mining electrocutions resulted from high-reaching mobile equipment that made contact with overhead electric power lines. A detailed analysis of these accidents revealed that 56% of the injured miners had contacted the equipment and ground simultaneously after the power line contact had occurred and were unaware of the shock hazard. These workers could have avoided injury had they simply known after the fact that the equipment had become energized. An overhead power line contact alarm, while not designed to avoid all related injuries, is a reliable, affordable, and practical alternative to proximity warning systems. Contact alarm technology could also reduce power line-related electrical injuries in other industries, such as construction. This system was developed to warn workers when a piece of mobile equipment becomes energized by a power line.

Research and Development Activities

NIOSH research identified one important aspect of power line electrocution little mentioned in the literature: workers are often killed or injured by electrically energized equipment before they are even aware of the hazard. NIOSH hypothesized that a system to alert operators and nearby ground crew workers could prevent more than half of these injuries in mining. Baseline experiments characterized voltage rises and danger areas on energized cranes and dump-bed trucks for equipment operators and other workers. Follow-on research identified two methods of power line contact detection. Undercarriage electric fields were identified as the most reliable detection method because of their ability to detect power line contact on all common road surfaces. Prototype technology was designed, built, tested, and transferred to industry.

R&D Outputs and Transfer Activities

The results of overhead power line hazard and contact alarm research and recommended hazard mitigations were published in several technical articles. An invited 90-minute workshop on Electrical Safety for Water Well Drillers was held at the National Ground Water Association annual meeting in Las Vegas, NV, December 12, 2004, and twice at the South Atlantic Water Well Driller's Jubilee, Myrtle Beach, SC, July 30-31, 2005. A U.S. patent for the "Alarm System for Detecting Hazards Due to Power Transmission Lines" was awarded on July 29, 2003.

Description of Intermediate Outcome

In 2004, the largest manufacturer of power line proximity warning alarms, Allied Safety Systems, Inc. (Sanford, FL), added undercarriage electric field detection as an option to its existing product line of power line proximity warning devices. This resulted, in part, from discussions with NIOSH engineers regarding the contact alarm concept. Allied plans to add a low-cost, stand-alone undercarriage power line contact alarm to its product line. Another manufacturer, Hirschmann Electronics, Inc./PAT America plans to introduce a power line proximity warning alarm that includes an undercarriage power line contact alarm as both an add-on and a low-cost, stand-alone product. With the market for proximity warning alarms systems estimated at 45,000 worldwide, the potential to reduce power line contact accidents is high.

Outputs

6 Outputs

Title	Year	Output Type	Strategic Goal
Alarm System for Detecting Hazards Due to Power Transmission Lines Sacks-HK; Yenchek-MR; Homce-GT; Cawley-JC | U.S Patent #6,600,426 (granted July 29, 2003)	2003	Patent	Traumatic injuries
Development of an Overhead Power Line Contact Alarm for Mobile Equipment Homce-GT; Cawley-JC; Sacks-HK; Yenchek-MR | International Journal of Heavy Vehicle Systems, (12)4, 2005 Apr; :87-103	2005	Publication	Traumatic injuries
Feasibility Study to Reduce Injuries and Fatalities Caused by Contact of Cranes, Drill Rigs, and Haul Trucks with High-Tension Lines Sacks-HK; Cawley-JC; Homce-GTR; Yenchek-MR | IEEE Trans Ind Appl, 37(3), 2001; :914-919	2001	Publication	Traumatic injuries
Heavy Equipment Near Overhead Power Lines? New Safety Research May Save Your Life: New Safety Research May Save Your Life Homce-GT; Cawley-JC; Sacks-HK; Yenchek-MR | Engineering and Mining Journal, (203)4, 2002 Apr :36-39	2002	Publication	Traumatic injuries
Electrical Safety for Water Well Drillers An invited, 90-minute workshop held at the National Ground Water Association annual meeting in Las Vegas, NV, December 12, 2004	2004	Workshop, Seminar, or OIB	Traumatic injuries
Electrical Safety for Water Well Drillers NIOSH | An invited, 90-minute workshop held twice at the South Atlantic Water Well Driller's Jubilee, Myrtle Beach, SC, July 30-31, 2005	2005	Workshop, Seminar, or OIB	Traumatic injuries

Intermediate Outcome related to Reducing Electrically Related Traumatic Injuries

Electrical Safety Training to Reduce Overhead Power Line Injuries

Description of Problem

The wide dissemination of electrical safety information depends on the actions of many groups. Based on its analysis of electrical safety in general industry, NIOSH was invited to participate on the Workplace Safety Committee of the Electrical Safety Foundation International (EFSI). ESFI is North America's only nonprofit organization dedicated exclusively to promoting electrical safety in the home, school, and workplace. NIOSH is now an active participant in this valuable collaboration to promote electrical safety.

Crane boom involved in an overhead power line contact fatal accident

Research and Development Activities

In 2004, the ESFI's Workplace Safety Committee produced the pamphlet "Look Up, Look Down, Look Out!" This was a joint educational effort between ESFI and its partners, including NIOSH, the Occupational Safety and Health Administration (OSHA), the National Safety Council, du Pont, Siemens, General Electric, Leviton, Square D, and other large electrical manufacturers and suppliers in the United States. The pamphlet raises awareness of the hazard of overhead power lines. A testimonial by Olympic gold medalist Cliff Meidl, who was injured in a power line accident, leads off the pamphlet. This is followed by a self-administered quiz to both attract the user's attention and to convey power line safety facts. All quiz responses contain true information regarding power line hazards. The reader is then referred to websites of CDC, OSHA, the National Fire Protection Association, and the Construction Safety Council for more information.

R&D Outputs and Transfer Activities

NIOSH played a major role in orienting the ESFI Workplace Safety Committee's educational effort. NIOSH also contributed significantly to the conceptual development of the pamphlet. Another educational pamphlet to emphasize electric shock prevention in the workplace is in process.

Description of Intermediate Outcome

During the 1990s, accidental contact with overhead power lines was implicated in 20% of mine electrical deaths and nearly half of all other on-the-job electrical deaths. The power line injury hazard is quite similar in mining, construction, manufacturing, and other industries. Electrical safety improvements in one industry can easily cross over into others. Small contractors and Latino workers are two high-risk target groups for power line accidents. These groups require innovative avenues for dissemination of information. The ESFI pamphlet carries the overhead power line hazard awareness message to small contractors via distribution at the contractor's sales desks of Home Depot and Lowe's stores, as well as equipment rental companies. Reaching the small

contractor audience in both English and Spanish will increase hazard awareness, a first step in accident reduction. The pamphlet is available in English and will soon be available in Spanish. About 800 copies have been sold. We expect future interactions between NIOSH and the ESFI to continue to raise workplace electrical hazard awareness in this and other areas.

Outputs

1 Output

Title	Year	Output Type	Strategic Goal
Look Up, Look Down, Look Out ESFI, OSHA, and NIOSH | Rosslyn, VA: Electrical Safety Foundation International, Inc.; :2 pp	2004	Publication	Traumatic injuries

Intermediate Outcome related to Reducing Electrically Related Traumatic Injuries

MSHA High-voltage Longwall Regulations

Description of Problem

High-voltage longwall equipment

The demand for larger, more powerful mining equipment stimulated the need for increased voltages for coal mine face machinery. Higher-voltage equipment can supply more power without the need for larger, heavier portable cables. Special design, use, and maintenance precautions are needed to ensure an equivalent level of safety when high-voltage systems are used in permissible areas. Prior to passage of the Mine Safety and Health Administration's (MSHA) final rule for high-voltage longwall machines, the voltage limit for type-accepted permissible longwall machines was 1,000 V ac. Equipment operating above 1,000 V ac required a petition for modification. This entailed an approval examination for each high-voltage longwall machine deployed inby, which greatly slowed the industry penetration of this more productive mining equipment.

Research and Development Activities

NIOSH research showed that higher voltages for face equipment was feasible with appropriate precautions. Under one study, a 750-kVA explosion-proof load center was built that was used by MSHA's Approval and Certification Center as a test bed. It provided important information about large-scale, high-voltage, explosion-proof equipment. Another research study produced finite-element stress calculations and a material analysis, the results of which helped formulate the final rule.

R&D Outputs and Transfer Activities

Several NIOSH reports provided technical information to MSHA that was used to help formulate new regulations to allow the use of high-voltage longwall machines in coal mines. The information included the enclosure pressures developed during electrical arcing at up to 15 kV in methane-air atmospheres. Also included were recommendations for high-voltage electrical creepage and clearance distances, design criteria for explosion-proof enclosures, and permissibility hazard reduction. The final rule credits two separate NIOSH research reports that were used to help formulate its technical language.

Description of Intermediate Outcome

MSHA published its final rule for 30 CFR 18 and 75, "Electric Motor-Driven Mine Equipment and Accessories and High-Voltage Longwall Equipment Standards for Underground Coal Mines" on March 11, 2002 (Federal Register, Vol. 67, No. 47, March 11, 2002, Rules and Regulations, pp. 10972-11005): http://www.dol.gov/msha/regs/fedreg/final/2002004863.pdf. This final rule established MSHA's new mandatory electrical safety standards for the installation, use, and maintenance of high-voltage longwall mining systems used in underground coal mines. The final rule also included design approval requirements for high-voltage equipment operated in longwall face areas of underground mines. The new provisions allow the use of high-voltage longwall face equipment with enhanced protection from fire, explosion, and shock hazards without the need for a petition for modification. This regulation ensures an equivalent level of electrical safety and streamlines the approvals process.

Outputs

8 Outputs

Title	Year	Output Type	Strategic Goal
A Design Guide for Explosion-Proof Electrical Enclosures Cox-PA; Scott-LW | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Information Circular 8893. NTIS No. PB 83-119487	1982	Publication	Traumatic injuries
A Study of Explosion-Proof Enclosures Cox-PA; Burnside-OH; Esparza-ED; Lin-FD; White-RE | San Antonio, TX: Southwest Research Institute. USBM contract No. H0-377052. OFR 96-83, NTIS No. PB 83-205450; :426 pp	1982	Publication	Traumatic injuries
Development of High-Voltage Permissible Loadcenter Berry-DR; Gillenwater-B | U.S. Bureau of Mines contract no. H0308093. NTIS No. PB 86-215803	1986	Publication	Traumatic injuries
Development of Recommended Criteria and Test Facilities for Acceptance of High-Voltage Permissible Loadcenters and Switchgear Enclosures Massey-AB | U.S. Department of Labor, Mine Safety and Health Administration. U.S. Bureau of Mines contract No. J0333909. NTIS No. PB 87-157434	1986	Publication	Traumatic injuries
Mine Electrical Systems Evaluation: Explosion-Proofing of Mine Containers Stefanko-R; Morley-LA | University Park, PA: The Pennsylvania State University, College of Earth and Mineral Sciences. U.S. Bureau of Mines Contract Report No. G0-133077, OFR 76(2)-75, NTIS Number: PB/245-928/As, 76 pp	1974	Publication	Traumatic injuries
Mine Power Systems Morely-LA | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Information Circular 9258. NTIS No. PB 91-241729	1990	Publication	Traumatic injuries
The Effects of Cable Capacitance on Longwall Power Systems Novak-T; Basar-J; Sottile-J; Kohler-JL | IEEE Trans Ind Appl 40(5), 2004; :1406-1412	2004	Publication	Traumatic injuries
Electric Motor-Driven Mine Equipment and Accessories and High-Voltage Longwall Equipment Standards for Underground Coal Mines Federal Register, Vol. 67, No. 47, March 11, 2002, Rules and Regulations, pp. 10972-11005	2002	Standards	Traumatic injuries

Intermediate Outcome related to Reducing Electrically Related Traumatic Injuries

Proposed MSHA Regulation to Improve High-voltage Continuous Miner Electrical Safety

Description of Problem

High-voltage continuous miner

The demand for larger, more powerful mining equipment stimulated the need for increased voltages for coal mine face machinery. Higher-voltage equipment can supply more power without the need for larger, heavier trailing cables. Special design, use, and maintenance precautions are needed to ensure an equivalent level of safety when high-voltage systems are used in permissible areas. The voltage limit for type-accepted continuous miners is 1,000 V ac. Equipment operating above 1,000 V ac requires a petition for modification. This entails an approval examination for each high-voltage continuous miner deployed inby.

Research and Development Activities

NIOSH conducted research studies indicating that higher voltages for face equipment was feasible with appropriate precautions. In addition to the studies used to develop the high-voltage longwall final rule, Information Circular (IC) 9258, "Mine Power Systems," provided information used to specify important shock protection sections of the continuous miner proposed rule.

R&D Outputs and Transfer Activities

Results drawn from at least five separate NIOSH reports were used to help formulate the technical language in the proposed rule. These studies provided critical parts of the technical basis for the proposed MSHA regulations. The information used from the reports included the enclosure pressures developed during electrical arcing at up to 15 kV in methane-air atmospheres. Also included were recommendations for high-voltage electrical creepage and clearance distances, design criteria for explosion-proof enclosures, permissibility hazard reduction, and ground fault protection. MSHA used these reports in rulemaking regarding Part 6 equivalency determinations for Part 18 enclosures. MSHA also used them to help reconcile philosophical differences in other standards (both foreign and domestic) for designing explosion-proof enclosures.

Description of Intermediate Outcome

MSHA has proposed new requirements (Federal Register, July 16, 2004, Vol. 69, No. 136, proposed rules, pp. 42811-42840) for the approval of high-voltage continuous mining machines operating in face areas of underground mines: http://www.msha.gov/REGS/FEDREG/PROPOSED/2004prop/04-15841.pdf. The proposed rule was published to allow type acceptance of continuous mining machines, thus avoiding the petition for modification process for each high-voltage continuous miner placed into service. MSHA also

proposed new mandatory electrical safety standards for the installation, use, and maintenance of high-voltage continuous mining machines used in underground coal mines. These provisions will enable mines to use type-accepted high-voltage continuous mining machines with enhanced safety protection from fire, explosion, and shock hazards.

Outputs

7 Outputs

Title	Year	Output Type	Strategic Goal
A Design Guide for Explosion-Proof Electrical Enclosures Cox-PA; Scott-LW | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Information Circular 8893. NTIS No. PB 83-119487	1982	Publication	Traumatic injuries
A Study of Explosion-Proof Enclosures Cox-PA; Burnside-OH; Esparza-ED; Lin-FD; White-RE | San Antonio, TX: Southwest Research Institute. USBM contract No. H0-377052. OFR 96-83, NTIS No. PB 83-205450; :426 pp	1982	Publication	Traumatic injuries
Development of High-Voltage Permissible Loadcenter Berry-DR; Gillenwater-B | U.S. Bureau of Mines contract no. H0308093. NTIS No. PB 86-215803	1986	Publication	Traumatic injuries
Development of Recommended Criteria and Test Facilities for Acceptance of High-Voltage Permissible Loadcenters and Switchgear Enclosures Massey-AB | U.S. Department of Labor, Mine Safety and Health Administration. U.S. Bureau of Mines contract No. J0333909. NTIS No. PB 87-157434	1986	Publication	Traumatic injuries
Mine Electrical Systems Evaluation: Explosion-Proofing of Mine Containers Stefanko-R; Morley-LA | University Park, PA: The Pennsylvania State University, College of Earth and Mineral Sciences. U.S. Bureau of Mines Contract Report No. G0-133077, OFR 76(2)-75, NTIS Number: PB/245-928/As, 76 pp	1974	Publication	Traumatic injuries
Mine Power Systems Morely-LA | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Information Circular 9258. NTIS No. PB 91-241729	1990	Publication	Traumatic injuries
High-Voltage Continuous Mining Machines RIN 1219-AB34, Federal Register, July 16, 2004, Vol. 69, No. 136, proposed rules, pp. 42811-42840	2004	Standards	Traumatic injuries

Intermediate Outcome related to Reducing Electrically Related Traumatic Injuries

Research Guidelines Based on an Analysis of Occupational Electrical Injuries

Description of Problem

Arc resistant personal protective clothing

A comprehensive look at electrical injury in mining and other industries was needed to help refocus the electrical safety research. Injury from electric arcs forms the largest single category of nonfatal electrical injuries in mining. A significant industrial electrical safety research effort has focused on protecting workers from electrical arcing hazards. National Fire Protection Association (NFPA) standard 70E, "Standard for Electrical Safety Requirements for Employee Workplaces," explicitly excludes underground mining from its scope. In addition, accidental contact with overhead power lines was implicated in 20% of mine electrical deaths and nearly half of all other on-the-job electrical deaths. Many of these power line accidents were thought to be preventable.

Research and Development Activities

Two analyses were completed. One focused specifically on mining electrical injury and helped refocus mine electrical safety research toward electrical arcing fault injury. The second analysis of electrical injury patterns showed that power line accidents are the single greatest on-the-job fatal electrical hazard in general industry. Recommendations to fill research gaps were made.

R&D Outputs and Transfer Activities

The NIOSH research products gained wide acceptance in the electrical safety community. Results were given at an invited presentation at the IEEE IAS PCIC Electrical Safety Workshop, Oakland, CA, in 2003 and were published in several technical articles that analyzed injuries in the electrical industry.

Description of Intermediate Outcome

Refocused NIOSH mine electrical research is now bringing the relevant aspects of NFPA 70E into the mining workplace to afford miners better protection from electrical arcing injury. NIOSH attacked the power line injury problem by attempting to influence stakeholder groups to devote more of their research efforts to this area. Influential contacts in the electrical safety community now recognize the magnitude of the power line problem and are more receptive to research and cooperation in this area. In addition, training efforts have made inroads into other industries such as water well drilling, where power line contact is the leading killer. The electrical industry injury analysis published by NIOSH was described by IEEE Industry Applications Applications Society

(IAS) President-elect H. Landis Floyd II as a "landmark study" of electrical injury in his column in the March-April 2004 issue of IEEE *Industry Applications Magazine*, and it was cited again in the May-June 2004 issue. This analysis has begun to shift research focus among IEEE Petroleum and Chemical Industry Committee (PCIC) electrical safety professionals toward the overhead power line problem. The analysis was also cited in several other technical journals.

Outputs

2 Outputs

Title	Year	Output Type	Strategic Goal
Electrical Accidents in the Mining Industry, 1990-1999 Cawley-JC | IEEE Trans Ind Appl 2003 Nov/Dec, 39(6;):1570-1577	2003	Publication	Traumatic injuries
Occupational Electrical Injuries in the United States, 1992-1998, and Recommendations for Safety Research Cawley-JC; Homce-GT | J Safety Research 2003 Aug; 34(3):241-248	2003	Publication	Traumatic injuries

Intermediate Outcome related to Reducing Electrically Related Traumatic Injuries

Using Lasers in Potentially Flammable Environments: Recommendations on Safer Limits

Description of Problem

The use of laser and other optical beam equipment in gassy and dusty atmospheres was generally thought to be safe. For example, laser-based level monitors are used in coal storage facilities. Laser-guiding fiber-optic cables for telecommunications have been installed inside natural gas pipelines in several states. Guidelines were needed to define if and when a laser beam can be considered a potential ignition source in such environments.

Installation of a fiber optic communications cable in a natural gas line

Research and Development Activities

Research to determine the risk of laser-based optical equipment igniting a flammable atmosphere was done to support the development of national and international laser safety standards. Continuous-wave, diode-array lasers and fiber lasers were used to measure the dimensions and durations of the laser beams needed to ignite flammable gas atmospheres and dust clouds. Atmospheres containing methane, propane, and butane were tested. Iron oxide was deposited on the end of a fiber to simulate a broken fiber in a dirty environment. Lean mixtures of methane ignited at 410 mW, rich mixtures of butane at 300 mW, and rich mixtures of propane at 250 mW. Two types of coal dust clouds were also tested. The significant findings were that Pittsburgh seam coal and Powder River Basin coal both ignited using 2 W out of a beam diameter of 0.2 mm. Corn starch, an easily ignitable grain dust, was also tested and found to ignite using 1.5 W out of a 0.2-mm-diam fiber.

R&D Outputs and Transfer Activities

NIOSH research helped form the basis of the American National Standards Institute (ANSI) and International Electrotechnical Commission (IEC) documents on laser safety in flammable atmospheres. Research results were published in two technical articles. A U.S. patent , "Method and Apparatus for Safety Testing Optical Systems for Hazardous Locations," was awarded on December 23, 2003.

Description of Intermediate Outcome

ANSI cited NIOSH research results in its technical report (ANSI/ISA-TR12.21.01-2004) on fiber optics used in flammable environments. The report also credits NIOSH as the lead developer of the document. It was used as the base document for an IEC standard, which is in the "committee draft for vote" stage. The draft document, IEC 60079-28 Ed. 1.0: "Protection of Equipment and Transmission Systems Using Optical Radiation," also cites NIOSH research. In addition, the Mine Safety and Health Administration published a notice of intent to review parts of the IEC 60079 standard for application to U.S. mining equipment approvals. Safety recommendations called out by the ANSI technical report are cited in a draft American Society for Testing and Materials International Standard WK2307, "Standard Specification for Selection of Fiber-optic Cable and System Components for Use in Natural Gas Pipelines." Collectively, these standards help ensure that laser applications can be installed safely in mines and other flammable environments.

Outputs

5 Outputs

Title	Year	Output Type	Strategic Goal
Continuous Wave Laser Ignition Thresholds of Coal Dust Clouds Dubaniewicz-TH Jr; Cashdollar-KL; Green-GM | Journal of Laser Applications, 2003 Aug; 15(3):184-191	2003	Publication	Mine disasters; Traumatic injuries
Ignition of Methane-Air Mixtures by Laser Heated Small Particles Dubaniewicz-TH Jr; Cashdollar-KL; Green-GM; Chaiken-RF | Journal of Loss Prevention in the Process Ind, 2000 May 13(3-5):349-359	2000	Publication	Traumatic injuries
Method and Apparatus for Safety Testing Optical Systems for Hazardous Locations Dubaniewicz-TH; Green-GM | U.S Patent #6,667,801 (granted December 23, 2003)	2003	Patent	Traumatic injuries
Draft ASTM International Standard - WK2307, Standard Specification for Selection of Fiber-Optic Cable and System Components for Use in Natural Gas Pipelines ASTM | Technical report ANSI/ISA-TR12.21.01-2004	2004	Standards	Traumatic injuries
Final Draft International Standard IEC 60079-28 Ed. 1.0: Protection of Equipment and Transmission Systems Using Optical Radiation IEC	2005	Standards	Traumatic injuries

Strategic Program Outcome for Traumatic Injuries

Reducing Machine-related Traumatic Injuries

Despite advances in mechanization, mining remains among the most physically demanding and hazardous of all occupations. Traumatic injuries resulting from machinery, powered haulage, and falls have long been identified as a significant problem for the mining industry. According to the Mine Safety and Health Administration (MSHA), during 1995-2004 there was a 42% decrease in days lost due to machinery injuries, a 51% decrease in days lost due to powered haulage injuries, and a 34% decrease in days lost due to falls.

NIOSH contributed to this significant improvement through its machine safety research program. NIOSH-developed research products and recognized experise are being used by our stakeholders to further reduce the risk of machine-related injuries. Examples include:

- *A close-proximity warning device:* The research product (HASARD - Hazardous Area Signaling and Ranging Device) has been recently licensed to three firms that manufacture the system for their own use and commercial sales.
- *Technical guidance in the application of proximity warning systems:* MSHA and equipment manufacturers make use of NIOSH expertise to aid in decision-making on effective proximity warning systems and technologies to prevent accidents.
- *A set of best practices for system safety:* NIOSH collaborative research has developed a set of documents relating to the safety life cycle for programmable electronic mining systems. The research has been integrated into the national and international mining communities.
- *A computer program that evaluates mine illumination systems:* NIOSH-developed software (called the Crewstation Analysis Program) is routinely used by MSHA´s Approval and Certification Center in the approval process for mine lighting systems.

Miners interact with a wide assortment of machinery and tools in the course of their work. They work in an environment that is dynamic and often unforgiving. Work environments involving extraction, bolting, and haulage require the integration of large mobile machinery working in confined space. It is a recipe for danger as the consequence of small errors can be serious. According to MSHA, 10 miners on average are killed each year by being run over or pinned by mobile mining equipment. Therefore, a systematic study of the interaction of miners, their tools and equipment, and their work environment is needed to reduce the risk of serious injury.

Both labor and industry have expressed the need for a "systems perspective" to reduce the risk of serious injury. A systems perspective requires the integration of human-centered design principles with new mining technology. Little research has been done in this area partially because of the difficulty and potential dangers in collecting sufficient data in the underground and surface work environments. However, with advances in computer modeling and simulation methods, coupled with the unique test facilities of the NIOSH Mining Program, most of the data can be collected either virtually or in simulated environments. This allows for the integration of human-centered design principles into work system and machinery design.

The basis for current and future work is risk assessment. Proactively researching issues that can integrate a large number of system variables (e.g., visibility, work station and control design, computerized control of machinery, and maintenance and repair tasks) will promote the better design of new technology to reduce risk. Partnering with the United Mine Workers of America, original equipment manufacturers (e.g., Joy Mining Machinery, Inc., J. H. Fletcher & Co., DBT America), and government agencies (MSHA) will proactively develop and disseminate science-based solutions to the mining industry.

Reducing accidents associated with machinery, powered haulage, and falls in mining requires full-scale testing and analysis of equipment and apparatus. Without a regulatory impetus, manufacturers are often unwilling to invest in finding solutions to these safety hazards. The NIOSH Mining Program is unique in its test facilities for full-scale evaluation of mining machinery. Our record of partnering with industry and labor will help to proactively develop and disseminate injury prevention strategies.

Intermediate Outcomes

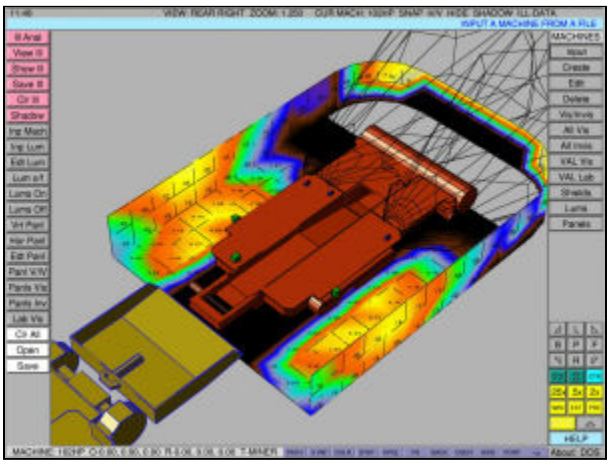
- Crewstation Analysis Programs (CAP) to Reduce Injuries Due to Sub-Optimal Machine Illumination Systems
- Guidance for Applying Proximity Warning Systems to Surface Mine Equipment
- Proximity Warning System for Reducing Injuries Pertaining to Mobile Mining Equipment
- System Safety Best Practices to Reduce Injuries due to Malfunctioning Computerized Mining Systems

Intermediate Outcome related to Reducing Machine-related Traumatic Injuries

Crewstation Analysis Programs (CAP) to Reduce Injuries Due to Sub-Optimal Machine Illumination Systems

Description of Problem

Restricted fields of vision are a common problem with underground mining equipment, particularly in lower seams. In addition, when lighting systems are provided underground, they are often positioned where they cause excessive glare. This limits visibility around the machines even further. Evaluations of mining lighting systems are required by 30 CFR 75.1719. Typical ways to do this are to take actual light readings on machines underground or on mockups in an accepted darkroom.



Screenshot of CAP evaluating an illumination system

Research and Development Activities

NIOSH collaborative research has led to improved practices for assessing alternative illumination designs for underground mining systems. Researchers developed an improved software package (Crewstation Analysis Programs (CAP)) to assess and evaluate machine-mounted illumination systems.

R&D Outputs and Transfer Activities

The Mine Safety and Health Administration's Approval and Certification Center routinely uses the CAP software in the approval process for mine lighting systems. Use of the software results in significant cost and time savings to mining machine manufacturers and MSHA for a critical aspect of machine design.

CAP software is used by all major U.S. mine lighting manufacturers (Ocenco, Inc., and Mining Controls, Inc.). MSHA uses CAP in its Statement of Test and Evaluation (STE) procedures because it is more accurate and less costly than traditional methods for assessing illumination levels. NIOSH continues to collaborate with MSHA to provide enhancements to the CAP software.

Although there are no illumination standards for surface mining, the CAP software has been used to design lighting systems for surface equipment. CAP has also been requested by several foreign countries, but NIOSH has not yet received any feedback on its use.

Description of Intermediate Outcome

- MSHA Criteria for Using the Crewstation Analysis Programs to Acquire Light Survey Data Required for STE Applications: http://www.msha.gov/techsupp/acc/application/acri2006.pdf

- MSHA has published requirements referencing the CAP software in its Standard Application Procedure for Statement of Test and Evaluation (STE) for Mining Machines and Longwall Mining Systems: http://www.msha.gov/techsupp/acc/application/asap2023.pdf
- MSHA has published criteria referencing CAP for Acquiring Illumination Data in an STE Applicant's Darkroom: http://www.msha.gov/techsupp/acc/application/acri2002.pdf
- MSHA has published a Standard Test Procedure to Collect ISO-Footcandle Illumination Curves at Independent Light Laboratories: http://www.msha.gov/techsupp/acc/standardtestprocs/astp2050.pdf

Outputs

4 Outputs

Title	Year	Output Type	Strategic Goal
An Easy to Use PC Based Lighting and Visibility Analysis Software Package for Underground Mining Equipment Unger-RL | Bureau of Mines Special Publication SP 18-94, 1994; :133-139	1994	Publication	Traumatic injuries
Computer Design and Evaluation Tool for Illuminating Underground Coal-Mining Equipment Gallagher-S; Mayton-AG; Unger-RL; Hamrick-CA; Sonier-P | Journal of the Illuminating Engineering Society 25(1), 1996; :3-12	1996	Publication	Traumatic injuries
Crewstation Analysis Programs Reference Manual: Procedures to Collect Photometric Data for the Computer Modeling of Underground Machine Mounted Lighting Systems - First Edition Unger-RL; Mayton-AG; Rossi-EW | Bureau of Mines Special Publication 23-94	1994	Publication	Traumatic injuries
Crewstation Analysis Programs (CAP) Unger-RL | NIOSH 1996; :Software	1996	Software	Traumatic injuries

Intermediate Outcome related to Reducing Machine-related Traumatic Injuries

Guidance for Applying Proximity Warning Systems to Surface Mine Equipment

Description of Problem

An accident due to lack of visibility

An average of 40 accidents and five fatalities occur each year in the U.S. surface mining industry that can be attributed to the lack of visibility around large, off-highway mining equipment. These accidents account for 12% of all surface mine fatalities. They fall into two main categories: (1) collisions between mining equipment and smaller vehicles, workers on foot, structures, or other equipment and (2) driving or backing over the edge of an embankment, stock pile, dump point, or other change in terrain. The areas surrounding the equipment that an operator cannot see from the cab can be extensive and are a major contributing factor.

Research and Development Activities

In 1998, the Mine Safety and Health Administration (MSHA) proposed rules requiring some type of sensor-based proximity warning system and cameras to monitor blind areas around mining equipment. At that time, no sensor-based technology had been thoroughly tested on large, off-highway mining equipment. Cameras had been applied only to a limited extent. NIOSH proposed that a test program be initiated for off-the-shelf proximity warning systems to see how they performed on mining equipment before finalizing any rules. For the past few years, NIOSH and MSHA have been working together to evaluate proximity warning systems in order to understand their applications and limitations on mining equipment.

NIOSH developed a test protocol to evaluate various warning systems and studied available technology to assess which systems are most effective in preventing collisions in surface mining conditions. A combination of an off-the-shelf radar system and a camera has been thoroughly tested at a surface mine. Tests have also been done on innovative systems developed in cooperation with outside organizations. These include a GPS-based system and a stereovision system.

R&D Outputs and Transfer Activities

During 2001-2005, the results of this research were transferred to the mining industry through 13 technical publications and nine presentations. This research also assisted MSHA in publishing a Web page with information and training material on proximity warning systems.

Description of Intermediate Outcome

The NIOSH-originated procedures for testing and integrating protocols for use of proximity warning systems are being used by the mining industry, MSHA, and equipment manufacturers to make decisions about the most effective technologies to prevent accidents. NIOSH has provided input to MSHA regarding new regulations to improve the safety of operating surface mine haulage equipment. Some of the outcomes are as follows:

- NIOSH researchers were asked to act as subject matter experts and committee members during the development of the International Standards Organization (ISO) standard 16001 - Earth moving machinery - Hazard detection systems and visual aids - Performance requirements and tests. NIOSH Reports of Investigations (Ris) were referenced in the standard. Also, a NIOSH researcher wrote sections of the standard dealing with test procedures for radar (annex C) and tag-based proximity warning systems (annex F). This ISO standard can be accessed at: http://www.iso.org/
- The Canadian CIM Bulletin (Vol. 93, No. 1045) cited a NIOSH study that is evaluating proximity warning systems to monitor blind areas near mining equipment. The article is entitled "New Technology Makes Safety Easier."
- The United Kingdom's Health and Safety Executive (HSE) cited NIOSH test results on proximity warning systems in its report entitled "Improving the Safety of Workers in the Vicinity of Mobile Plant" (contract research report 358/2001). The NIOSH work was referred to as "arguably the most comprehensive comparative testing of vehicle and personnel detection systems."
- MSHA used NIOSH study results to publish a Web page describing available proximity warning systems for mining equipment. It is entitled "Accident Prevention through the use of New Technologies" and is available at http://www.msha.gov/.
- Caterpillar, Inc. and Phelps Dodge, Inc. are using NIOSH study results to make decisions about implementing proximity warning systems on mining equipment. A NIOSH researcher has been asked by Caterpillar to act as a subject matter expert on a work group that is designing a system for mining and construction equipment. Phelps Dodge has participated in NIOSH tests and is using NIOSH study results to select systems for large-scale tests.
- NIOSH worked closely with Preco Electronics, Boise, ID, to modify its existing radar-based proximity warning system so that it would work more effectively on large, off-highway equipment. NIOSH recommendations were incorporated in a radar system that uses multiple antennas to provide a wider obstacle detection area while monitoring both the front and rear of the equipment.

Outputs

17 Outputs

Title	Year	Output Type	Strategic Goal
Application of Radar To Detect Pedestrian Workers Near Mining Equipment Ruff-TM | Applied Occupational and Environmental Hygiene, 16(8), 2001; :798-808	2001	Publication	Traumatic injuries
Application of Radio-Frequency Identification Systems to Collision Avoidance in Metal/Nonmetal Mines Ruff-TM; Hession-Kunz-D | IEEE Transactions on Industry Applications, 37(1), 2001; :112-116	2001	Publication	Traumatic injuries
Evaluation of Devices to Prevent Construction Equipment Backing Incidents Ruff-TM | SAE Commercial Vehicle Engineering Congress and Exhibition (Oct. 26-28, 2004; Chicago, IL). Paper 2004-01-2725; :10 pp	2004	Publication	Traumatic injuries
Evaluation of Systems to Monitor Blind Areas Behind Trucks Used in Road Construction and Maintenance: Phase 1 Ruff-TM | NIOSH Report of Investigations 9660, 2003 Feb; :1-15	2003	Publication	Traumatic injuries
Mine Eyes: Proximity Alert for Monster Trucks Ruff-TM; Holden-TP | GPS World, 2002 Jul; :16-22	2002	Publication	Traumatic injuries
Miner Training Simulator: Users Guide and Scripting Language Documentation Ruff-TM | NIOSH Information Circular 9457, 2001 Jun; :1-21	2001	Publication	Surveillance and training; Traumatic injuries
Monitoring Blind Spots: A Major Concern for Haul Trucks Ruff-TM | Engineering and Mining Journal, 202(12), 2001 Dec; :17-26	2001	Publication	Traumatic injuries
New Technology To Monitor Blind Areas Near Surface Mining Equipment Ruff-T | Crossroads to Innovation, Conference Record of the 2003 Institute of Electrical and Electronics Engineers and 38th Annual Meeting of Industry Applications Society (Oct 12-16, 2003; Salt Lake City, UT), Available from the author and on CD-ROM from IEEE, Piscataway, NJ, 2003 Oct; :7 pp	2003	Publication	Traumatic injuries
Preventing Collisions Involving Surface Mining Equipment: A GPS-Based Approach Ruff, Todd M., and Thomas P. Holden | Journal of Safety Research, vol. 34, 2003; :175-181	2003	Publication	Traumatic injuries
Recent Advances in Proximity Warning Technology for Surface Mining Equipment Ruff-TM; Steele-J | Mining Engineering, 56(12); :68-72	2004	Publication	Traumatic injuries
Recommendations for Testing Radar-Based Collision Warning Systems on Heavy Equipment Ruff-TM | NIOSH Report of Investigations 9657, 2002 May; :1-17	2002	Publication (guidelines)	Traumatic injuries
Safety Analysis of Surface Haulage Accidents - Part 1 Randolph-RF; Boldt-CMK | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin May-June, 1997; :1-7	1997	Publication	Surveillance and training; Traumatic injuries
Safety Analysis of Surface Haulage Accidents - Part 2 Randolph-RF; Boldt-CMK | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin July, 1997; :6-7	1997	Publication	Surveillance and training; Traumatic injuries

Title	Year	Output Type	Strategic Goal
Technology News 484 - Devices to Monitor Blind Spots Near Large Haulage Equipment Ruff-TM | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 484, 2001 Jan :1-2	2001	Publication	Traumatic injuries
Test Results of Collision Warning Systems for Surface Mining Dump Trucks Ruff-TM | NIOSH Report of Investigations 9652, 2000 May; :44 pp	2000	Publication	Traumatic injuries
Test Results of Collision Warning Systems on Off-Highway Dump Trucks: Phase 2 Ruff-TM | NIOSH Report of Investigations 9654, 2001 Feb; :1-21	2001	Publication	Traumatic injuries
Proximity Warning Systems for Underground and Surface Mining NIOSH | Open Industry Briefing (Aug 9, 2005; Pittsburgh, PA). Approximately 125 attendees from government (MSHA), industry, labor, and academia	2005	Workshop, Seminar, or OIB	Traumatic injuries

Intermediate Outcome related to Reducing Machine-related Traumatic Injuries

Proximity Warning System for Reducing Injuries Pertaining to Mobile Mining Equipment

Description of Problem

Mining has always been a dangerous occupation. Although advances in technology can significantly reduce the risk of injury, that same technology can introduce new hazards. This is especially the case in underground and surface mines, where restricted workspace around larger, more productive mining machinery has resulted in serious traumatic injuries involving crushing and pinning. At underground mines, the risk involves workers in close proximity to remote-control continuous mining machines. At surface mines, the risk involves workers being injured while in close proximity to large haul trucks.

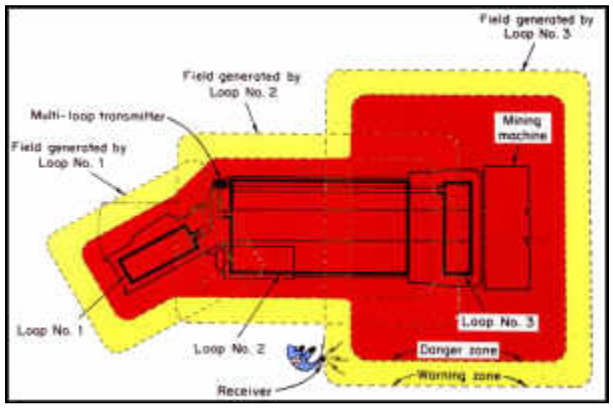


Illustration of a close proximity warning device on a continuous miner

Research and Development Activities

NIOSH collaborative research has led to better technology to warn miners who work around mobile equipment and in hazardous work areas. The Hazardous Area Signaling and Ranging Device (HASARD) offers a personal alert to the worker, along with remote shutdown capability. The HASARD system has patented features (e.g., a robust marker) to achieve greater reliability while minimizing nuisance alarms.

R&D Outputs and Transfer Activities

Several mining machine manufacturers have expressed interest in the application of the HASARD system. Workshops have been presented at the request of the Mine Safety and Health Administration (MSHA) and the United Mine Workers of America to help customers understand and consider application of the proximity warning technology.

A Cooperative Research and Development Agreement is pending to transfer HASARD technology to a South African firm (AIR SUN AUTO). NIOSH continues to work with MSHA and mining companies to field test the proximity warning technology.

Description of Intermediate Outcome

The HASARD system has been recently licensed to three firms. GeoSteering Mining Services is marketing its version of the system for use in underground mines. GeoSteering is also developing prototypes of its version of the NIOSH technology for use on surface haul trucks. ICG ADDCAR has adapted the system for use on highwall mining machines. Alliance Coal is presently prototyping the system for potential use on continuous mining machines.

Two licenses are pending: SSA Marine and DBT America Inc.

Outputs

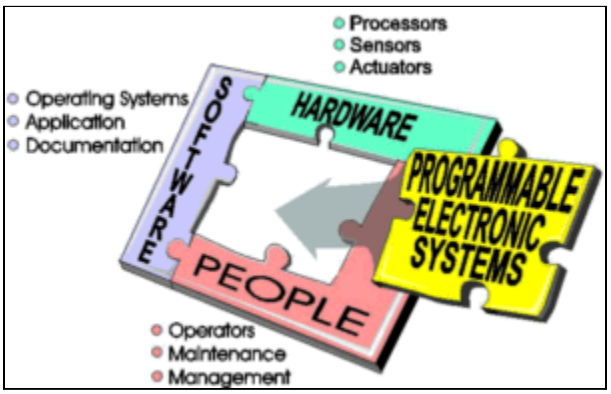
7 Outputs

Title	Year	Output Type	Strategic Goal
A Workplace Safety Device for Operators of Remote-Controlled Continuous Mining Machines Schiffbauer-WH | American Journal of Indus Med, Vol 36, Sup 1, 1999 Sep; :69-71	1999	Publication	Traumatic injuries
Active Promixity Warning Systems for Surface and Underground Mining Applications Schiffbauer-WH | Min Eng 54(12):40-48	2002	Publication	Traumatic injuries
An Active Proximity Warning System for Surface and Underground Mining Applications Schiffbauer-WH | SME Annual Meeting (Denver, CO; Feb 26-28, 2001), Preprint No. 01-117, SME, Inc., 2001 Feb; :1-8	2001	Publication	Traumatic injuries
An Environmentally Robust Proximity Warning System for Hazardous Areas Schiffbauer-WH; Mowrey-GL | in: Proceedings of the ISA Emerging Technologies Conference. Research, 2001, Triangle Park, North Carolina, Instrumentation, Systems, and Automation Society, Paper No. 2091; 2001; :10 pp	2001	Publication	Traumatic injuries
Mobile Machine Hazardous Working Zone Warning System Schiffbauer-WH; Ganoe-CW | U.S Patent #5,939,986 (granted Aug 17, 1999)	1999	Patent	Traumatic injuries
Non-directional Magnet Field-Based Proximity receiver with Multiple Warning and Machine Shutdown Capability Schiffbauer-WH | U.S. Patent #6,810,353 B2 (granted Oct 26, 2004)	2004	Patent	Traumatic injuries
Proximity Warning Systems for Underground and Surface Mining NIOSH | Open Industry Briefing (Aug 9, 2005; Pittsburgh, PA). Approximately 125 attendees from government (MSHA), industry, labor, and academia	2005	Workshop, Seminar, or OIB	Traumatic injuries

Intermediate Outcome related to Reducing Machine-related Traumatic Injuries

System Safety Best Practices to Reduce Injuries due to Malfunctioning Computerized Mining Systems

Description of Problem



Programmable electronics to monitor and control machine functions is increasingly common in mining systems. Computerized mining systems are very cost-effective and, when they function properly, can help reduce health and safety risk. When they randomly malfunction, however, they can introduce unexpected machine movements, resulting in workers being struck, pinned, or crushed. Although these incidents are rare, the consequences are quite severe. The mining industry does not have a formalized system safety process. As a result, safety is often addressed on an ad hoc basis.

Research and Development Activities

NIOSH collaborative research has developed a set of documents relating to the safety life cycle for programmable electronic mining systems based on International Electrotechnical Commission (IEC) Standard 61508 (part 1). They ensure that safety is considered with hardware, software, and human intervention all integrated together. The best practices are distilled from about 200 existing safety standards pertaining to programmable electronics.

R&D Outputs and Transfer Activities

Educational workshops held in the United States and Australia helped customers understand and apply the best practices. The Minerals Industry Safety and Health Centre of the University of Queensland (Australia) used the results for an academic course on Minerals Industry Risk Analysis.

Minerals Resources New South Wales (NSW) requested that two workshops and a keynote address be given at its 2001 Annual Electrical Safety Seminar. Minerals Resources NSW decided to start using the research as part of its approval process, as documented in a letter to the NIOSH Associate Director for Mining and Construction (January 21, 2002).

Description of Intermediate Outcome

Joy Mining Machinery, Inc., Forced Potato Mining Electronics, and DBT America, Inc. have integrated NIOSH research into their best practices/business plans.

Mining machine customers for Joy Mining Machinery, Inc. have specified that new equipment comply with the System Safety Best Practices.

The Mine Safety and Health Administration (MSHA) and the Pennsylvania Department of Environmental Protection have used the research results as part of the approval process for permits (http://www.msha.gov/techsupp/acc/sysafety/sysafety.htm).

NIOSH's National Personal Protective Technology Laboratory has used our methods and format for approval of programmable personal protective equipment.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Minerals Resources NSW (Australia) agreed to use the research for a rapid roadway development project, as documented in a letter to the NIOSH Associate Director for Mining and Construction (January 21, 2002). Minerals Resources NSW incorporated the research into the document "Policy for Implementing Safety Alert SA01-09 Radio Remote Control Mining Machines," as documented in a letter to the NIOSH Associate Director for Mining and Construction (July 21, 2001).

Outputs

16 Outputs

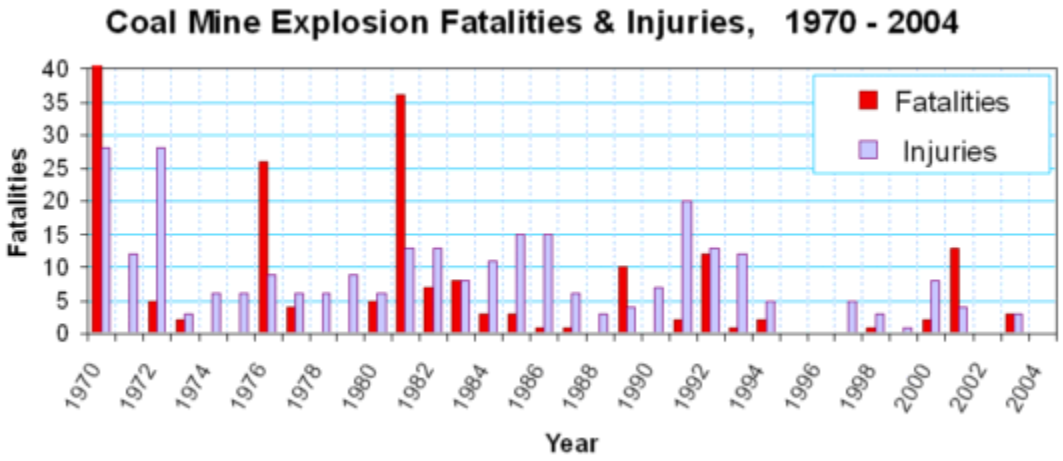
Title	Year	Output Type	Strategic Goal
A Complexity Assessment Methodology for Programmable Electronic Mining Systems Sammarco-JJ | Proc 20th Int System Safety Conf (Aug. 5-9, 2002; Denver, CO), 2002 Aug :177-186	2002	Publication	Traumatic injuries
Addressing the Safety of Programmable Electronic Mining Systems: Lessons Learned Sammarco-JJ | Proc 2002 IEEE 37th Industry Applications Society Ann Meet, Pittsburgh, Pennsylvania, 2003 :692-698	2003	Publication	Traumatic injuries
Programmable Electronic and Hard-Wired Emergency Shutdown Systems: A Quantified Safety Analysis Sammarco-JJ | In: Proceedings of the IEEE Industry Applications Society 40th Annual Meeting. Hong Kong. October 2005	2005	Publication	Traumatic injuries
Programmable Electronic Mining Systems: Best Practice Recommendations (In Nine Parts): Part 6: 5.1 System Safety Guidance Sammarco-JJ | NIOSH Publication No. 2005-150, Information Circular 9480, 2005 Aug; :1-87	2005	Publication	Traumatic injuries
Programmable Electronic Mining Systems: Best Practice Recommendations (In Nine Parts): Part 4: 3.0 Safety File Mowrey-GL; Fisher-TJ; Sammarco-JJ; Fries-EF | NIOSH Publication No. 2002-134, Information Circular 9461, 2002 May :1-57	2002	Publication (guidelines)	Traumatic injuries
Programmable Electronic Mining Systems: Best Practice Recommendations (In Nine Parts): Part 5: 4.0 Independent Functional Safety Assessment Sammarco-JJ; Fries-EF | NIOSH Publication No. 2003-138, Information Circular 9464, 2003 May; :1-35	2003	Publication (guidelines)	Traumatic injuries
Programmable Electronic Mining Systems: Best Practice Recommendations (In Nine Parts): Part 3: 2.2 Software Safety Fries-EF; Fisher-TJ; Jobes-CC | NIOSH Publication No. 2001-164, Information Circular 9460, 2001 Sep :1-45	2001	Publication (guidelines)	Traumatic injuries
Programmable Electronic Mining Systems: Best Practice Recommendations (In Nine Parts): Part 2: 2.1 System Safety Sammarco-JJ; Fisher-TJ | NIOSH Publication No. 2001-137, Information Circular 9458, 2001 Apr; :1-47	2001	Publication (guidelines)	Traumatic injuries
Programmable Electronic Mining Systems: Best Practice Recommendations (In Nine Parts): Part 1: 1.0 Introduction Sammarco-JJ; Fisher-TJ; Welsh-JH; Pazuchanics-MJ | NIOSH Publication No. 2001-132, Information Circular 9456, 2001 Apr; :1-10	2001	Publication (guidelines)	Traumatic injuries
Progress in Developing Software Safety Guidelines for the Mining Industry Sammarco-JJ | In: Gurgenci H, Hood M, eds. Proceedings of the Fourth International Symposium on Mine Mechanisation and Automation. Vol. 2 (Brisbane, Queensland, Australia), 1997; :B9-9 to B9-15	1997	Publication (guidelines)	Traumatic injuries
Safety Framework for Programmable Electronics in Mining Sammarco-JJ | Min Eng, 51(12), 1999 Dec; :30-33	1999	Publication (guidelines)	Traumatic injuries

Title	Year	Output Type	Strategic Goal
Safety Issues and the Use of Software-Controlled Equipment in the Mining Industry Sammarco-JJ; Kohler-JL; Novak-T; Morley-LA | IEEE Industry Applications Society 32nd Annual Meeting (Oct. 5-9, 1997; New Orleans, LA), 1997 Oct; :1-7	1997	Publication	Traumatic injuries
Safety Issues and the Use of Software-Controlled Equipment in the Mining Industry Sammarco-JJ; Kohler-JL; Novak-T; Morley-LA | In Lindsay PA, ed. Proceedings of the 1997 Australian Workshop on Industrial Experience With Safety Critical Systems and Software, Australian Computer Society: 1997; :25-32	1997	Publication	Traumatic injuries
Technology News 477 - A Systems Safety Approach for Programmable Electronics Sammarco-JJ | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 477, 1999 Aug; :1-2	1999	Publication (guidelines)	Traumatic injuries
Programmable Electronic Mining Systems (PEMS): Best Practice Recommendations Sammarco-JJ; Jobes-C | Joint NIOSH/MSHA Workshop (Sept. 26, 2002; Triadelphia, WV)	2002	Workshop, Seminar, or OIB	Traumatic injuries
Programmable Electronic Mining Systems: An Introduction to Safety Sammarco-JJ; Mowrey-G; Jobes-C; Welsh-J | Joint NIOSH/MSHA Workshop (Aug 17, 1999; Triadelphia, WV)	1999	Workshop, Seminar, or OIB	Traumatic injuries

Strategic Program Outcome for Mine Disasters

Preventing and Mitigating Mine Fires and Explosions

Mine fires and explosions remain a significant hazard in the mining industry. Since 2000, 18 underground mine fires have occurred in the United States. There were serious underground coal mine explosions in July 2000 at the Willow Creek Mine in Utah (2 fatalities and 8 injuries), in September 2001 at Jim Walter Resources´ No. 5 Mine in Alabama (13 fatalities and 3 injuries), and in January 2003 at the McElroy Mine in West Virginia (3 fatalities and 3 injuries).



The number of fatalities and injuries from mine fires and explosions declined greatly from 1970 to 1999. There were several "zero" years during the late 1990s despite a 700% increase in coal production during the same period. A rise in the number of injuries and fatalities since 2000 has prompted further NIOSH research into the causes and preventability of these accidents. These events, unlike other types of accidents where only a few workers are involved, often extend to every underground worker in the mine.

Since the mid-1990s, our research has led to the development of prevention, detection, control, and survivability technologies to reduce the probability of and fatalities from devastating fires and explosions. Many of these technologies have been adopted by the coal-producing and equipment manufacturing industry and are recognized in Mine Safety and Health Administration (MSHA) rulemaking. These technologies have also contributed to fire and explosion protection improvements in Australia and the Republic of South Africa.

Open industry briefings on mine fire preparedness conducted at NIOSH´s Lake Lynn Lab near Fairchance, PA, have enhanced the mining industry´s awareness of the dangers of underground mine fires. Realistic rescue and response training exercises for federal, state, and mine rescue teams at Lake Lynn have improved the effectiveness of rescue teams during numerous mine emergencies.

Development and implementation of a fire prevention checklist for profiling fire prevention and response capabilities at a mine site have played a key role in preventing and responding to incipient mine fires. NIOSH-developed discriminating fire sensors and optimum deployment strategies based on neural networks and combustion particle detection have reduced the number of false fire alarms when used in mining operations where smoke must be distinguished from normal diesel equipment exhaust.

Implementation of automatic fire suppression systems on conveyor belt drives and underground diesel storage areas has successfully controlled the rapid spread of belt fires within mine entries. NIOSH research on flammability of noise control materials in operator cabs led to MSHA´s acceptance of the American Society for Testing and Materials (ASTM) E-162 Radiant Panel Test as a major criterion in the selection and use of these materials.

Fire and explosion safety expertise, test equipment, and test procedures that we developed for the mining industry have been transferred to other industries. The consensus standard test methods of the ASTM International committee E27 on the Hazard Potential of Chemicals apply to numerous other industries besides mining. Many of NIOSH´s research findings were incorporated into the 2004 revised National Fire Protection Association (NFPA) mining fire protection standards (NFPA 120 (underground coal) and NFPA 122 (metal and nonmetal)).

NIOSH research to determine the risk of ignition of flammable atmospheres by laser-based optical and telecommunications equipment (fiber-optic networks) led to the development of ANSI standards governing the power thresholds for such lasers.

Postexplosion accident investigation and forensics tools were developed and used by MSHA to help understand and identify the root cause of explosions. Blast-resistant seals and performance test methods were developed at Lake Lynn Lab and implemented in partnership with MSHA. Passive and active explosion suppression techniques developed at Lake Lynn are routinely used in underground mines throughout the United States and in other countries, such as Australia and the Republic of South Africa.

Real-time, automated gob gas venthole monitoring and wireless data transmission permits continuous monitoring of individual gob gas ventholes to optimize methane drainage and reduce the potential for explosive methane-air mixtures.

NIOSH testing showed that safety for roof bolter operators could be improved by sweeping the area inby the bolter with a methanometer in addition to the machine-mounted methane monitor. This requirement was implemented in MSHA´s methane testing requirements.

Based on data obtained by NIOSH, the Pennsylvania Bureau of Deep Mine Safety permits the use of powered haulage to evacuate a mine in case of a main mine fan outage. Prior to NIOSH´s evaluation of worker safety during egress, the use of powered haulage was prohibited during main mine fan stoppages.

The mining industry has undergone tremendous advances in technology. These have provided opportunities to increase production and eliminate old hazards. However, they have often created new risks to workers. In many cases, these advances have introduced significant new fire and explosion safety hazards, such as increased methane emissions due to higher production levels. NIOSH research has helped improve fire detection and control and protection for mine workers against the hazards of underground mine fires and explosions.

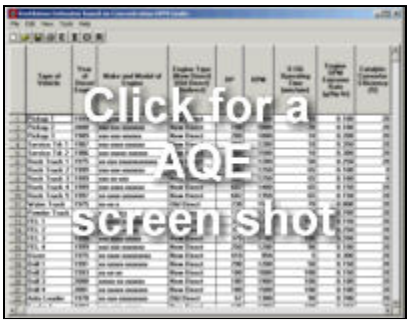
Intermediate Outcomes

- A Software Tool to Estimate the Required Ventilation Air Quantity for Mines Using Diesel Equipment
- Analysis of Fires in the Mining Industry
- Collaborative Research with Other Countries (1997-2002)
- Development and Evaluation of a Communication System for Mine Rescue Operations
- Development and Testing of a Smart Sensor System to Detect Mine Fires
- Development of a Fire Preparedness and Response Checklist for Mining Operations
- Evacuation of Underground Mine Workers During Main Fan Stoppages through Use of Electrically Powered Haulage
- Evaluation of a Directional Lifeline for Mine Evacuations
- Flammability Hazard Assessment of Noise Control Materials in Operator Cabs
- Forensic Investigations of Mine Fires and Explosions (1993-2005)
- Improved Methane Sampling During Roof Bolting
- Managing Methane in Underground Coal Mines
- Optimizing the Spacing of Fire Sensors in Mine Entries
- Protecting Coal Miners from Gob Explosions through Explosion-Resistant Mine Ventilation Seals (1993-2005)
- Realistic Training for Mine Emergency Responders
- Revised Standards for National Fire Protection Association (2002-2004)
- Transfer of Explosions and Fire Expertise and Test Procedures to Industry (1992-2005)
- Utilization of Large-Diameter Propeller Fans
- Ventilating Large-Opening Stone Mines using Novel Ventilation Techniques

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

A Software Tool to Estimate the Required Ventilation Air Quantity for Mines Using Diesel Equipment

Description of Problem



Underground workers in metal and nonmetal mines are exposed to various airborne contaminants, including diesel particulate matter (DPM). The operators of large-opening mines have long relied on natural ventilation and, in some cases, the use of auxiliary fans, in an attempt to reduce the concentration levels of these airborne contaminants. However, with the passage of regulatory standards in 2002 to limit DPM concentrations, the industry needed better tools to estimate the ventilation airflow requirements needed to meet the new statutory limits. An assessment of the ventilation airflow quantities required to meet the statutory DPM limits is the first step in developing engineering- based solutions to reduce worker exposure to this potential health hazard in the underground workplace.

Research and Development Activities

NIOSH developed a PC-based program called the Air Quantity Estimator (AQE) to meet this industry need. The air quantity estimates derived from the AQE are based on operating parameters of the mine´s underground diesel-powered equipment fleet. The results of the AQE analysis are used as the basis for designing engineering controls such as optimized mine layouts, proper ventilation fan selection, and stoppings to direct the ventilation airflow to the active working areas of the mine. In addition, the AQE analysis allows operators to identify vehicles that are high DPM sources. The engines in those vehicles can then be modified or upgraded to reduce their emissions, resulting in a lower total mine DPM load.

R&D Outputs and Transfer Activities

NIOSH researchers have demonstrated the AQE at several industry seminars and symposia. In addition, NIOSH has established partnerships with several large stone mine operators, including Coolspring Stone Supply, Inc., and Better Materials Corp. Hanson Aggregates' Whitney Mine and Coolspring Stone Supply, Inc.'s Coolspring Mine have used the AQE for their ventilation planning purposes.

Description of Intermediate Outcome

The AQE software program has been requested by 25 engineers from the stone industry. The program has been a direct benefit to operators in at least three known instances. One operator was able to identify that two diesel-powered vehicles accounted for 25% of the DPM emissions from the entire fleet operating in the mine. Also, two mines have exchanged diesel engines to improve their air quality based on insights provided by the AQE.

Outputs

3 Outputs

Title	Year	Output Type	Strategic Goal
A Computer Software Program that Estimates Air Quantity Requirements in Large Opening Stone Mines Robertson-SB; Grau-RH; Dolgos-JG; Mucho-TP | In: Ganguli R, Bandopadhyay S, eds. Mine ventilation: Proceedings of the 10th U.S./North American Mine Ventilation Symposium (Anchorage, Alaska, May 16-19, 2004). Leiden, Netherlands: Balkema, 2004 May; :363-369	2004	Publication	Mine disasters
NIOSH Ventilation Research Addressing Diesel Emissions and Other Air Quality Issues in Nonmetal Mines Grau-RH; Robertson-SB; Mucho-TP; Garcia-F; Smith-AC | 2002 SME Annual Meeting (Phoenix, Arizona; Feb 25-27, 2002). SME preprint 02-187. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc; :1-7	2002	Publication	Mine disasters; Respiratory diseases
Air Quantity Estimator (AQE) Grau-RH III; Robertson-SB; Dolgos-JG | NIOSH 2004 Jan; :software	2004	Software	Mine disasters; Respiratory diseases

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Analysis of Fires in the Mining Industry

Description of Problem

A mobile equipment fire

During 1990-1999, there were 912 reportable fires (i.e., those lasting 30 minutes or more) within the mining industry. These resulted in 439 injuries, 3 fatalities, and 44,108 lost workdays. The diversity of fire locations, material and equipment involved, and types of ignition sources reflect the complexity and diversity of today's mining industry. Fires can lead to catastrophic events with disastrous consequences. For fire prevention research to have a significant impact in reducing the incidence of fires and injuries, these incidents must be understood in greater detail.

Research and Development Activities

Statistics and detailed documentation provided by the Mine Safety and Health Administration (MSHA) and information provided by mining companies were used in this research. The data from all of the reportable fires were analyzed as to their location, combustible material, equipment involved, ignition source, detection and suppression methods, and several other factors. The findings resulted in a better understanding of the causes and hazards associated with mine fires and formed the basis for future fire research.

R&D Outputs and Transfer Activities

These detailed analyses have been reported in three NIOSH Information Circulars (ICs) and presented at fire safety conferences.

Description of Intermediate Outcome

These analyses have also been used by NIOSH researchers as a guide for developing long-range strategies for mine fire research and are directly impacting the focus of the NIOSH fire prevention research program. Research is being done in areas of high incidence and severity. This will have a significant impact on reducing the number of fires and resultant fatalities and injuries in the mining industry. The results are also being used by MSHA to pinpoint critical areas for fire protection and prevention and by the National Fire Protection Association to develop fire protection standards for the mining industry.

Outputs

4 Outputs

Title	Year	Output Type	Strategic Goal
Analyses of Mobile Equipment Fires for All U.S. Surface and Underground Coal and Metal/Nonmetal Mining Categories, 1990-1999 De Rosa-MI | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevetnion, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publicaion No. 2004-105, IC 9467, 2004 Jan; :1-53	2004	Publication	Mine disasters; Surveillance and training
Analysis of Mine Fires for All U.S. Metal/Nonmetal Mining Categories, 1990-2001 De Rosa-MI | Pittsburgh, PA: U.S. Department of Heatlh and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-105, IC 9476, 2004 Nov; :1-52	2004	Publication	Mine disasters
Analysis of Mine Fires for All U.S. Underground and Surface Coal Mining Categories: 1990-1999 De Rosa-MI | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health , DHHS (NIOSH) Publication No. 2004-167, 2004 Sep; IC 9470; :1-36	2004	Publication	Mine disasters
Equipment Fires Cause Injuries De Rosa-MI | Coal Age 109(10), 2004; :28-31	2004	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Collaborative Research with Other Countries (1997-2002)

Description of Problem

As a result of research accomplishments by the NIOSH Pittsburgh Research Laboratory (PRL) in the area of fires and explosions, the worldwide scientific and engineering community has recognized our unique facilities and capabilities, especially the Lake Lynn Experimental Mine (LLEM).

Mining personnel and government researchers from both Australia and the Republic of South Africa have requested technical assistance from PRL to help address safety issues associated with underground fires and explosions in their coal mines. Two companies from Australia requested PRL's support in the performance testing of special high-strength seals for use in controlling spontaneous heating within sealed areas of coal mines. The Council for Scientific and Industrial Research (CSIR) of South Africa requested support in the full-scale testing of passive barriers to suppress propagating dust explosions in coal mines. In both cases, the LLEM was the only research facility in the world that could perform the required full-scale evaluations in a multiple-entry mining configuration. These joint research efforts were fully funded by Australia and the Republic of South Africa.

Research and Development Activities

Reliable seals are needed to control airflow to sealed areas prone to spontaneous combustion while containing blast effects should an explosion occur within the sealed area. Mining regulations in Queensland, Australia, require thorough evaluations of proposed seals and stoppings. Thus, the Australian companies contacted PRL for assistance. PRL researchers designed and conducted full-scale tests in the LLEM during 1997-1998 to evaluate the explosion-resistant characteristics of several mine seals, stoppings, and an overcast. The results were used by the Australians to assess the proper use of these ventilation structures in their coal mines.

The South Africans needed full-scale evaluations of their passive explosion barriers. These consist of a series of strategically placed bags of limestone rock dust suspended from the mine roof. This new passive barrier system relies on the pressure forces developed during an explosion to rupture the bags. This disperses the rock dust into the entry and suppresses the explosion. PRL researchers designed and conducted full-scale dust explosion tests in 1999-2000 to evaluate the barriers. Based on the results of these tests, the South Africans have implemented these barriers to protect workers in their coal mines.

R&D Outputs and Transfer Activities

Results of the joint seal evaluation research with Australia are documented in two NIOSH Reports of Investigations (RIs) in 1999 and 2002. Results from the joint research study with South Africa on the explosion barriers were presented at the Seventh International Mine Ventilation Congress in 2001 and published in the proceedings.

Description of Intermediate Outcome

Based on the successful conclusions to these joint projects and the implementation of new regulations, these seals and barriers are now being used to protect miners from underground explosions in both Australia and the Republic of South Africa.

Outputs

3 Outputs

Title	Year	Output Type	Strategic Goal
Evaluation of Explosion-Resistant Seals, Stoppings, and Overcast for Ventilation Control in Underground Coal Mining Weiss-ES; Cashdollar-KL; Sapko-MJ | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centrs for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2003-104, Report of Investigations 9659, 2002	2002	Publication	Mine disasters
Evaluation of Reinforced Cementitious Seals Weiss-ES; Cashdollar-KL; Mutton-IVS; Kohli-DR; Slivensky-WA | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Publication No. 99-136, Report of Investigations 9647, 1999	1999	Publication	Mine disasters
Evaluation of the Bagged Stone Dust Barrier Effectiveness in a Bord and Pillar Mine Du Plessis-JJL; Weiss-ES; Cashdollar-KL | In: Wasilewski S, ed., Proceedings of the Seventh International Mine Ventilation Congress (June 17-22, 2001, Crakow, Poland), chapter 81, :573-580	2001	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Development and Evaluation of a Communication System for Mine Rescue Operations

Description of Problem

When a rescue team explores complex underground passageways, such as those found in mines, a lifeline and reliable communication system is essential. Current mine rescue team communication technology is based on a sound-powered phone system developed in 1946 that provides communication from only one team member to one other location, the underground fresh air base. Mine rescue teams requested a reliable system that would permit communication among all team members, the fresh air base, and the surface command center. Existing communication systems are not readily adaptable for underground mine use.

Rescue team members testing the Res-Q-Com system

Research and Development Activities

NIOSH and Transtek, Inc. (Pittsburgh, PA), collaborated in developing and evaluating the Ron Conti Res-Q-Com System. The Res Q-Com is a self-contained, portable, battery-operated system that provides voice communication and a lifeline for rescue teams, such as those summoned for an underground mine emergency. It consists of a mobile reel, 1,000-foot lifeline, and electronics, repeaters, and handheld radios. The system provides a choice of communication modes that include team members only, the team members and an underground fresh air base, the fresh air base and a surface command center, or all of the above. A team member can also leave the team lifeline and explore the underground surroundings for a distance of several hundred feet while retaining communications with the team and fresh air base.

R&D Outputs and Transfer Activities

The Res-Q-Com system was evaluated during training exercises with mine rescue teams at Lake Lynn Lab. The findings were presented at mining conferences, workshops, and operating mines.

Description of Intermediate Outcome

The Res-Q-Com system is now commercially available. It represents a significant advancement in rescue technology for the mining environment. The system was highlighted in *International Longwall News* (December 19, 2003) and in *Coal Age* magazine (February 2004). It is named after the NIOSH researcher, now deceased, who pioneered its development.

Outputs

1 Output

Title	Year	Output Type	Strategic Goal
Fire Response Preparedness for Underground Mines Conti-RS; Chasko-LL; Wiehagen-WJ; Lazzara-CP | Pittsburgh, PA, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. , NIOSH IC 9481	2005	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Development and Testing of a Smart Sensor System to Detect Mine Fires

Description of Problem

There is a need to provide early and reliable mine fire detection in the event of a mine fire. The discrimination of mine fires from nuisance signatures, such as emissions from diesel equipment, flame-cutting and welding activities, and battery-charging operations, is an ongoing problem for early and reliable mine fire detection. Carbon monoxide sensors are subject to false signals from diesel equipment nuisance emissions and hydrogen cross-interference from battery-charging operations. Smoke sensors are subject to false signals from diesel equipment and rock-dusting operations.

Sensors used to discriminate a mine fire from nuisance emissions

Research and Development Activities

NIOSH developed a multiple-type mine fire sensor approach to nuisance signal discrimination. A neural network was constructed for a base set of four fire sensor types. Mine fire discrimination experiments were done with coal, belt, diesel fuel, and wood fires in the presence of diesel emissions in the Pittsburgh Research Laboratory's (PRL) Safety Research Coal Mine. From a training set of experiments, a neural network algorithm was developed. The trained neural network was evaluated with a real-time application to additional mine fire experiments.

R&D Outputs and Transfer Activities

Results from this research were transferred to the mining community through publications and conferences. In addition, a mine fire detection workshop was held in September 2003 at PRL.

Description of Intermediate Outcome

The sensors and neural network are currently being evaluated at Foundation Coal's Cumberland coal mine in Pennsylvania as part of a demonstration project. Mine monitoring software was provided by Conspec Controls. The sensors are located in a high-vehicular traffic area in which rock dusting occurs occasionally. This research will provide an impetus to sensor manufacturers to apply state-of-the-art software analysis methods to discriminatory mine fire detection for improved early and reliable mine fire detection.

Outputs

15 Outputs

Title	Year	Output Type	Strategic Goal
CFD Analysis of Mine Fire Smoke Spread and Reverse Flow Conditions Edwards-JC; Hwang-CC | Proc Eighth U.S. Mine Ventilation Symposium. Rolla, MO; University of Missouri-Rolla, Press, Rolla, Missouri, 1999 Jun; :417-422	1999	Publication	Mine disasters
CFD Modeling of Smoke Reversal Hwang-CC; Edwards-JC | Proc International Conference on Engineered Fire Protection Design (Jun 11-15, 2001; San Francisco, CA), Bethesda, MD: Society of Fire Protection Engineers, Inc. :376-387	2001	Publication	Mine disasters
Discriminatory Mine Fire Source Detection Edwards-JC; Franks-RA; Friel-GF; Lazzara-CP; Opferman-JJ | In: Wasilewski S, ed. Proceedings of the Seventh International Mine Ventilation Congress (Jun 17-22, 2001; Krakow, Poland) Ch 91, 2001; :649-655	2001	Publication	Mine disasters
In Mine Evaluation of Discriminating Mine Fire Sensors Edwards-JC; Franks-RA; Friel-GF; Lazzara-CP; Opferman-JJ | In: E. DeSouza, ed. Proceedings of the North American/Ninth U.S. Mine Ventilation Symposium (June 8-12, 2002, Kingston, Ontario, Canada). A. A. Balkema Publishers, Lisse, Netherlands; :527-532	2002	Publication	Mine disasters
Mine Fire Detection in the Presence of Diesel Emissions Edwards-JC; Franks-RA; Friel-GF; Lazzara-CP; Opferman-JJ | Chemical and Physical Process of Combusion. The Fall Technical Meeting of the Eastern States Section of the Combustion Institute (Oct 10-13, 1999; Raleigh, NC), North Carolina State University; :89-92	1999	Publication	Mine disasters
Mine Fire Detection in the Presence of Diesel Emissions Edwards-JC; Franks-RA; Friel-GF; Lazzara-CP; Opferman-JJ | Proc Eighth U.S. Mine Ventilation Symposium. Rolla, MO: University of Missouri-Rolla, Press, 1999 Jun; :295-301	1999	Publication	Mine disasters
Mine Fire Detection in the Presence of Diesel Emissions Edwards-JC; Franks-RA; Friel-GF; Lazzara-CP; Opferman-JJ | Journal of the Mine Ventilation Society of South Africa. 2000 53(2); :66-71	2000	Publication	Mine disasters
Mine Fire Source Discrimination Using Fire Sensors and Neural Network Analysis Edwards-JC; Friel-GF; Franks-RA; Lazzara-CP; Opferman-JJ | Combustion Fundamentals and Applications - Proceedings of the 2000 Technical Meeting of the Central States Section of the Combustion Institute (April 17-18, 2000, Indianapolis, IN); :207-211	2000	Publication	Mine disasters
Multiple Type Discriminating Mine Fire Sensors Edwards-JC; Franks-RA; Friel-GF; Lazzara-CP; Opferman-JJ | Trans Soc Min Metal Explor, Transactions, Vol 314, 2003 Dec; :166-171	2003	Publication	Mine disasters
Neural Network Application to Mine-Fire Diesel-Exhaust Discrimination Friel-GF; Edwards-JC | In: De Souze E, Ed. Proceedings of the North American/Ninth U.S. Mine Ventilation Symposium (Jun 8-12, 2002; Kingston, Ontario, Canada). A. A. Balkema Publishers, Lisse, Netherlands; :533-538	2002	Publication	Mine disasters
Overview of Mine Fire Detection Edwards-JC | Proc Second International Conference on Fire Research and Engineering (August 3-8, 1997; Bethesda, MD), 1998 Aug :489-499	1998	Publication	Mine disasters

Title	Year	Output Type	Strategic Goal
Real-time Neural Network Application to Mine Fire - Nuisance Emissions Discrimination Edwards-JC; Franks-RA; Friel-GF; Lazzara-CP; Opferman-JJ | In: Ganguli-R and Bandopadhyay-S, eds. Mine Ventilation: Proc 10th U.S./North American Mine Ventilation Symposium (May 16-19, 2004, Anchorage, AK). A. A. Balkema Publishers, Lisse, Netherlands; :425-431	2004	Publication	Mine disasters
Technology News 498 - Multiple Fire Sensors for Mine Fire Detection and Nuisance Discrimination NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 498, 2002 Sep :1-2	2002	Publication	Mine disasters
Underground Fire Detection and Nuisance Alarm Discrimination Edwards-JC; Franks-RA; Friel-GF; Lazzara-CP; Opferman-JJ | Coal Age, Intertec Publishing, 106(7), 2001 Jul; :70-72	2001	Publication	Mine disasters
Fire Detection Technology Workshop Workshop conducted for 43 participants from coal companies, sensor manufacturers, MSHA, the UMWA, a university, and NIOSH (Pittsburgh Research Laboratory, Sept 4, 2003)	2003	Workshop, Seminar, or OIB	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Development of a Fire Preparedness and Response Checklist for Mining Operations

Description of Problem

Fires are still too common an occurrence in the U.S. coal mining industry and a major concern for those who work underground. Statistics from the Mine Safety and Health Administration (MSHA) show that 152 reportable fires (i.e., those lasting 30 minutes or more) occurred at underground coal mines during 1990-1999. Several recent coal mine fires have resulted in sealing the mines for long periods. This resulted in loss of jobs and worker stress and greatly impacted the economic health of the community.

Research and Development Activities

To address this problem, an underground coal mine fire preparedness and response checklist was developed and evaluated. It was field tested under a Cooperative Research and Development Agreement with Twentymile Coal Co. (Oak Creek, CO) and at several other operating mines. The checklist is a data collection instrument for profiling the fire prevention and response capabilities of a mine site. It encompasses conditions, procedures, and equipment that often have been identified as the main or contributing causes of underground coal mine fires. Topics covered include combustible materials, water systems, fire detection and suppression systems, firefighting equipment, mine rescue teams, and fire brigades.

R&D Outputs and Transfer Activities

The checklist has been highlighted in presentations at mining conferences, fire prevention workshops, and mine sites. A NIOSH Information Circular (IC) was also published in 2000. More than 200 copies of the IC have been distributed and continue to be requested.

Description of Intermediate Outcome

Coal mines are using the checklist to assist in their fire prevention programs and enhance their fire response capabilities. MSHA has adopted portions of the checklist for its training materials to prevent mine fires and for conducting mine fire prevention audits. The checklist was highlighted in *International Longwall News* (August 25, 2003).

Outputs

1 Output

Title	Year	Output Type	Strategic Goal
An Underground Coal Mine Fire Preparedness and Response Checklist: The Instrument Conti-RS; Chasko-LL; Lazzara-CP; Braselton-G | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Publication No. 2000-144, IC 9452, 2000 Aug; :151 pp	2000	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Evacuation of Underground Mine Workers During Main Fan Stoppages through Use of Electrically Powered Haulage

Description of Problem

A main mine fan outage can lead to a rapid increase in methane levels in the mine because the dilution effect of ventilating air is lost. Mine personnel must be evacuated due to the potential for a mine explosion. Powered haulage can be used to transport workers quickly from the working areas of the mine to the surface. However, Pennsylvania state mining law prohibited the use of powered haulage during a main mine fan outage. Many mining companies challenged this law, arguing that it would take miners longer to evacuate the mine traveling on foot. Studies were needed to assess how much methane accumulates in haulageways when a main mine fan stops.

A researcher installs a methane monitoring device

Research and Development Activities

NIOSH performed studies in four Pennsylvania underground mines to develop criteria for evaluating the rate and level of methane concentration increases along haulageways where workers would travel while leaving a mine after a fan stoppage. The fan stoppages at the mines lasted from 3 to 5 hours. Guidelines were developed for the use of the sampling instruments and the selection of sampling locations. Methane monitors, equipped with data loggers, were placed in the mine before the fan was stopped and retrieved from the mine after the fan was restarted. The data showed that measurable increases in methane occurred at some of the mining faces during fan stoppage. However, methane increases along haulageways were minimal during the 3- to 5-hour fan stoppages.

R&D Outputs and Transfer Activities

The results were communicated to the Pennsylvania Bureau of Deep Mine Safety, which had prohibited the practice of using powered haulage to evacuate a mine during main fan stoppages. The findings at each of the individual mine test sites were also provided to the specific mines. They were presented at several national and international mining conferences and were published in a peer-reviewed journal.

Description of Intermediate Outcome

The Pennsylvania Bureau of Deep Mine Safety used the data obtained by NIOSH to evaluate the safety of workers leaving a mine following a fan stoppage. Based on the findings of these studies, the agency adopted a policy of granting permission to Pennsylvania mines to use powered haulage during main mine fan shutdowns on a case-by-case basis. Several Pennsylvania mines have been able to obtain this approval.

NIOSH sampling procedures developed during this study provide a way for underground coal mines to evaluate the rate and level of methane concentrations along powered haulageways following a stoppage of the main mine fan.

Outputs

2 Outputs

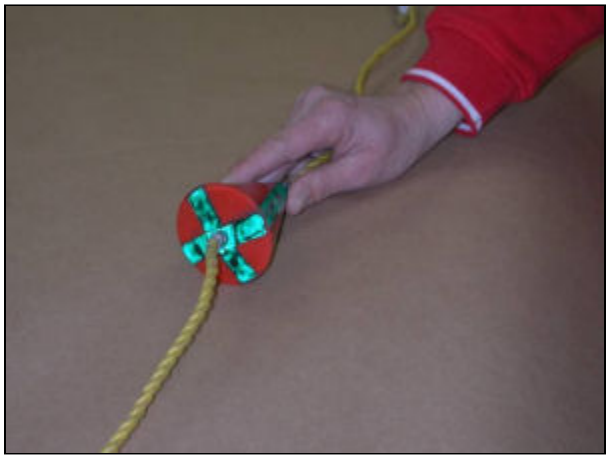
Title	Year	Output Type	Strategic Goal
Safety Concerns Associated With the Use of Electrically Powered Haulage to Remove Workers from Mines During Main Fan Stoppages Taylor-CD; Timko-RJ; Thimons-ED; Zimmer-JA | In: De Souze E, ed. Proc North American/Ninth U.S. Mine Ventilation Symposium (Jun 8-12, 2002; Kingston, Ontario, Canada). Lisse, The Netherlands: A. A. Balkema; 2002 Oct; :649-653	2002	Publication	Mine disasters
Safety Concerns Associated With the Use of Electrically Powered Haulage to Remove Workers from Mines During Main Fan Stoppages Taylor-CD; Timko-RJ; Thimons-ED; Zimmer-JA | J Mine Vent Soc S Afr 56(1), Jan/Mar 2003; :6-10	2003	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Evaluation of a Directional Lifeline for Mine Evacuations

Description of Problem

Evacuating an underground mine during a fire or after an explosion can be hard due to the long distances involved and potential smoke-filled passageways that greatly limit visibility. Although some mines use lifelines to guide escaping miners, the miners can become disoriented in the smoke and travel in the wrong direction.



Directional lifeline

Research and Development Activities

To address this issue, NIOSH evaluated a commercially available directional lifeline (CAB Products) during evacuation exercises through nontoxic, smoke-filled entries in the Lake Lynn Experimental Mine and in operating mines. The rope lifeline has cones spaced at regular intervals along its length. If the miner's hand slides over the cone, he or she is going in the correct direction. If the hand is blocked by the cone, he or she is heading in the wrong direction. More than one cone can be located just before an obstacle, such as a mine door. Since 2000, the directional lifeline was chosen by more than 1,300 miners during evacuation exercises as the best means of guiding them to safety through smoke-filled passageways.

R&D Outputs and Transfer Activities

The findings on the directional lifeline were presented at mining conferences, fire prevention and response workshops, mine rescue competitions, and operating mines.

Description of Intermediate Outcome

As a result of this work, several mines have installed directional lifelines in their escapeways. The Mine Safety and Health Administration has required directional lifelines in escapeways of underground coal mines that are ventilated with return air from working sections that are ventilated with belt entry air (30 CFR 75.380(n)). The directional lifeline was highlighted in *International Longwall News* (March 21, 2005).

Outputs

2 Outputs

Title	Year	Output Type	Strategic Goal
Emerging Technologies: Aiding Responders in Mine Emergences and During the Escape From Smoke-Filled Passageways Conti-RS | Proc Northwest Mining Association 107th Annual Meeting, Exposition and Short Courses (December 3-7, 2001; Spokane, WA); :14 pp	2001	Publication	Mine disasters; Surveillance and training
Technologies for Today's Mine Emergency Responders Conti-RS; Chasko-LL | International Journal of Emergency Management, 1(1); :13-29	2001	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Flammability Hazard Assessment of Noise Control Materials in Operator Cabs

Description of Problem

In 2001, the Mine Safety and Health Administration (MSHA) promulgated regulations requiring the use of noise control materials within the mining industry, in particular within the operator cabs of large mining equipment, to reduce the incidence of injuries resulting in hearing loss. Although the new regulations provided specific acoustic criteria for the selection and use of these materials, little guidance was provided with regard to their flammability and fire resistance. The limited flammability data available were mainly from small-scale flammability testing, such as SAE J369 and UL 94, and were not considered to be indicative of end-use conditions.

Testing the flammability of noise materials in laboratory tunnel

Research and Development Activities

In order to assess the potential hazards from fires involving these materials, both intermediate- and large-scale experiments were conducted. Intermediate-scale experiments were conducted in a horizontal tunnel under conditions of forced airflow. Large-scale experiments were conducted by lining the interior walls and roof of a full-size cab. A total of 21 different materials were evaluated and rated using a heat parameter (HP), which is the ratio of maximum fire heat output to enclosed air volume. The HP values were then correlated with flame spread indices obtained at MSHA's Approval and Certification Center using the standard American Society for Testing and Materials (ASTM) E-162 Radiant Panel Test. The experimental program confirmed that small-scale flammability tests were grossly inadequate and that the standard ASTM E-84 tunnel test was not reliable for predicting the fire hazard of these materials.

R&D Outputs and Transfer Activities

Research results were presented at the Fire and Materials Conference in January 2003 and published in the conference proceedings. Results have also been presented at NIOSH technology transfer seminars.

Description of Intermediate Outcome

MSHA subsequently adopted a set of guidelines for selecting these materials that addresses the material flammability and fire resistance and cites NIOSH's work in support of its guidelines. Copies of the NIOSH technical paper describing the experimental program, the results, and the selection guidelines recommended by MSHA are made available to the mining industry for its use in selecting noise control materials that satisfy both acoustic and fire-resistance criteria.

Outputs

1 Output

Title	Year	Output Type	Strategic Goal
Flammability of Noise Abatement Materials Used in Cabs of Mobile Mining Equipment Litton-CD; Mura-KE; Thomas-RA; Verakis-HC | Proc: Fire & Materials 2003. London: Interscience Communications, 2003 Feb; :297-306	2003	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Forensic Investigations of Mine Fires and Explosions (1993-2005)

Description of Problem

The mining and scientific communities have long recognized the unique facilities and capabilities of the NIOSH Pittsburgh Research Laboratory (PRL) in fire and explosion research. PRL scientists continue to receive requests from a variety of research organizations, industries, and government agencies to provide technical assistance related to the fire and explosion hazards of dusts, gases, liquids, and explosives. In particular, the Mine Safety and Health Administration (MSHA) has often requested help from PRL in its forensic investigations of mine ignitions, fires, and explosions. Identification of the root cause of these accidents often requires detailed analysis of small samples of residue and a basic understanding of the mechanisms of dust and gas ignitions and explosion propagation.

Collection of post-explosion dust samples for forensic analysis

Research and Development Activities

PRL has used optical microscopes, a scanning electron microscope (SEM), and thermodynamic models to aid MSHA in accident investigations. The SEM and auxiliary x-ray elemental analysis system have been used to identify types of particles and whether particles have been heated in explosions. The following are examples of PRL assistance to MSHA:

1. The Elmo No. 5 coal mine in Kentucky had a methane explosion in 1993 that killed one miner and injured another. Articles of the miner's clothing and a charred lighter were examined at PRL using optical macro and microscopic techniques. MSHA used our analyses to conclude that the ignition had been caused by prohibited smoking.
2. An ignition event at the Anderson limestone mine in Tennessee in 2000 was attributed to the frictional ignition of a rock inclusion that might contain sulfur. MSHA requested PRL to examine a sample of the suspect rock. PRL used optical microscopy, the SEM facility, and a simple heating test to identify the presence of elemental sulfur. Sulfur is known to be easily ignited and was the evident cause of the mine incident.

3. Multiple explosions occurred at the Pinnacle Mine in West Virginia in September-October 2003. MSHA requested that PRL investigate a borehole cover plate for evidence of a possible lightning strike and an explosion within the borehole. No obvious evidence of a lightning strike was found, but soot was found on the inside of the borehole cover plate.

R&D Outputs and Transfer Activities

The results of the PRL analyses were reported to MSHA. MSHA then used the information as part of its accident investigation reports. Additional information on the postexplosion observations at PRL's Lake Lynn Experimental Mine have been reported in various publications.

Description of Intermediate Outcome

PRL has helped MSHA determine the root causes of mine explosion accidents. The resulting MSHA investigation reports help prevent future accidents.

Outputs

2 Outputs

Title	Year	Output Type	Strategic Goal
Coal Dust Inerting and Postexplosion Dust Sampling Research in a 1-M3 Laboratory Chamber and an Experimental Mine Cashdollar-KL; Going-JE | In: Proceedings of the 2003 Technical Meeting of the Eastern States Section of the Combustion Institute (The Pennsylvania State University, University Park, PA, October 26-29, 2003). Pittsburgh, PA: The Combustion Institute, 2003; :97-100	2003	Publication	Mine disasters
Experimental Mine and Laboratory Dust Explosion Research at NIOSH Sapko-MJ; Weiss-ES; Cashdollar-KL; Zlochower-IA | J Loss Prev Process Ind 2000 May; 13(3) :229-242	2000	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Improved Methane Sampling During Roof Bolting

Description of Problem

Roof bolter operator making a methane check

Federal regulations require that face methane samples must be taken at least once every 20 minutes within 1 foot of the working face during the coal mining and roof bolting process. On deep-cut sections, the freshly cut face can be 40 feet away from the last row of bolts. Because workers at roof bolters are forbidden to move forward beyond the last row of bolts, they cannot walk forward to sample for methane at the face. They must attach a methanometer to a long pole or a cart with a long handle. These pole and cart methods are difficult and time-consuming. As a result, face methane readings are often taken in an inefficient manner or are not taken at all.

Research and Development Activities

NIOSH was approached by both industry (Bituminous Coal Operators' Association (BCOA)) and labor (United Mine Workers of America (UMWA)) to investigate alternative approaches to methane sampling. NIOSH conducted a study on alternative methods for measuring methane levels during bolting operations, especially when bolting in deep cuts. Accident reports showed that methane gas was released at the face and from roof bolt holes. NIOSH testing was performed in a full-scale simulated continuous miner face gallery equipped with a model roof bolter. Gas was released from the face and from roof bolt holes and then measured with methanometers placed on the model bolter and between the bolter and the face. A variety of practical mining configurations was simulated. The results showed that worker safety could be improved if a combination of (1) a portable monitor, mounted on a short pole, was used to "sweep" the area about 10 feet inby the bolter and (2) a roof bolter-mounted monitor was used to measure gas near the bolt holes. This system of face methane monitoring during roof bolting was easier and provided a greater degree of safety than the required single 20-minute reading at the immediate working face.

R&D Outputs and Transfer Activities

A meeting was held in Washington, DC, where NIOSH researchers presented the findings to the BCOA and UMWA. The results were also communicated directly to the Mine Safety and Health Administration (MSHA). NIOSH also presented the findings at several mining conferences and published them in a peer-reviewed journal.

Description of Intermediate Outcome

The UMWA and BCOA jointly recommended that MSHA amend current methane sampling requirements during roof bolting based on the results of the NIOSH study. MSHA found the results of the NIOSH study compelling enough that the final rule was published on July 7, 2003 (Federal Register, Vol. 68, No. 129, pp. 40132-40138).

Outputs

2 Outputs

Title	Year	Output Type	Strategic Goal
Comparison of Methane Concentrations at a Simulated Coal Mine Face During Bolting Taylor-CD; Thimons-ED; Zimmer-JA | In: Tien JC, ed. Proceedings of the Eighth U.S. Mine Ventilation Symposium, Rolla, MO: University of Missouri-Rolla Press, 1999; :171-178	1999	Publication	Mine disasters
Comparison of Methane Concentrations at a Simulated Coal Mine Face During Bolting Taylor-CD; Thimons-ED; Zimmer-JA | J Mine Vent Soc S Afr, 52(2),1999 Apr; :48-52	1999	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Managing Methane in Underground Coal Mines

Description of Problem

Gob gas venthole with pump and methane monitoring system

Mine operators have been unable to quantitatively forecast the potential for hazardous accumulations and emissions of methane under varying mining conditions. This has contributed to circumstances that led to 110 U.S. coal miner deaths in explosions since 1980. Recent methane explosions occurred (1) in West Virginia in 2003 (3 fatalities and 3 injuries), (2) in Alabama in 2001 (13 fatalities and 3 injuries), and (3) in Utah in 2000 (2 fatalities and 8 injuries). The presence of combustible concentrations of methane is also indicated by the occurrence of frictional ignitions. They are still relatively common in U.S. coal mines and averaged about 60 annually from 1995 to 2004. The Black Warrior Basin in Alabama has consistently led the nation in annual frictional ignitions (as high as 50% in some years) since the beginning of NIOSH industry surveys.

Research and Development Activities

NIOSH researchers conducted reservoir and rock mechanics modeling as part of an effort to develop a comprehensive, mine-wide predictive model to quantify methane emissions in advance of mining. At a cooperating Pennsylvania mine, the modeling of gob gas movement revealed inefficiencies in the removal of methane by gob gas ventholes using the mine's traditional borehole configurations. Modeling showed that a modification to the venthole completion design would enhance methane drainage and potentially reduce the amount of gas entering the mine workings. Improvements in gob gas venthole performance were achieved through the use of automated gob gas venthole monitoring and data acquisition systems. NIOSH scientists sampled the mined coalbed and adjacent strata at a mine in Alabama with a history of frictional ignition problems. Mineralogical analysis confirmed that a hard, quartz-rich floor rock was the source of frictional ignitions when contacted by the mining bit.

R&D Outputs and Transfer Activities

The reservoir modeling findings have been presented at conferences, published in conference proceedings, and reviewed with mine management. The NIOSH-developed remote gob gas venthole monitoring and cellular telephone based real time data transmission system was presented and published in conference proceedings. It has been discussed with a vendor that is considering offering components of the system as a service to mine operators. The analytical findings for the Alabama floor rock were discussed with mine management, and potential remedial measures were reviewed.

Description of Intermediate Outcome

The NIOSH longwall gob gas flow modeling research results have led a Pennsylvania mine operator to adopt our recommendations for gob gas venthole completion configurations for its longwall mines. The NIOSH-developed remote gob gas venthole monitoring system is currently in use on several gob vent boreholes in Pennsylvania.

Outputs

3 Outputs

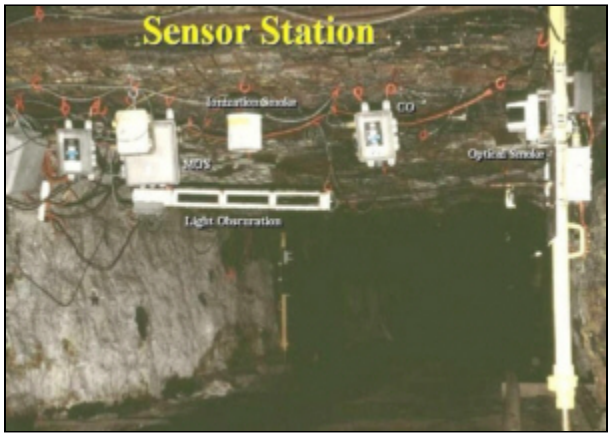
Title	Year	Output Type	Strategic Goal
Application of Numerical Models to Investigate Permeability Changes and Gas Emissions Around Longwall Mining Panels Esterhuizen-G; Karacan-CO | Proceedings of the 40th US Rock Mechanics Symposium (Anchorage, Alaska), CD-ROM, paper 05-744; :13 pp	2005	Publication	Mine disasters
Numerical Analysis of the Impact of Longwall Panel Width on Methane Emissions and Performance af Gob Gas Ventholes Karacan-CO; Diamond-WP; Esterhuizen-GS; Schatzel-SJ | In: Proceedings of the International Coalbed Methane Symposium (Tuscaloosa, AL; May 18-19, 2005). University of Alabama, 2005; :28 pp	2005	Publication	Mine disasters
Remote Gob Gas Venthole Monitoring and Cellular Telephone-Based Real-Time Data Transmission System Garcia-F; Diamond-WP; Marshall-JK | In: De Souze E, ed. Proceedings of the North American/Ninth U.S. Mine Ventilation Symposium (Kingston, Ontario, Canada). Lisse, Netherlands: Balkema, 2002; :324-329	2002	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Optimizing the Spacing of Fire Sensors in Mine Entries

Description of Problem

The use of belt air directed toward the working face of a coal mine requires the installation of carbon monoxide (CO) sensors. CO and smoke sensor spacing guidelines required in belt entries were not established for low airflows less than 50 feet per minute. The Mine Safety and Health Administration (MSHA) required this information for the development of belt air regulations when belt air is used to ventilate the working face of a coal mine.



Sensors used to monitor smoke and CO movement from a mine fire

Research and Development Activities

Experiments were conducted to determine the carbon monoxide sensor alarm time response to diesel fires with intensities between 30 and 495 kW under zero airflow in the Pittsburgh Research Laboratory's Safety Research Coal Mine. It was found that the sensor spacing required to provide a 14-minute warning for a small 30-kW fire was 350 feet. It had been previously established that 14 minutes was required for a small flaming coal fire to ignite a conveyor belt.

R&D Outputs and Transfer Activities

Research results were published in the Proceedings of the Sixth International Mine Ventilation Congress held in Pittsburgh, PA, in 1997.

Description of Intermediate Outcome

The research led to rulemaking by MSHA for atmospheric mine monitoring in a belt air course, as established in 30 CFR 75.351(e)(3), effective July 1, 2004: "In areas along each belt entry where air velocities are less than 50 feet per minute, the sensor spacing must not exceed 350 feet." This sensor spacing for an atmospheric monitoring system is required in a belt entry used to ventilate a working face, as specified in 30 CFR 75.350(b)(1). As a result of this impact, early mine fire detection will be ensured in a belt entry when belt entry air is used to ventilate a mine working face. This research has contributed to a rule in the Code of Federal Regulations, which provides a safe working environment for underground miners.

Outputs

1 Output

Title	Year	Output Type	Strategic Goal
Mine Fire Detection Under Zero Airflow Conditions Edwards-JC; Friel-GF; Franks-RA; Opferman-JJ | Proceedings of the 6th International Mine Ventilation Congress, Chapter 52, Ramani RV, ed., Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 1997 Feb; :331-336	1997	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Protecting Coal Miners from Gob Explosions through Explosion-Resistant Mine Ventilation Seals (1993-2005)

Description of Problem

Ventilation seals are used extensively in mining to safely isolate old workings and fire areas from the active sections of a mine to protect underground workers from explosions. Without reliable seal designs, miners' lives could be in jeopardy from the consequences of an underground explosion.

NIOSH researchers inspecting a mine seal before hydrostatic testing

Research and Development Activities

The NIOSH Pittsburgh Research Laboratory (PRL), in partnership with national and international mine operators, seal manufacturers, and the Mine Safety and Health Administration (MSHA), has developed and evaluated numerous new and innovative seal designs. The main focus of the effort was to develop mine sealing technologies for use during mine emergencies, within unique geological conditions in the mine, and/or for generalized mine gob sealing.

All new seal designs were performance-tested in PRL's Lake Lynn Experimental Mine (LLEM) for strength characteristics against explosions and for air leakage resistance before and after an explosion. If the seal design met the requirements of the program as set forth at 30 CFR 75.335, MSHA then deemed the seal design acceptable for use in underground coal mines. Twenty-seven different seal designs have been developed and evaluated in the LLEM.

R&D Outputs and Transfer Activities

The results of this research have been distributed through reports to MSHA, publications, and workshops. NIOSH researchers have collaborated closely with manufacturers and mine operators to translate this research into practice. The seal designs that have been developed and proven in the LLEM have been deemed suitable by MSHA and are now being built and used daily in the United States and abroad.

Description of Intermediate Outcome

More than 35,000 seals based on designs tested in the LLEM have been installed in commercial coal mines in recent years. For example, Strata Mine Products has installed more than 5,000 seals since June 1999. This novel seal design, which consists of a locking, solid-concrete-block wall preloaded on the sides and near the mine roof with packsetter pumpable grout bags, is an important item in this company's product line. Burrell Mining Products has successfully commercialized a new lightweight concrete block seal design based on results from full-scale seal research in the LLEM. This design is easier to build, resulting in less musculoskeletal stress typically associated with conventional heavy solid-concrete-block designs and handling techniques. Since NIOSH's evaluation of the new seal design in June 2002, Burrell has been averaging about 70 seal installations per month.

A gob gas explosion occurred on or about June 16, 1995, where lightning initiated an explosion in a sealed section of the Gary 50 Mine in Pineville, WV. Several 4-foot-thick pumpable cementitious seal designs, which had been previously performance-tested in the LLEM and subsequently approved by MSHA, effectively contained the explosion, thereby sparing the miners working nearby.

Outputs

11 Outputs

Title	Year	Output Type	Strategic Goal
Alternative Methodologies for Evaluating Explosion-resistant Mine Ventilation Seals Sapko-MJ; Weiss-ES; Harteis-SP | In Proceedings of the 30th International Conference of Safety in Mines Research Institutes. Johannesburg, Republic of South Africa: South African Institute of Mining and Metallurgy, 2003 Oct; :615-640	2003	Publication	Mine disasters
Designs for Rapid In-Situ Sealing Sapko-MJ; Weiss-ES; Trackemas-J; Stephan-CR | In: Proceedings of the Annual Meeting of the Society for Mining, Metallurgy, and Exploration, Inc (Feb 2003; Cincinnati, OH). Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc; :8 pp	2003	Publication	Mine disasters
Evaluation of Explosion-Resistant Seals, Stoppings, and Overcast for Ventilation Control in Underground Coal Mining Weiss-ES; Cashdollar-KL; Sapko-MJ | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centrs for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2003-104, Report of Investigations 9659, 2002	2002	Publication	Mine disasters
Evaluation of New Methods and Facilities to Test Explosion-Resistant Seals Sapko-MJ; Weiss-ES | In: Proceedings of the 29th International Conference of Safety in Mines Research Institutes. Vol. 1. Katowice, Poland: Central Mining Institute, 2001; :157-166	2001	Publication	Mine disasters
Evaluation of Reinforced Cementitious Seals Weiss-ES; Cashdollar-KL; Mutton-IVS; Kohli-DR; Slivensky-WA | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Publication No. 99-136, Report of Investigations 9647, 1999	1999	Publication	Mine disasters
Evaluation of Water Trap Designs and Alternative Mine Seal Construction Materials Weiss-ES; Slivensky-WA; Schultz-MJ; Stephan-CR | In: Dhar BB, Bhowmick BC, eds. Proceedings of the 27th International Conference of Safety in Mines Research Institutes Vol. 2, New Delhi, India: Oxford & IBH Publishing Co. Pvt. Ltd., 1997; :973-981	1997	Publication	Mine disasters
Methods for Evaluating Explosion Resistant Ventilation Structures Sapko-MJ; Weiss-ES; Harteis-SP | In: Eighth International Mine Ventilation Congress (Brisbane, Australia); :211-219	2005	Publication	Mine disasters
Overview of NIOSH's Mine Seal Research Sapko-MJ; Weiss-ES; Cashdollar-KL; Greninger-NB | In: Proceedings of the 28th International Conference of Safety in Mines Research Institutes (Sinaia, Romania). Vol. I, 1999; :71-85	1999	Publication	Mine disasters
Recent Mine Seal Research Conducted by NIOSH Sapko-MJ; Weiss-ES; Greninger-NB | In: Sealbarr '99 - Proceedings of the Polish-American Seminar on Seals and Barriers as a Means of Protection Against Fires and Explosions in Mines (Katowice, Poland, May 27-28, 1999),1999 May; :39-53	1999	Publication	Mine disasters
Technology News 490 - An Inexpensive Device for Monitoring Explosions in Sealed Areas of Underground Mines NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 490, 2001 Jun :1-2	2001	Publication	Mine disasters
Alternative Methodologies for Evaluating Strength of Mine Seals Workshop NIOSH | Workshop presented to the coal industry, seal manufacturers, MSHA, PA Bureau of Deep Mine Safety, and the United Mine Workers of America (Sept 8, 2004, Pittsburgh, PA; 77 participants)	2004	Workshop, Seminar, or OIB	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Realistic Training for Mine Emergency Responders

Description of Problem

Because of the unique hazards in the underground mine environment, responders to mine emergencies, including miners, fire brigades, and mine rescue teams, need realistic training exercises to ensure their safety and readiness.

Injured miner receiving first aid during rescue team training

Research and Development Activities

In partnership with state agencies, the Mine Safety and Health Administration, and mining companies, realistic underground training exercises were and are being developed, conducted, and evaluated. Since 1998, more than 150 mine rescue, firefighting, and escape simulations have been held at Lake Lynn Lab and at operating coal and metal/nonmetal mines. More than 3,000 miners have participated.

R&D Outputs and Transfer Activities

Miners experienced traveling through smoke-filled entries using directional lifelines, handheld lasers, chemical light sticks, and strobe lights to guide them. Fire brigade members fought actual conveyor belt fires and extinguished diesel fuel tray fires with water lines, chemical powder, and foam. Mine rescue teams explored smoke-filled underground passageways, built stoppings and cribs, rescued "injured" miners, and reestablished ventilation to remove hazardous gases. During the exercises, the participants evaluated various NIOSH-identified and/or developed technologies to enhance their safety and operational effectiveness. These include the patented lighted team link line, extendable wheeled stretcher cart, lifeline pulleys, and emergency communication systems.

Description of Intermediate Outcome

The exercises were highly rated by the participants, agency instructors, and mine safety officials. As a result of the exercises, the participants, including command center personnel, gained a better awareness of the hazards associated with mine emergencies, increased their skill and confidence levels, improved decision-making capabilities, and enhanced the safety and operational effectiveness of mine rescue teams and fire brigades. Rescue team members who had successfully extinguished a conveyor belt fire at Mine 84 (Eighty Four Mining Co.) in Pennsylvania in January 2003 stated that NIOSH training was the best preparation they had received for fighting an actual fire. Several rescue teams, including the six Pennsylvania state-trained teams, have adopted the lifeline pulleys, magnetic mapboards, and chemical light sticks. Consol Energy, Inc., teams used 50 lifeline pulleys and chemical light sticks to help in recovering the Buchanan Mine, which was temporarily sealed because of a fire in 2005.

Outputs

5 Outputs

Title	Year	Output Type	Strategic Goal
An Overview of Technology and Training Simulations for Mine Rescue Teams Conti-RS; Chasko-LL; Cool-JD | Proceedings of the 28th International Conference of Safety in Mines Research Institutes (Jun 7-11, 1999; Sinaia, Romania), Vol. II; :521-538	1999	Publication	Mine disasters
Emerging Technologies: Aiding Responders in Mine Emergences and During the Escape From Smoke-Filled Passageways Conti-RS | Proc Northwest Mining Association 107th Annual Meeting, Exposition and Short Courses (December 3-7, 2001; Spokane, WA); :14 pp	2001	Publication	Mine disasters; Surveillance and training
Lighted Line Conti-RS; Chasko-LL | U.S. Patent #6,742,909	2004	Patent	Mine disasters
Mine Rescue and Response Conti-RS | Proceedings of the 12th International Conference on Coal Research - Coal the Future (Sep 12-15, 2000; Sandton, Republic of South Africa). Symposium Series S26, International Committee for Coal Research, Washington, DC; :127-136	2000	Publication	Mine disasters
Responders To Underground Mine Fires Conti-RS | Proceedings of the 32nd Annual Conference of the Institute on Mining Health, Safety and Research (Aug 5-7, 2001; Salt Lake City, UT), University of Utah; :111-121	2001	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Revised Standards for National Fire Protection Association (2002-2004)

Description of Problem

In January 2002, the National Fire Protection Association (NFPA) began an effort to completely rewrite the outdated mining fire protection standards to bring them up to the state of the art in fire protection. The standards were also to include new sections to cover surface mining equipment, crushing operations, and coal loadouts. This was the first major rewrite since the standards had been adopted in 1981.

A fire suppression experiment in a diesel fuel storage area

Research and Development Activities

NIOSH played a key role in developing the 2004 revised mining standards: NFPA 120 - Standard for Fire Prevention and Control in Underground Coal Mines, and NFPA 122 - Standard for Fire Prevention and Control in Metal and Nonmetal Mines. NIOSH experts were invited to serve on the NFPA Technical Committee on Mining Facilities. The committee is composed of representatives from the mining industry, manufacturers of mining equipment, insurance and risk management firms, the fire protection industry, and consultants to the mining industry. During the rewrite, four separate standards were combined into two (120 and 122). These four standards were: NFPA 120 - Standard for Coal Preparation Plants, NFPA 121 - Standard on Fire Protection for Self-Propelled and Mobile Surface Mining Equipment, NFPA 122 - Standard for Fire Prevention and Control in Underground Metal and Nonmetal Mines, and NFPA 123 - Standard for Fire Prevention and Control in Underground Bituminous Coal Mines.

R&D Outputs and Transfer Activities

Two standards, NFPA 120 and 122, were completed and published in August 2004. The diverse membership of the technical committee ensures that the research results are disseminated to a wide spectrum of industries. NIOSH research is referenced extensively in the new standards, particularly in sections on detecting and suppressing mine fires, surface mobile equipment fires, and mine fire statistics.

Description of Intermediate Outcome

NFPA's mission is to reduce the worldwide burden of fire and other hazards on the quality of life by providing and advocating scientifically based consensus codes and standards, research, training, and education. The NFPA serves as the world's leading advocate of fire prevention and is an authoritative source on public safety. The NFPA's 300 codes and standards influence every building, process, service, design, and installation in the United States, as well as many of those used in other countries. NFPA's focus on true consensus has helped the association's code development process earn accreditation from the American National Standards Institute (ANSI).

Outputs

2 Outputs

Title	Year	Output Type	Strategic Goal
NFPA 120 - Standard for Fire Prevention and Control in Coal Mines National Fire Protection Association | Quincy, MA: National Fire Protection Association	2004	Standards	Mine disasters
NFPA 122 - Standard for Fire Prevention and Control in Metal/Nonmetal Mining and Metal Mineral Processing Facilities National Fire Protection Association | Quincy, MA: National Fire Protection Association	2004	Standards	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Transfer of Explosions and Fire Expertise and Test Procedures to Industry (1992-2005)

Description of Problem

Knowledge of material flammability and explosibility characteristics is essential to industries that manufacture, process, generate, or use combustible dusts and gases. These industries include mining, metals, chemicals, plastics, agriculture, and electric power generation. Most important to their mission is the need for reliable, peer-reviewed information, guidelines, and standards to help protect workers from accidental fires or explosions.

Research and Development Activities

Fire and explosion safety expertise, test equipment, and test procedures developed at the NIOSH Pittsburgh Research Laboratory (PRL) for the mining industry have been transferred to other industries. This included the development of consensus standard test methods through the American Society for Testing and Materials (ASTM) International Committee E27 on the Hazard Potential of Chemicals. The four test methods approved are: E1491 for the Minimum Autoignition Temperature of Dust Clouds (1992), E1515 for the Minimum Explosible Concentration of Combustible Dusts (1993, revised in 2003), E2021 for the Hot-surface Ignition Temperature of Dust Layers (2001), and E2079 for the Limiting Oxygen Concentration in Gases and Vapors (2001). Additional test methods for limiting oxygen concentrations of dust clouds and flammability limits of gases using a pressure criterion are currently being considered by the ASTM E27 committee.

R&D Outputs and Transfer Activities

These consensus standard test methods have been published by ASTM International and are now being used by the Occupational Safety and Health Administration (OSHA), private testing labs, and various industrial labs to evaluate the ignitability and explosibility of dusts and gases. Information on the measurement of gas and dust explosibility characteristics has also been widely distributed to various safety personnel in industry through various journal and book publications.

Description of Intermediate Outcome

Based on an ASTM survey in 2004, the four test methods are used more than 400 times per year by various industries to assess their explosion hazards. The data from these tests are used to develop protective measures in industry to prevent gas and dust explosions and fires. Copies of the summary explosion publications were requested by members of the Chemical Safety and Hazard Investigation Board to assist in their investigations of recent industrial dust explosions. The summary dust explosion publications provide help and guidance to the practicing safety engineer regarding the important variables in dust explosibility, particularly the importance of particle size.

Outputs

6 Outputs

Title	Year	Output Type	Strategic Goal
Flammability Limit Measurements for Dusts in 20-L and 1-m3 Vessels Going-JE; Chatrathi-K; Cashdollar-KL | Journal of Loss Prevention in the Process Ind, 13(3), 2003 May; :209-219	2000	Publication	Mine disasters
Flammability of Methane, Propane, and Hydrogen Gases Cashdollar-KL; Zlochower-IA; Green-GM; Thomas-RA; Hertzberg-M | Journal of Loss Prevention in the Process Industries, 13(3-5), 2000 May; :327-340	2000	Publication	Mine disasters
Overview of Dust Explosibility Characteristics Cashdollar-KL | J Loss Prevention in the Process Industries, 2000 May; 13(3-5); :183-199	2000	Publication	Mine disasters
Predicting Flammability of Gas Mixtures Containing Volatile Organic Compounds Liekhus-K; Zlochower-IA; Cashdollar-KL; Djordjevic-S; Loehr-C | J. Loss Prev. Process Industries, v 13; :377 384	2000	Publication	Mine disasters
Properties of Combustible Dusts (Safety Characteristics) Hensel-W; Cashdollar-KL | Chapter In: Hattwig M and Steen H, eds. Handbook of Explosion Prevention and Protection (English translation of Handbuch des Explosionsschutzes, originally published in German, April 2000), Wiley-VCH, 2004; :379-417	2004	Publication	Mine disasters
The Role of ASTM E27 Methods in Hazard Assessment: Part II - Flammability and Ignitability Britton-LG; Cashdollar-KL; Fenlon-W; Frurip-D; Going-J; Harrison-BK; Niemeier-J; Ural-EA | Process Saf Prog 24(1), 2005; :12-28	2005	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Utilization of Large-Diameter Propeller Fans

Description of Problem

Most operators of large-opening mines have relied on inadequate mine ventilation methods, such as natural ventilation or mine ventilation fans typically designed for coal mines. It became evident that the ventilation practices and fan selections were inadequate to reduce worker exposure to airborne contaminants.

Installation of large diameter propeller fan in large opening mine

Research and Development Activities

NIOSH researchers conducted an extensive review of available ventilation fans and their potential suitability for large-opening mines. It was determined that large-diameter propeller fans would be best suited for these mines. The researchers conducted a mine case study where two large-diameter propeller fans were selected, installed, and evaluated in an operating large-opening stone mine. The study demonstrated that propeller fans could effectively increase ventilation airflow quantities. Propeller fans are more efficient than axial vane fans in large-opening mine conditions. They create less noise, require less capital investment, and have lower operating costs compared to axial vane fans previously used in these mining operations.

R&D Outputs and Transfer Activities

The successful use of propeller fans was described during presentations at three annual NIOSH Safety Seminars for Underground Stone Mines and at two mining symposia. The concept has been demonstrated in a case study at a commercial mine, and several on-site technology transfer sessions have been presented to other mine operators.

Description of Intermediate Outcome

Propeller fans have become more common in underground large-opening mines. Currently, there are at least seven mining operations that use propeller fans as main mine fans. Spendrup Fan Co. started manufacturing main mine propeller fans. Both Hartzell Fan Co. and Spendrup Fan Co. started manufacturing portable diesel-powered propeller fans.

Outputs

5 Outputs

Title	Year	Output Type	Strategic Goal
NIOSH Ventilation Research Addressing Diesel Emissions and Other Air Quality Issues in Nonmetal Mines Grau-RH III; Robertson-SB; Mucho-T; Garcia-F, Smith-AC | Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., Transactions 2004, Vol. 316; :149-158	2004	Publication	Mine disasters
NIOSH Ventilation Research Addressing Diesel Emissions and Other Air Quality Issues in Nonmetal Mines Grau-RH; Robertson-SB; Mucho-TP; Garcia-F; Smith-AC | 2002 SME Annual Meeting (Phoenix, Arizona; Feb 25-27, 2002). SME preprint 02-187. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc; :1-7	2002	Publication	Mine disasters; Respiratory diseases
Practical Techniques to Improve the Air Quality in Underground Stone Mines Grau-RH; Mucho-TP; Robertson-SB; Smith-AC; Garcia-SF | In: De Souze E, ed. Mine Ventilation: Proceedings of the North American/Ninth U.S. Mine Ventilation Symposium (Kingston, Ontario, Canada) Lisse, Netherlands: A. A. Balkema, 2002 Oct; :123-129	2002	Publication	Mine disasters; Respiratory diseases
Raising the Bar of Ventilation for Large-Opening Stone Mines Grau-RH; Robertson-SB; Krog-RB; Chekan-GJ; Mucho-TP | In: Ganguli R, Bandopadhyay S, eds. Mine Ventilation: Proc 10th U.S./North American Mine Ventilation Symposium (Anchorage, Alaska, May 16-19 2004). Leiden, Netherlands: A. A. Balkema, 2004 May; :349-355	2004	Publication	Mine disasters; Respiratory diseases
Technology News 499 - Using Propeller Fans to Improve Ventilation in Large-Entry Stone Mines Grau-RH III; Robertson-SB | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 499, 2002 Dec :1-2	2002	Publication	Mine disasters

Intermediate Outcome related to Preventing and Mitigating Mine Fires and Explosions

Ventilating Large-Opening Stone Mines using Novel Ventilation Techniques

Description of Problem

NIOSH researchers investigated ventilation practices at several large-opening mines and determined that a more efficient ventilation design was needed to establish a sufficient and stable airflow to the working face of the mine in order to reduce airborne contaminants to acceptable levels.

Propeller fan blowing into a new mine using split-mine ventilation

Research and Development Activities

Effective ventilation planning in conjunction with mine design is essential for creating an efficient ventilation system for the life of the mine. Prior to this research, the common mining and ventilation practice in large-opening mines gave little regard to the integration of ventilation into the mining plan. These mines relied on natural ventilation and less-than-optimal use of freestanding auxiliary fans. This resulted in inadequate ventilation at the face of the mine.

NIOSH researchers developed two improved ventilation concepts - perimeter ventilation and split ventilation. Both concepts use a stopping line to separate the intake air from the return air in order to create a larger pressure drop between the two airstreams. Ventilation planning becomes an integral part of the mine design process by using either concept. Perimeter ventilation has the advantage that it can be applied to older, mature mines that have an extensive network of large openings. It requires a minimum number of stoppings to be built to properly course the air to the active mine workings. Split ventilation is better suited for newer or smaller mines. In these mines, the stopping line is built concurrent with mine development by leaving long pillars.

R&D Outputs and Transfer Activities

Results of this research have been presented at several industry seminars and conferences, as well as during site visits to the engineering staffs at two partnering mining operations. Several mine operators have visited the mine site of the successful application of the perimeter-ventilation method to learn firsthand how it works. The concepts to improve large-opening mine ventilation have also been described in depth to the Mine Safety and Health Administration's (MSHA) Technical Support group during several meetings.

Description of Intermediate Outcome

Hanson Aggregates (Latrobe and Whitney Mines) is using perimeter ventilation, and Coolspring Stone Supply, Inc., (Coolspring Mine) is using split ventilation. The use of the NIOSH-developed ventilation concepts by these mine operators is a long-term commitment and verifies acceptance by the industry.

MSHA is providing information to stone mine operators about this research to help them improve their ventilation systems.

Outputs

7 Outputs

Title	Year	Output Type	Strategic Goal
Evaluating Ventilating Air Movement in Underground Limestone Mines by Monitoring Respirable Dust Generated from Production Shots Chekan-GJ; Colinet-JF; Grau-RH III | In: Ganguli R, Bandopadhyay S, eds. Mine ventilation: Proceedings of the 10th U.S./North American Mine Ventilation Sympsoim (Anchorage, AK, May 16-19, 2004). Leiden, Netherlands: Balkema,2004; :221-232	2004	Publication	Mine disasters; Respiratory diseases
NIOSH Ventilation Research Addressing Diesel Emissions and Other Air Quality Issues in Nonmetal Mines Grau-RH III; Robertson-SB; Mucho-T; Garcia-F, Smith-AC | Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., Transactions 2004, Vol. 316; :149-158	2004	Publication	Mine disasters
NIOSH Ventilation Research Addressing Diesel Emissions and Other Air Quality Issues in Nonmetal Mines Grau-RH; Robertson-SB; Mucho-TP; Garcia-F; Smith-AC | 2002 SME Annual Meeting (Phoenix, Arizona; Feb 25-27, 2002). SME preprint 02-187. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc; :1-7	2002	Publication	Mine disasters; Respiratory diseases
Practical Techniques to Improve the Air Quality in Underground Stone Mines Grau-RH; Mucho-TP; Robertson-SB; Smith-AC; Garcia-SF | In: De Souze E, ed. Mine Ventilation: Proceedings of the North American/Ninth U.S. Mine Ventilation Symposium (Kingston, Ontario, Canada) Lisse, Netherlands: A. A. Balkema, 2002 Oct; :123-129	2002	Publication	Mine disasters; Respiratory diseases
Raising the Bar of Ventilation for Large-Opening Stone Mines Grau-RH; Robertson-SB; Krog-RB; Chekan-GJ; Mucho-TP | In: Ganguli R, Bandopadhyay S, eds. Mine Ventilation: Proc 10th U.S./North American Mine Ventilation Symposium (Anchorage, Alaska, May 16-19 2004). Leiden, Netherlands: A. A. Balkema, 2004 May; :349-355	2004	Publication	Mine disasters; Respiratory diseases
Technology News 500 - Using In-Place Stone Stoppings to Direct Air in Underground Stone Mines NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 500, 2002 Dec :1-2	2002	Publication	Mine disasters; Respiratory diseases
Ventilation Planning Layouts for Large Opening Mines Krog-RB; Grau-RH; Mucho-TP; Robertson-SB | 2004 SME Annual Meeting, Feb 23-25, Denver, Colorado, preprint 04-187. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2004 Feb; :1-9	2004	Publication	Mine disasters; Respiratory diseases

Strategic Program Outcome for Ground Control

Reducing Fatalities and Injuries Due to Ground Failures

Ground falls in U.S. underground mines (coal and nonmetal) caused more than 50,000 deaths or about half of all mining fatalities during the 20th century. Over the past 10 years, there have been significant improvements in ground control safety. Figure 1 shows that the roof fall fatality rate in U.S. underground mines has averaged 0.001 per 200,000 during the past 3 years, down 69% from its average during 1980-1995. In addition, the rock fall injury rate has fallen in each of the last 4 years to a level about 25% below its former plateau.

NIOSH has contributed to this historic improvement through its customer-focused, goal-oriented ground control research program. Important NIOSH research products that have been successfully transferred to and implemented by the mining community during the past decade include:

- The Support Technology Optimization Program (STOP) and Analysis of Longwall Pillar Stability (ALPS) programs, which together have contributed to a virtual elimination of tailgate blockages.
- The underground stone ground control safety initiative. This initiative has increased awareness about rock fall hazards and helped to greatly reduce fatalities in stone mines.
- Guidelines for coal pillar recovery and widespread use of mobile roof supports. These have helped make pillar recovery much safer.
- Guidelines for designing deep-cover mines to prevent coal bumps (violent failures of highly stressed coal). These guidelines have contributed to 7 consecutive years with no fatalities due to coal bumps.
- New standing roof supports. These have helped reduce the number of roof falls and the number of injuries to miners while installing roof support.
- A research and educational campaign aimed at increasing awareness about rock fall injuries and the use of surface controls in coal mines. This has helped reduce rock fall injury rates.
- Mine design technologies such as the Coal Mine Roof Rating (CMRR) and Analysis of Horizontal Stress in Mines (AHSM), and guidelines for preventing massive pillar collapses. These have helped provide more stable mining environments.

More details on each of these accomplishments and impacts can be found in the "Intermediate Outcome" write-ups.

An essential part of the success of the NIOSH ground control program has been an effective technology transfer effort. The centerpiece has been the suite of ground control software packages that has been developed from the research. There are now eight NIOSH programs. These address nearly every aspect of ground control planning for coal mines. This includes geologic characterization, mine layout, pillar design, and support selection. These products are used throughout the mining community. They are among the most requested and downloaded products from the NIOSH Mining Website. Other technology transfer efforts include:

- Hands-on ground control software computer training workshops held in six U.S. coalfield locations. These were attended by nearly 300 mine planners.
- Annual safety seminars for underground stone mines. These are attended by more than 150 professionals in the stone industry each year.
- Open industry briefings on coal mine roof support. These were held in eight U.S. coalfield locations and reached 750 mining industry personnel.
- Ground control short courses conducted for Massey Energy and Peabody Energy.
- Ground control training provided in eight sessions for all 400 coal mine inspectors from the Mine Safety and Health Administration (MSHA) at the agency´s request.
- An annual response to an average of 200 technical requests and 40 visits at coal and nonmetal mine sites.

Another important component of our technology transfer program is the MSHA-NIOSH partnership in the Preventative Roof-Rib Outreach Program (PROP). PROP has sponsored nearly a dozen full-day or half-day seminars in nearly every MSHA coal mining district. These seminars are tailored for the specific needs of each district. Attendance at these seminars is usually 50 to 100. NIOSH provides about half of the speakers. In addition, PROP has sponsored 2-day seminars at MSHA´s National Mine Health and Safety Academy in each of the last 5 years. These were attended by about 150 miners each year.

NIOSH has developed a particularly close relationship with the MSHA Technical Support group at Bruceton, PA. Our collaborations with them facilitate quick results and implementation by the MSHA districts. Partnerships with mine roof support manufacturers have greatly enhanced the effectiveness of the NIOSH mine roof simulator (MRS). The impartiality of safety testing in the MRS is accepted across the mining community. Thus, NIOSH has been able to help in the rapid commercialization of more than 40 new roof support technologies over the past 5 years.

International collaboration is another measure of the caliber and impact of the NIOSH ground control program. During the past 8 years, six major funded research projects in Australia, Canada, the European Union, and the Republic of South Africa were based on NIOSH research. These focused on the STOP, ALPS, Analysis of Retreat Mining Pillar Stability (ARMPS), and CMRR software packages.

A new initiative is aimed at developing a set of engineering design guidelines to minimize unplanned roof failures in underground stone mines. Another software package will help coal mine planners minimize hazards when using multiple-seam mining techniques. Recent advances have coupled microseismic monitoring of rock failure events to measurements of mine roof movements. This has resulted in a sensor-based roof fall warning technology for identifying potentially hazardous areas. Standing support improvements and a better understanding of rock mass behaviors will provide opportunities for reducing the threat posed by massive roof falls to underground workers.

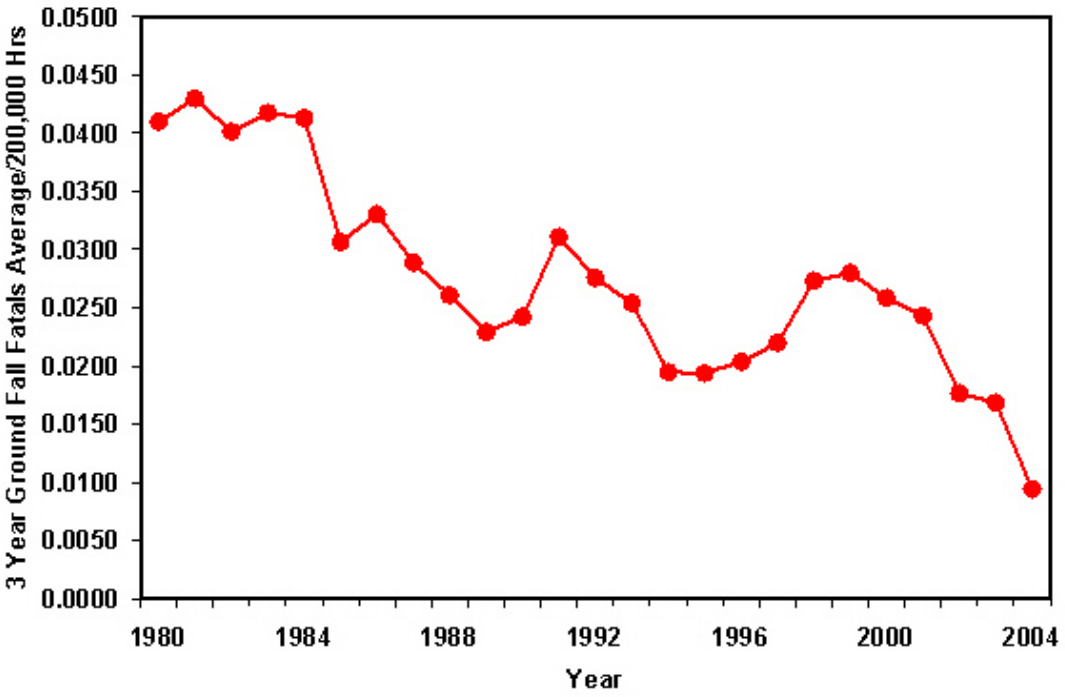


Figure 1. Ground fall fatality rate in underground mines (3-year moving average).

Rock burst control for hard-rock mines has been part of the ground control research program for more than 30 years. Great progress has been made in alleviating the rock burst problem in U.S. deep-metal mines. Seismic monitoring, in conjunction with rock mass behavior measurements and numerical modeling, has led to the development of safer mining methods and layouts.

NIOSH has also provided solutions to reduce ground fall hazards in Nevada underground mines. From 1999 to 2005, the mine design curves and applicable nomograms resulting from this research were transferred to the mining industry through 11 technical papers and 9 presentations.

Intermediate Outcomes

- Characterizing Coal Measure Rocks Using the Coal Mine Roof Rating System
- Control of Horizontal Stress in Mining to Reduce Injuries and Fatalities
- Design Guidelines for Safe Highwall Mining Systems
- Guidelines for Coal Pillar Recovery
- Mitigating Ground Fall Hazards in Underground Stone Mines
- Mobile Roof Supports for Retreat Room-and-Pillar Mines
- NIOSH Support Technology Optimization Program (STOP) Design Software
- Preventing Longwall Tailgate Blockages
- Preventing Massive Coal Pillar Collapses
- Reducing Rock Fall Injuries to Coal Miners
- Rock Burst Control in Deep Metal Mines

Intermediate Outcome related to Reducing Fatalities and Injuries Due to Ground Failures

Characterizing Coal Measure Rocks Using the Coal Mine Roof Rating System

Description of Problem

Roof falls continue to be one of the greatest hazards faced by underground coal miners. They can damage equipment, disrupt ventilation, and block critical emergency escape routes. One reason that roof falls have been so difficult to eradicate is that the structural integrity of a coal mine´s roof is greatly affected by natural weaknesses, including bedding planes, fractures, and small faults. The engineering properties of rock cannot be quantified solely by lab tests because the strength of a small specimen is representative only of that sample and does not take into account the imperfections caused by discontinuities.

Researchers examining a roof fall to calculate roof strength using CMRR observational techniques

Research and Development Activities

NIOSH developed the Coal Mine Roof Rating (CMRR) system 10 years ago to fill the gap between geologic characterization and engineering design. It combines many years of geologic studies in underground coal mines with worldwide experience with rock mass classification systems. New CMRR procedures for borehole drill core, together with a software package, were developed in 2000 and made it possible to routinely collect CMRR data during geologic exploration. Worldwide experience has shown that the CMRR is a reliable, meaningful, and repeatable measure of mine roof quality.

R&D Outputs and Transfer Activities

NIOSH transferred the new CMRR software package to the mining community through a series of open industry briefings that included hands-on computer training sessions. Presentations on the CMRR have also been given at conferences in the United States and Australia. In addition, NIOSH has responded to requests for assistance in using the CMRR from many mining companies and geologic consultants, both domestic and abroad.

Description of Intermediate Outcome

NIOSH developed a wide variety of ground control design tools based on the CMRR. These tools address a broad range of issues, including longwall pillar design, roof support selection, feasibility studies, extended-cut evaluation, and others. As a result, the CMRR is becoming the accepted standard for geotechnical characterization of mine roof and is often referred to in the technical literature. Peabody Energy, the largest U.S. coal producer, routinely uses the CMRR

in all of its exploration and mine planning activities. The CMRR has also become truly international. It is involved in mine designs and in research projects funded by the Safety in Mines Research Advisory Committee (South Africa), the Canada Centre for Mineral and Energy Technology, and the Australian Coal Association Research Program.

Outputs

13 Outputs

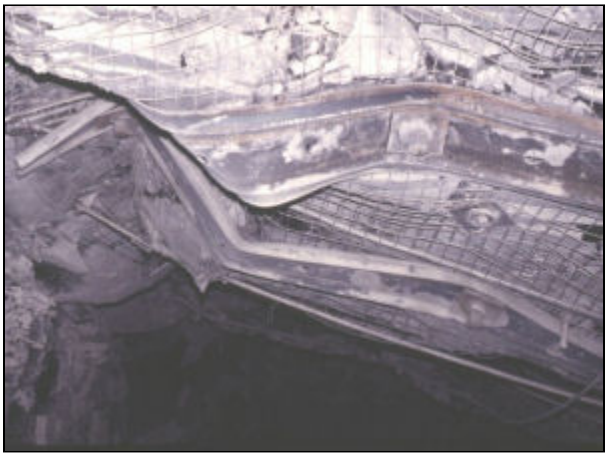
Title	Year	Output Type	Strategic Goal
Application of the Coal Mine Roof Rating (CMRR) to Extended Cuts Mark-C | Min Eng 51(4); :52-56	1999	Publication	Ground control
Comparison of Ground Conditions and Ground Control Practices in the United States and Australia Marc-C | Min Eng 51(4):52-56	1998	Publication	Ground control
Geologic Hazards and Roof Stability in Coal Mines Molinda-GM | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2003-152, IC 9466; 1-33	2003	Publication	Ground control
Ground Control in South African Coal Mines: A U.S. Perspective Mark-C | In: Proceedings of the 18th International Conference on Ground Control in Mining, Peng SS, Mark C, eds., Morgantown, WV: West Virginia University, 1999; :186-193	1999	Publication	Ground control
New Coal Mine Roof Rating (CMRR) Improves Safety in U.S. Underground Mines Molinda-GM; Mark-C | In: Proceedings of the 27th International Conference of Safety in Mines Research Institutes, Dhar BB, Bhowmick BC, eds., Vol. 2. New Delhi, India: Oxford & IBH Publishing Co. Pvt. Ltd., 1997; :1001-1011	1997	Publication	Ground control
New Developments with the Coal Mine Roof Rating Mark-C; Molinda-GM; Barton-TM | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 21st International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2002 Aug; :294-301	2002	Publication	Ground control
Spatial Trends in Rock Strength - Can They Be Determined From Coreholes? Mark-C; McWilliams-LJ; Pappas-DM; Rusnak-JA | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, pp. 177-182	2004	Publication	Ground control
Standardization of Geological and Geomechanical Assessment at Underground Coal Mines in Canada Forgeron-S; Mark-C; Forrester-DJ | CIM Bulletin 2001 Jul; :83-90	2001	Publication	Ground control
Technology News 505 - NIOSH Releases New Coal Mine Roof Rating Software NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 505, April 2003; :1-2	2003	Publication	Ground control
The Coal Mine Roof Rating in Mining Engineering Practice Mark-C; Molinda-GM | In: Aziz N, Kininmonth B, eds. Proceedings of the Fourth Underground Coal Operators' Conference. Carlton, Australia: Australian Institute of Mining and Metallurgy	2003	Publication	Ground control
Using the Coal Mine Roof Rating (CMRR) to Assess Roof Stability in U.S. Coal Mines Molinda-GM; Mark-C; Debasis-D | Journal of Mines, Metals, and Fuels (India) Aug-Sep 2001; :314-321	2001	Publication	Ground control
Using the Point Load Test to Determine the Uniaxial Compressive Strength of Coal Measure Rock Rusnak J; Mark C | In: Peng SS, Mark C, eds. Proceedings of the 19th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, pp. 362-371	2000	Publication	Ground control
Coal Mine Roof Rating (CMRR) NIOSH | NIOSH 2004 Dec; :Software	2004	Software	Ground control

Intermediate Outcome related to Reducing Fatalities and Injuries Due to Ground Failures

Control of Horizontal Stress in Mining to Reduce Injuries and Fatalities

Description of Problem

Horizontal stresses have contributed to thousands of ground falls in underground mines throughout the Eastern United States. Fifteen years ago, however, the very existence of horizontal stress was questioned by many within the mining community. NIOSH research proved that horizontal stresses are directly linked to plate tectonics and continental drift and that they are the most significant ground stress (exceeding the gravity load) in most underground mines.



Horizontal cutter roof created by high horizontal mine stresses

Research and Development Activities

NIOSH has built upon its fundamental scientific breakthrough to develop a variety of stress control technologies. For coal mines, NIOSH products include:

- Guidelines for mine layout to minimize stress (1994)
- Methods for orientating and sequencing of longwall panels to prevent extreme headgate stress concentrations (1997)
- An innovative advance-and-relieve mine design for pillar recovery (1999)
- Analysis of Horizontal Stress in Mines (AHSEM), a computer program that aids mine planners in designing safer mines (2001)

NIOSH research has also aided underground stone mines that suffer from horizontal stress. NIOSH has measured horizontal stress levels that were as great as 10 times gravity overburden loads in stiff limestone roof. NIOSH also developed a novel stress control mine design that has greatly reduced the number of roof falls at several underground limestone mines.

R&D Outputs and Transfer Activities

All of these technologies have been transferred to the mining community through an aggressive program of publications, workshops, and open industry briefings:

- An Information Circular (IC) entitled "New Technology for Longwall Ground Control" and associated open industry briefings in several U.S. coalfields (1994)
- A seminal paper, published in Mining Engineering magazine, describing horizontal stress concentrations in longwall headgates and methods to prevent them

- Presentations at NIOSH's annual Safety Seminar for Underground Stone Mines
- A series of hands-on computer training workshops on the AHSEM program
- Numerous presentations at conferences, open industry briefings, company ground control short courses, Preventative Roof-Rib Outreach Program (PROP) seminars, and other venues

Description of Intermediate Outcome

Proper orientation and sequencing has largely eliminated the major headgate failures that were quite common in longwall mines before 1998. Thanks in large part to the educational effort undertaken by NIOSH, today's mine planners understand horizontal stress and consider it during mine layout. The NIOSH-developed control technologies are used widely throughout the mining community and are often referenced.

Outputs

15 Outputs

Title	Year	Output Type	Strategic Goal
Advance and Relieve Mining: A Method to Mitigate the Effects of High Horizontal Stress on the Mine Roof Dolinar-DR; Mucho-TP; Oyler-DC; Pablic-J | SME, Inc., Preprint 01-113, SME Annual Meeting, Denver, Colorado - February 26-28, 2001; :1-12	2001	Publication	Ground control
Controlling Roof Beam Failures From High Horizontal Stresses in Underground Stone Mines Iannacchione-AT; Dolinar-DR; Prosser-LJ; Marshall-TE; Oyler-DC; Compton-CS | In: Proceedings of the 17th International Conference on Ground Control in Mining, Peng SS, ed., Morgantown, WV: University of West Virginia, 1998 Aug 4-6, 1998 Aug; :102-112.	1998	Publication	Ground control
Controlling Roof Beam Failures From High Horizontal Stresses in Underground Stone Mines Iannacchione AT, Dolinar DR, Prosser LJ Jr., Marshall TE, Oyler DC, Compton CS | In: Aziz NI, Indraratna B, eds. Proceedings of the International Conference on Geomechanics/Ground Control in Mining and Underground Construction, Wollongong, New South Wales, Australia: University of Wollongong, Vol. 2, 1998; :525-541	1998	Publication	Ground control
Development and Use of a High-pressure Packer for Measuring Horizontal Stress Using the Hydraulic Fracturing Method Oyler-DC | In: Elsworth D, Tinucci JP, Heasley KA, eds. Rock Mechanics in the National Interest. Vol. I. Lisse, Netherlands: Swets & Zeitlinger; :227-234	2001	Publication	Ground control
Development of a Fiber Optic Stress Sensor Heasley-KA; Dubaniewicz-TH Jr.; DiMartino-MD | In: Proceedings of the 36th U.S. Rock Mechanics Symposium, Hudson JA, ed., New York, NY: Columbia University, Paper No. 066, 1997	1997	Publication	Ground control
Focus on Ground Control: Horizontal Stress Mark-C | Coal Age 106(3):47-51	2001	Publication	Ground control
High Stress Mining Under Shallow Overburden in Underground U.S. Stone Mines Iannacchione-AT; Dolinar-DR; Mucho-TP | In: Proceedings of the First International Seminar on Deep and High-Stress Mining. Nedlands, Australia: Australian Centre for Geomechanics, section 32, 2002 Nov; :1-11	2002	Publication	Ground control
Horizontal Stress And Longwall Headgate Ground Control Mark-C; Mucho-TP; Dolinar-D | SME preprint 97-187, 1997	1997	Publication	Ground control
Horizontal Stress and Longwall Headgate Ground Control Mark-C; Mucho-TP; Dolinar-D | Min Eng 1998 Jan :61-68	1998	Publication	Ground control
Rock Mechanics Study of Lateral Destressing for the Advance-and-Relieve Mining Method Maleki-H; Dolinar-DR; Dubbert-J | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 22nd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University; :105-113	2003	Publication	Ground control
Safer Mine Layouts for Underground Stone Mines Subjected to Excessive Levels of Horizontal Stress Iannacchione-AT; Marshall-TE; Burke-L; Melville-R; Litsenberger-J | Mining Engineering, 55(4), 2003 Apr; :25-31	2003	Publication	Ground control

Title	Year	Output Type	Strategic Goal
The Advance-and-Relieve Mining Method: a Horizontal Stress Control Technique Chase-FE; Mark-C; Mucho-TP; Campbell-PL | In: Proceedings of the 18th International Conference on Ground Control in Mining, Peng SS, Mark C, eds., SMorgantown, WV: West Virginia University, 1999; :300-308	1999	Publication	Ground control
Utilizing the 'Advance and Relieve' Method to Reduce Horizontal Stress Affects on the Mine Roof, A Case Study Dolinar-DR; Mucho-TP; Oyler-DC; Pablic-J | In: Proceedings of the 19th International Conference on Ground Control in Mining, Peng SS, Mark C, eds., Morgantown, WV: West Virginia University, 2000 Jan; :137-148	2000	Publication	Ground control
Variation of Horizontal Stresses and Strains in Mines in Bedded Deposits in the Eastern and Midwestern United States Dolinar-DR | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 22nd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University; :178-185	2003	Publication	Ground control
Analysis of Horizontal Stress Effects in Mining (AHSM) NIOSH | NIOSH, 2004 Sep, :software	2004	Software	Ground control

Intermediate Outcome related to Reducing Fatalities and Injuries Due to Ground Failures

Design Guidelines for Safe Highwall Mining Systems

Description of Problem

The use of highwall mining systems has increased substantially in open-pit coal mines where overburden depth exceeds economical recovery. Highwall stability is a major concern during highwall mining. The Mine Safety and Health Administration requires highwall miner operators to follow ground control plans that specify the web and barrier pillar sizes necessary to prevent a pillar collapse that would threaten highwall stability. Other safety concerns arise when a highwall miner is trapped underground and it becomes necessary to tunnel in to retrieve it.

Highwall mining system extracting a 13 ft thick seam in Wyoming

Research and Development Activities

NIOSH has developed a number of design tools that are relevant to improving ground control during highwall mining operations. The Analysis of Retreat Mining Pillar Stability (ARMPS) computer program is considered particularly useful. It uses the Mark-Bieniawski formula to estimate the strength of long strip pillars. The NIOSH guidelines for preventing massive pillar collapses and the Coal Mine Roof Rating (CMRR) are also applicable to highwall mining. Most recently, NIOSH has developed simple design charts for selecting web and barrier pillar widths, together with guidelines for highwall mining in areas containing old auger holes or two seams in close proximity.

R&D Outputs and Transfer Activities

NIOSH has transferred the ARMPS program to the general mining community through open industry briefings, publications, and computer training workshops. A short course specifically devoted to highwall mining ground control was held for Massey Energy, the largest single user of highwall mining equipment, in 2004. A series of three professional papers on the topic was recently published. Perhaps most importantly, over the past decade, NIOSH ground control experts have responded to more than 50 requests for information about using ARMPS and other NIOSH products to develop safe highwall mining designs.

Description of Intermediate Outcome

A recent survey showed that several MSHA-approved ground control plans for highwall mining specifically mention the ARMPS program. In fact, as evidenced through discussions and training sessions held at open industry briefings, Massey Energy, Fola Coal, and several leading highwall mining consultants routinely use ARMPS or the new design charts for their highwall mining designs.

Outputs

4 Outputs

Title	Year	Output Type	Strategic Goal
Analysis of Practical Ground Control Issues in Highwall Mining Zipf Jr-RK; Bhatt-SK | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining. Morgantown, WV, August 3-5, 2004: West Virginia University, 2004 Aug; :210-219	2004	Publication	Ground control
Ground Control Design for Highwall Mining Zipf-RK | 2005 SME Annual Meeting, February 28 - March 2, Salt Lake City, Utah, SME preprint 05-82. Littleton, CO, Society for Mining, Metallurgy, and Exploration, Inc., 2005 Feb; :1-7	2005	Publication	Ground control
Analysis of Retreat Mining Pillar Stability (ARMPS) NIOSH | NIOSH, 2003 Aug, :software	2003	Software	Ground control
Coal Mine Roof Rating (CMRR) NIOSH | NIOSH 2004 Dec; :Software	2004	Software	Ground control

Intermediate Outcome related to Reducing Fatalities and Injuries Due to Ground Failures

Guidelines for Coal Pillar Recovery

Description of Problem

When coal is first mined, large pillars of coal are left to support the rock between the mine and the surface. When these pillars are later recovered, the ground collapses. Nationally, coal pillar recovery accounts for just 10% of coal mined underground, but it is associated with more than 30% of mine roof fall fatalities.

Retreat mining pillar line roof fall fatality site, Mingo County, West Virginia

Research and Development Activities

NIOSH has been conducting research to reduce the ground fall hazard during coal pillar recovery since the early 1990s. Significant research products include:

- The Analysis of Retreat Mining Pillar Stability (ARMPS) computer program (1994-1997)
- Advocacy of the use of mobile roof supports for temporary roof support (1994-present)
- Guidelines for coal pillar and panel design to prevent massive pillar collapses (1993-1997)
- Guidelines for panel and barrier pillars for pillar recovery under deep cover (2002)
- Guidelines for sizing the final stump to prevent unplanned roof collapse (2001)
- Guidelines for cut sequencing and roof bolting, and identification of other risk factors for pillar recovery, such as old works, multiple-seam mining, and wide roof spans (2002)

R&D Outputs and Transfer Activities

NIOSH has transferred these results through:

- Distribution of more than 1,000 copies of the ARMPS computer program
- A NIOSH Information Circular entitled "New Technology for Ground Control in Retreat Mining." This publication was used in conjunction with an open industry briefing held throughout the U.S. coalfields and attended by more than 300
- Industry short courses for Arch Coal, Massey Energy, and Peabody Energy (100 attendees)
- Joint MSHA-NIOSH Preventative Roof-Rib Outreach Program (PROP) seminars held in MSHA districts and attended by at least 500
- Numerous conference papers and presentations

Description of Intermediate Outcome

Following a series of meetings with MSHA District 4, the West Virginia Office of Miners' Safety, Health, and Training, and the West Virginia Board of Coal Mine Health and Safety, many of the guidelines included in the checklist were incorporated into the roof control plans of nearly 100 mines in southern West Virginia. Others have been implemented in the mining plans of several large mining companies (for example, Massey Energy does not extract the pushout, or remnant pillar). In the 3 years since the guidelines were implemented in District 4, there has been just one fatality associated with coal pillar recovery. This compares with an average of one per year during the prior 5 years. The research has also contributed to significant changes in the way pillar recovery is practiced throughout the United States. Today, more than one-half of all pillars are recovered using mobile roof supports. Fewer and fewer roof control plans allow extraction of the final stump. Mine operators, MSHA, and state regulators are more aware of the risk factors and often specify extra support in pillar recovery sections. Although it is still early to be certain, there is every reason to believe that the national fatality rate for coal pillar recovery will decrease in the future.

Outputs

10 Outputs

Title	Year	Output Type	Strategic Goal
A Statistical Overview of Retreat Mining of Coal Pillars in the United States Mark-C; McCall-FE; Pappas-DM | In: Peng SS, ed., Proceedings of the 16th International Conference on Ground Control in Mining, Morgantown, WV: West Virginia University; 204-210	1997	Publication	Ground control; Surveillance and training
Deep Cover Pillar Extraction in the U.S. Coalfields Chase-FE; Mark-C; Heasley-KA | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 21st International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2002 Aug; :68-80	2002	Publication	Ground control
Evaluation of Pillar Recovery in Southern West Virginia Mark-C; Karabin-G; Zelanko-JC; Hoch-MT; Chase-F | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 21st International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2002 Aug; : 81-89	2002	Publication	Ground control
Full-scale Performance Evaluation of Mobile Roof Supports Barczak-TM; Gearhart-DF | In: Proceedings of the 16th International Conference on Ground Control in Mining, Peng SS, ed., Morgantown, WV: West Virginia University, 1997; :211-220	1997	Publication	Ground control
Proceedings: New Technology for Ground Control in Retreat Mining Mark-C; Tuchman-RJ | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 97-122, IC 9446, 1997 Mar: :1-129	1997	Publication	Ground control
Reducing the Risk of Ground Falls During Pillar Recovery Mark-C; Chase-FE; Pappas-DM | In: Yernberg WR, ed. Transactions of Society for Mining, Metallurgy, and Explorations, Inc., Vol. 314. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2003; :153-160	2003	Publication	Ground control
Retreat Mining Pillar Stability Mark-C | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin, 1998 Nov; :15	1998	Publication	Ground control
Sizing of Final Stumps for Safer Pillar Extraction Mark-C; Zelanko-JC | In: Peng SS, Mark C, Khair AW, eds. Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2001 Aug; :59-66	2001	Publication	Ground control
Technology News 464 - Analysis of Retreat Mining Pillar Stability (ARMPS): Version 4.0 for Windows NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 464, 1997 Jul; :1-2	1997	Publication	Ground control
Analysis of Retreat Mining Pillar Stability (ARMPS) NIOSH | NIOSH, 2003 Aug, :software	2003	Software	Ground control

Intermediate Outcome related to Reducing Fatalities and Injuries Due to Ground Failures

Mitigating Ground Fall Hazards in Underground Stone Mines

Description of Problem

During 1986-1995, more than 20% of the fatalities in the U.S. stone mining industry occurred at underground operations. Large number deaths occurred during 1992-1993 when 14 stone industry fatalities occurred, of which 10 were in underground mines. Ground control problems were targeted for research because 8 of those 10 deaths were attributed to roof and rib falls. In the early 1990s, most stone mines were much smaller and lacked even the most basic levels of ground control.

NIOSH researchers collecting rock stability data in a limestone mine

Research and Development Activities

Before 1994, only the Mine Safety and Health Administration and the National Stone, Sand & Gravel Association focused on safety issues in stone mines. Most of their activities were geared toward surface quarries. However, over the last 10 years, NIOSH initiated a program to raise the awareness and application of sound ground control practices for underground stone mines. Three methods were used to achieve this goal: (1) increase the use of roof monitoring technology to warn of roof falls, (2) promote safe mine design layouts, and (3) transfer this knowledge, along with other common techniques, to control the ground through annual seminars and one-on-one interactions at the mine sites. The broadest measure of NIOSH's impact in lowering ground fall fatalities and injuries is the documented exposure (estimated 70%) to operators and miners working in the underground stone sector since 1999.

Description of Intermediate Outcome

Following a rash of ground fall injuries in the early 1990s, NIOSH became active in promoting sound engineering safety practices in the underground stone industry. NIOSH researchers observed that this industry was not using the most advanced monitoring and design technology to control its fall-of-ground problems as practiced in other underground mining sectors. To this end, roof fall forecasting techniques were promoted and improved upon, producing more monitoring activities at mine sites than in past years. In addition, innovative mine layout designs were researched and implemented at several underground mine sites. These new designs have resulted in safer engineered mine layouts with less hazardous ground conditions. Finally, an extensive technology transfer program was initiated that included the annual Safety Seminar for Underground Stone Mines, mine site visits, and technical publications. All of these promote the safest practices and procedures for controlling hazardous ground conditions.

Outputs

31 Outputs

Title	Year	Output Type	Strategic Goal
100 Years of Improvement in Aggregate Worker Safety Iannacchione-A; Mucho-T | Stone, Sand and Gravel Review 2003 Mar; :28-34	2003	Publication	Surveillance and training
An Examination of the Loyalhanna Limestone's Structural Features and their Impact on Mining and Ground Control Practices Iannacchione-AT; Coyle-PA | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 21st International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2002 Aug; :218-227	2002	Publication	Ground control
An Overview of Groundfall Injuries and Worker Activity in Underground Stone Mines Pappas-DM; Prosser-LJ Jr | MSHA Holmes Safety Association Bulletin, 2001 Aug:8-14	2001	Publication	Ground control
Analysis of Pillar Design Practices and Techniques for U.S. Limestone Mines Iannacchione-AT | In Trans Inst Min Metall, (Sec A: Mining Industry), 1999 Dec 108(Sept-Dec):A152-A160	1999	Publication	Ground control
Application of Ground Penetrating Radar to Assess Ground Control Problems in Two Underground Limestone Mines Trevits-MA; Monaghan-WD; Mucho-TP | In: Proceedings of the Symposium on the Application of Geophysics to Environmental and Engineering Problems (SAGEEP 2004). Denver, CO: Environmental and Engineering Geophysical Society 2004; :788-805	2004	Publication	Ground control
Behavior of a Limestone Roof Supported by Spot Bolting Dolinar-DR; Mucho-TP | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin 1999 Mar; :19	1999	Publication	Ground control
Considerations for Using Roof Monitors in Underground Limestone Mines in the USA Prosser-LJ; Marshall-TE; Tadolini-SC; Iannacchione-AT; Banta-C | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 22nd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2003 Aug; :119-126	2003	Publication	Ground control
Controlling Roof Beam Failures From High Horizontal Stresses in Underground Stone Mines Iannacchione AT, Dolinar DR, Prosser LJ Jr., Marshall TE, Oyler DC, Compton CS | In: Aziz NI, Indraratna B, eds. Proceedings of the International Conference on Geomechanics/Ground Control in Mining and Underground Construction, Wollongong, New South Wales, Australia: University of Wollongong, Vol. 2, 1998; :525-541	1998	Publication	Ground control
Controlling Roof Beam Failures From High Horizontal Stresses in Underground Stone Mines Iannacchione-AT; Dolinar-DR; Prosser-LJ; Marshall-TE; Oyler-DC; Compton-CS | In: Proceedings of the 17th International Conference on Ground Control in Mining, Peng SS, ed., Morgantown, WV: University of West Virginia, 1998 Aug 4-6, 1998 Aug; :102-112.	1998	Publication	Ground control
Failure Characteristics of Roof Falls at an Underground Stone Mine in Southwestern Pennsylvania Iannacchione-AT; Marshall-TE; Prosser-LJ, Jr | In: Peng SS, Mark C, Khair AW, eds. Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2001 Aug; :119-125	2001	Publication	Ground control
High Stress Mining Under Shallow Overburden in Underground U.S. Stone Mines Iannacchione-AT; Dolinar-DR; Mucho-TP | In: Proceedings of the First International Seminar on Deep and High-Stress Mining. Nedlands, Australia: Australian Centre for Geomechanics, section 32, 2002 Nov; :1-11	2002	Publication	Ground control

Title	Year	Output Type	Strategic Goal
Investigation of Pillar-Roof Contact Failure in Northern Appalachian Stone Mine Workings Esterhuizen-GS; Iannacchione-AT | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2004 Aug; :320-326	2004	Publication	Ground control
Mapping Hazards with Microseismic Technology to Anticipate Roof Falls - A Case Study Iannacchione-AT; Batchler-T; Marshall-TE | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University,2004 Aug; pp. 327-333	2004	Publication	Ground control
Pillar Design Issues for Underground Stone Mines Iannacchione-AT | In: Proceedings of the 18th International Conference on Ground Control in Mining, Peng SS, Mark C, eds.,Morgantown, WV: West Virginia University, 1999 Jan; :271-281	1999	Publication	Ground control
Preventing Injuries Caused by Unrecognized Stone Mine Roof Beam Failures With a Pro-Active Roof Control Plan Iannacchione-AT; Prosser-LJ; Grau-R; Oyler-DC; Dolinar-DR; Marshall-TE; Compton-CS | SME Preprint 99-87. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc. 1999 :1-10	1999	Publication	Ground control
Relationship of Roof Movement and Strata-induced Microseismic Emissions to Roof Falls Iannacchione-AT; Coyle-PR; Prosser-LJ Jr; Marshall-TE, Litsenberger-J | Min Eng 56(12):53-60	2004	Publication	Ground control
Remote Roof Stability Monitoring for Underground Nonmetal Mines Grau-RH III; Iannacchione-AT; Prosser-LJ Jr | In: Proceedings of the 1999 Structures Congress. Reston, VA: American Society of Civil Engineers,1999; :727-730	1999	Publication	Ground control
Roof and Rib Hazard Assessment for Underground Stone Mines Iannacchione-AT; Prosser-LJ Jr. | Mining Eng 50(2), 1998; :76-80	1998	Publication	Ground control
Roof and Rib Hazard Assessment for Underground Stone Mines Iannacchione-AT; Prosser-LJ Jr | SME preprint 97-113, 1997	1997	Publication	Ground control
Roof Monitoring Helps Prevent Injuries in Stone Mines Iannacchione-AT; Prosser-LJ Jr; Grau-RH III; Oyler-DC; Dolinar-DR; Marshall-TE; Compton-C | Min Eng 2000 Nov; 52(11):32-37	2000	Publication	Ground control
Roof Monitoring in Limestone - Experience with the Roof Monitoring Safety System (RMSS) Marshall-TE; Prosser-LJ Jr.; Iannacchione-AT; Dunn-M | In: Proceedings of the 19th International Conference on Ground Control in Mining, Peng SS, Mark C, eds., Morgantown, WV: West Virginia University, 2000 Jan; :185-191	2000	Publication	Ground control
Safer Mine Layouts for Underground Stone Mines Subjected to Excessive Levels of Horizontal Stress Iannacchione-AT; Marshall-TE; Burke-L; Melville-R; Litsenberger-J | Mining Engineering, 55(4), 2003 Apr; :25-31	2003	Publication	Ground control
Scaling Accidents in Underground Stone Mines Grau-RH III; Prosser-LJ Jr | Rock Products 100(1), 1997 Jan; 39-41	1997	Publication	Ground control
Stability of Underground Openings Adjacent to the Sink Hole at the NIOSH Lake Lynn Research Laboratory Dolinar-DR; Marshall-TE; Barczak-TM; Mucho-TP | 2003 SME Annual Meeting, Feb 24-26, Cincinnati, Ohio, preprint 03-154. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2003 Feb; :1-7	2003	Publication	Ground control

Title	Year	Output Type	Strategic Goal
Technology News 455 - Roof Hazard Alert Modules NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 455, 1997 May; :1-2	1997	Publication	Ground control
Technology News 471 - Innovative Hazard Recognition Training for Underground Limestone Miners NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 471, 1998 May; :1-2	1998	Publication	Ground control; Surveillance and training
Technology News 475 - Roof Monitoring Safety System for Underground Stone Mines NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 475, 1998; :1-2	1998	Publication	Ground control
Technology News 481 - Update: Roof Monitoring Safety System for Underground Stone Mines NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 481, 2000 Jun; :1-2	2000	Publication	Ground control
The Long-term Performance of Surface Support Liners for Ground Control in an Underground Limestone Mine Pappas-DM; Barton-TM; Weiss-ES | In: Hadjigeorgiou J, ed. Proceedings of the Third International Seminar on Surface Support Liners: Thin Spray-On Liners, Shotcrete, and Mesh (Quebec City, Canada, August 25-26, 2003). Section 10, 2003 Aug; :1-22	2003	Publication	Ground control
The Relationship of Roof Movement and Strata-Induced Microseismic Emissions to Roof Falls Iannacchione-AT; Coyle-PR; Prosser-LJ; Marshall-TE; Litsenberger-J | 2004 SME Annual Meeting, Feb 23-25, Denver, Colorado, preprint 04-58. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2004 Feb; :1-9	2004	Publication	Ground control
Workplace Solutions: Ground Fall Injuries in Underground Stone Mines NIOSH | Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2004-106, 2003 Nov; :1-4	2003	Publication	Ground control

Intermediate Outcome related to Reducing Fatalities and Injuries Due to Ground Failures

Mobile Roof Supports for Retreat Room-and-Pillar Mines

Description of Problem

Mobile roof support equipped with a load rate monitor

Historically, one of the most common mining methods used to extract coal from underground mines has been room-and-pillar mining in which a series of pillars is developed as a section is advanced and extracted on retreat. Although longwall mining has overtaken room-and-pillar mining in popularity, pillar recovery still accounts for about 10% of U.S. underground coal mining. In the past, pillar recovery has been associated with a disproportionate rate of roof fall fatalities. During 1980-1997, nearly 25% of all roof fall fatalities occurred on pillar sections. The main danger is premature caving of the roof at the face where mining crews are working to install wood posts as they extract the coal pillars.

Research and Development Activities

Research by NIOSH engineers in the 1980s resulted in the development of mobile roof supports (MRS). These remotely controlled, hydraulically operated systems support the mine roof during pillar extraction and replace the use of wooden posts. The successful demonstration of MRS technology led to their commercialization by the mining manufacturer, J. H. Fletcher and Co. However, the MRS did not provide critical feedback to workers of impending ground failure as do the wood posts, which begin cracking and "popping" under load. The Mine Safety and Health Administration asked that guidelines be developed for safe use of the MRS and that a warning system be developed to alert miners to impending roof caving. NIOSH developed and field tested a warning system for the MRS that would alert miners to unstable roof and pillar conditions during pillar mining. It provides a visual indication of current loading, as well as changes in loading on the MRS. An increase in load rate tells miners that the pillars are yielding and failing, and the loads that were once carried by the pillars are transferred to the MRS. This condition often triggers failure of the mine roof.

R&D Outputs and Transfer Activities

During 1997-2002, the results of this research, which includes both hardware and computer logic for MRS warning systems and guidelines for safe MRS use, were transferred to the mining industry through 7 technical papers and 12 presentations. This research was also presented at five MSHA/NIOSH-sponsored seminars.

Description of Intermediate Outcome

The use of MRSs in U.S. retreat mines has grown dramatically in recent years. In 1988, four MRSs were in use. The number has grown to about 270 currently in operation at 34 U.S. coal mines. However, six fatalities have occurred where MRSs were being used. In four of these fatalities, the miners were standing in the active intersection (an unsafe location) as the last lift was being mined or after it had been completed. The successful demonstration of the load-warning system resulted in the incorporation of this system into the design of the Fletcher MRS.

Field studies were also done to evaluate the safety and performance of MRSs under varying geologic conditions to provide data that MSHA and the mining industry could use to improve safety in retreat operations. The studies resulted in recommendations for optimum MRS setting pressures, optimum number of MRSs in a section, location of an MRS with respect to a continuous miner, pillar extraction method, and the need to orient the retreat panel to major joint sets to optimize caving.

Outputs

8 Outputs

Title	Year	Output Type	Strategic Goal
An Overview of Geomechanics Safety Research on Mobile Roof Supports Maleki-H; Owens-J | System Safety at the Dawn of a New Millennium. Proceedings, 17th International System Safety Conference, Orlando, FL, Aug 16-21, 1999. Unionville, VA: System Safety Society, 1999 Jan; :554-563	1999	Publication	Ground control
Analysis of the Interaction Between Mobile Roof Supports and Mine Strata Maleki-H; Owens-J | Design and Construction in Mining, Petroleum and Civil Engineering, 1998, Nov :287-293	1998	Publication	Ground control
Application of Computational and Statistical Techniques to an Evaluation of Mobile Roof Supports Maleki-H; Owens-J | In: S.S. Desai, T. Kundu, S. Hatpalani, D. Contractor, and J. Kemeny, eds. Computer Methods and Advances in Geomechanics. Proceedings of the Tenth International Conference on Computer Methods and Advances in Geomechanics (Jan 7-12, 2001; Tucson, AZ), Vol. 2, 2001; :1705-1711	2001	Publication	Ground control
Field Evaluation of Mobile Roof Support Technologies Maleki-H; Owens-J; Endicott-M | Paper in Proceedings: 20th International Conference on Ground Control in Mining, ed. By Syd S. Peng, Christopher Mark, and A. Wahab Khair (Morgantown WV, Aug. 7-9, 2001). WV University, Morgantown, WV, 2001; :67-77	2001	Publication	Ground control
Method and Apparatus for Load Rate Monitoring Howie-WL; Owens-JK | U.S. Patent No. 6,957,166 (granted Oct. 18, 2005)	2005	Patent	Ground control
Mobile Roof Support Load Rate Monitoring System Howie-WL; Owens-JK | Proceedings of the IEEE Industry Applications Society (Phoenix, AZ, October 3-7, 1999). Vol. 1, :234-239	1999	Publication	Traumatic injuries
Mobile Roof Support Safety Research - An Update Owens-J; Howie-W; Maleki-H | In: Jenkins FM, Langton J, McCarter MK, and Rowe B, eds. Proceedings: Thirtieth Annual Institute on Mining Health, Safety, and Research (Salt Lake City, UT, Aug. 8-11, 1999). Blacksburg, VA: Department of Mining and Minerals Engineering, Virginia Polytechnical Institute, 2001 Aug; :101-113	2001	Publication	Ground control; Traumatic injuries
Monitoring Mobile Roof Supports Hay-KE; Signer-SP; King-ME; Owens-JK | In: Mark-C PhD, Tuchman-RJ, eds. Proceedings: New Technology for Ground Control in Retreat Mining, US Bureau of Mines, Report of Investigations 9446, 1997; :89-98	1997	Publication	Ground control; Traumatic injuries

Intermediate Outcome related to Reducing Fatalities and Injuries Due to Ground Failures

NIOSH Support Technology Optimization Program (STOP) Design Software

Description of Problem

New mine roof support products with distinct performance characteristics are developed each year. The performance characteristics and limitations of these support systems are evaluated through full-scale testing in the NIOSH mine roof simulator at the Pittsburgh Research Laboratory. This information provides the basis for which these support systems are considered for specific applications by mining companies and approved for use by the Mine Safety and Health Administration.

The NIOSH STOP software program is interactive and user driven to accomplish several support design requirements

Research and Development Activities

To facilitate the application of these technologies to improve mine safety, NIOSH developed the Support Technology Optimization Program (STOP). STOP is a Window´s-based software program that provides mine operators with a simple and practical tool to make engineering decisions about the selection and placement strategy of these various mine roof support technologies.

R&D Outputs and Transfer Activities

Training workshops on the use of the STOP software have been held in Pennsylvania, West Virginia, Virginia, Kentucky, Illinois, Indiana, Colorado, and Utah. To date, about 1,000 copies of the STOP software program have been distributed through these technology transfer seminars and from software downloads on the NIOSH webpage. The program has been used internationally in Mexico, the United Kingdom, Germany, Australia, and the Republic of South Africa.

Description of Intermediate Outcome

The performance testing of new support products in the NIOSH mine roof simulator and the implementation of this information into the STOP design software has eliminated the trial-and-error approach to new support technologies that was common in the past. This provides insurance toward successful support applications without exposing miners to uncertain, potentially hazardous support performance. STOP can provide an engineering foundation to ensure that inadequate support designs, as well as ultraconservative support applications, are avoided. Safety will be improved by matching support performance to mine conditions. This reduces the likelihood of roof falls and

blocked travel and escapeways. Material handling injuries associated with support construction account for about 5,000 lost workdays per year in U.S. underground coal mines. STOP can help define the material handling advantages of alternative support technologies that use lighter-weight materials or systems that can be installed with mechanical-assist equipment.

Outputs

11 Outputs

Title	Year	Output Type	Strategic Goal
Investigation of the Jacking Force Capability of Tunnel Liners Barczak-TM; Smith-R | 2002 SME Annual Meeting, Feb 25-27, Phoenix, Arizona, preprint 02-186. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2002 Feb; :1-13	2002	Publication	Ground control
Load and Deflection Response of Ventilation Stoppings to Longwall Abutment Loading: A Case Study Oyler-DC; Hasenfus-G; Molinda-GM | In: Peng SS, Mark C, Khair AW, eds. Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2001 Aug; :34-41	2001	Publication	Ground control
Mistakes, Misconceptions, and Key Points Regarding Secondary Roof Support Systems Barczak-TM | In: Peng SS, Mark C, Khair AW, eds. Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2001 Aug; :347-356	2001	Publication	Ground control
Numerical Modeling for Increased Understanding of the Behavior and Performance of Coal Mine Stoppings Burke-LM; Iannacchione-AT; Barczak-TM; Westman-EC | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining (August 3-5, 2004). Morgantown, WV: West Virginia University, 2004; :112-118	2004	Publication	Ground control
Optimizing Secondary Roof Support with the NIOSH Support Technology Optimization Program (STOP) Barczak-TM | In: Proceedings of the 19th International Conference on Ground Control in Mining,Peng SS, Mark C, eds., Morgantown, WV: West Virginia University, August 8-10, 2000 Aug; :74-83	2000	Publication	Ground control
Performance and Safety Considerations of Hydraulic Support Systems Barczak-TM; Gearhart-DF | In: Proceedings of the 17th International Conference on Ground Control in Mining, Peng SS, ed., Morgantown, WV: University of West Virginia, 1998 Aug; :176-186	1998	Publication	Ground control
Performance Characteristics of Wood Cribs and Alternative Roof Support Technologies Barczak-TM | NIOSH Internal Report 4944	2000	Publication	All
Pumpable Roof Supports: Developing Design Criteria by Measurement of the Ground Reaction Curve Barczak-TM; Chen-J; Bower-J | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 22nd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2003 Aug; :283-294	2003	Publication	Ground control
The Effect of Standing Support Stiffness on Primary and Secondary Bolting Systems Tadolini-SC; Barczak-TM; Zhang-Y | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 22nd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2003 Aug; pp. 300-307	2003	Publication	Ground control
Updating the NIOSH Support Technology Optimization Program (STOP) With New Support Technologies and Additional Design Features Barczak-TM | In: Peng SS, Mark C, Khair AW, eds. Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2001 Aug; :337-346	2001	Publication	Ground control

Title	Year	Output Type	Strategic Goal
Support Technology Optimization Program (STOP) NIOSH	2004	Software	Ground control

Intermediate Outcome related to Reducing Fatalities and Injuries Due to Ground Failures

Preventing Longwall Tailgate Blockages

Description of Problem

Safe longwall mining depends on maintaining ground control in the gate entries. These are the lifelines that provide access to the longwall face. When a gate entry is blocked by rock falls, miners must use their emergency escape route. At the Wilberg mine fire in Utah in 1984, 27 miners were killed from carbon monoxide poisoning that may have been exacerbated by a roof fall in the longwall tailgate entry. The tailgate entry is essential for maintaining adequate ventilation on the longwall mining face. It also serves as the secondary escapeway in the event of a mine disaster.

A brittle failure of a concrete tailgate support

Research and Development Activities

NIOSH scientists realized that maintaining safe tailgates would require an integrated approach that considered not only pillar design, but also roof rock quality and roof support. One research effort used an innovative method based on multivariate statistical analysis of a comprehensive database of mining case histories. The results of this effort were implemented in the Analysis of Longwall Pillar Stability (ALPS) computer program. A second research effort focused on fostering improved roof support technology to replace wood cribs. Numerous new support concepts were tested in the mine roof simulator (MRS) at the Pittsburgh Research Laboratory, which provided detailed information on their performance characteristics. These test results also provided the basis for the Support Technology Optimization Program (STOP) computer program.

R&D Outputs and Transfer Activities

The ALPS design guidelines, the STOP program, and the performance testing of new tailgate roof supports have been the subject of numerous open industry briefings, industry short courses, and hands-on computer training sessions. These continue to be requested on a regular basis.

Description of Intermediate Outcome

Today, nearly every U.S. longwall has replaced wood cribs with modern supports tested in the MRS and inputted into the STOP design program. More than 40 new types of tailgate supports have been commercialized in the United States. The rapid spread of this new technology can be attributed in large part to the impartial scientific credibility of the performance testing done by NIOSH. In

addition, the ALPS method, combined with support systems designed using the STOP program, has become the industry standard for longwall pillar and support design. Thousands of copies of the computer program have been requested, and the program is used routinely by U.S. longwall coal operators. The Mine Safety and Health Administration and state regulatory agencies make extensive use of ALPS and STOP. It is also part of the curriculum at mining schools, including West Virginia University, Virginia Polytechnic Institute and State University, The Pennsylvania State University, and Southern Illinois University. In addition, ALPS has received considerable attention abroad. A project under the Australian Coal Association Research Program was funded to calibrate the ALPS method for Australian conditions. The resulting Analysis of Longwall Tailgate Stability is now the standard for Australian longwall mines.

Outputs

14 Outputs

Title	Year	Output Type	Strategic Goal
Calibration of the Analysis of Longwall Pillar Stability (ALPS) Chain Pillar Design Methodology for Australian Conditions Colwell-M; Frith-RC; Mark-C | In: Proceedings of the 18th International Conference on Ground Control in Mining, Peng SS, Mark C, eds., Morgantown, WV: West Virginia University,1999; :282-290	1999	Publication	Ground control
Design Methodology for Standing Secondary Roof Support in Longwall Tailgates Mucho-TP; Barczak-TM; Dolinar-DR; Bower-J; Bryja-JJ | In: Proceedings of the 18th International Conference on Ground Control in Mining, Peng SS, Mark C, eds., Morgantown, WV: West Virginia University, 1999; :136-148	1999	Publication	Ground control
Hydraulic Prestressing Units: An Innovation in Roof Support Technology Barczak-TM; Tadolini-SC; McKelvey-P | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, August 3-5, 2004; :286-294	2004	Publication	Ground control
In the Field - Cribs Versus Cables Mucho-TP | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin, 1998 Mar; :5-6	1998	Publication	Ground control
Longwall Tailgate Support: Consideration, Design, and Experience Barczak-TM; Mucho-TP; Dolinar-D; Bower-J; Bryja-J | In: Proceedings of Longwall USA International Exhibition & Conference, 1999; :79-104	1999	Publication	Ground control
Longwall Tailgates: the Technology for Roof Support has Improved, but Optimization is Still Not There Barczak-TM | In: Proceedings of Longwall USA (Pittsburgh, PA, June 3-5, 2003), 2003 Jun; :105-130	2003	Publication	Ground control
Performance of Various Standing and Cribless Tailgate Support Configurations in a Large Eastern Coal Mine Molinda-GM; Dolinar-DR; Barczak-TM; Hustus-J | In: Proceedings of the 16th International Conference on Ground Control in Mining, Peng SS, ed., Morgantown, WV: West Virginia University, 1997; :9-15	1997	Publication	Ground control
Proceedings of the Second International Workshop on Coal Pillar Mechanics and Design Mark-C; Heasley-KA; Iannacchione-AT; Tuchman-RJ, eds. | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Pub No. 99-114, Information Circular 9448, 1999	1999	Publication	Ground control
Standing Support Alternatives in Western Longwalls Barczak-TM; Tadolini-SC | 2005 SME Annual Meeting, February 28 - March 2, Salt Lake City, Utah, preprint 05-78. Littleton, CO, Society for Mining, Metallurgy, and Exploration, Inc., 2005 Feb; :1-10	2005	Publication	Ground control
Technology News 467 - Wood Crib Performance Model NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH 1997 Nov; :1-2	1997	Publication	Ground control
Technology News 492 - Proceedings of the Second International Workshop on Coal Pillar Mechanics and Design NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 492, 2001 Aug; :1-2	2001	Publication	Ground control

Title	Year	Output Type	Strategic Goal
Analysis of Longwall Pillar Stability (ALPS) Mark-C | NIOSH, 2003 Aug, :software	2003	Software	Ground control
Coal Mine Roof Rating (CMRR) NIOSH | NIOSH 2004 Dec; :Software	2004	Software	Ground control
Support Technology Optimization Program (STOP) NIOSH	2004	Software	Ground control

Intermediate Outcome related to Reducing Fatalities and Injuries Due to Ground Failures

Preventing Massive Coal Pillar Collapses

Description of Problem

During the decade prior to 1998, massive pillar collapses occurred in 12 U.S. underground coal mines. In each incident, the resulting airblast caused major damage throughout the mine. Fortunately, there were no fatalities, although a number of miners were injured. Massive pillar collapses are a major threat to the safety of miners. In 1960, more than 400 miners were killed in a South African coal mine when the pillars collapsed. A pillar collapse in a U.S. trona mine in 1995 also caused a fatality.

Massive pillar collapses can hurl 30 pound cinder blocks over 500 feet through the mine workings and blow out ventilation stoppings

Research and Development Activities

NIOSH research focused on determining why sudden, violent collapse occurred in these cases rather than the more typical "slow squeeze" failure. The cause was linked to the unique failure mechanics of slender coal pillars in particular geologic environments. The research findings were the basis for guidelines for mine design to avoid these massive pillar collapses. The NIOSH-developed Analysis of Retreat Mining Pillar Stability (ARMPS) computer program is a key component of the guidelines. The guidelines also consider pillar width-to-height ratios, the use of barrier pillars, and panel size.

R&D Outputs and Transfer Activities

The guidelines have been transmitted to the mining community through a combination of open industry briefings, industry ground control short courses, Preventative Roof-Rib Outreach Program (PROP) seminars, and other venues. Of particular importance has been the effort to educate Mine Safety and Health Administration's (MSHA) Tech Support personnel, MSHA roof control specialists, and district personnel as to the hazards of massive pillar collapses and the preventive measures.

Description of Intermediate Outcome

MSHA has been using the NIOSH-based guidelines and preventative measures to evaluate mine roof control plans since 1998. This proactive approach has eliminated these catastrophic-type failures, as no further collapses have taken place since then.

Outputs

4 Outputs

Title	Year	Output Type	Strategic Goal
Design Methods to Control Violent Pillar Failures in Room-and-Pillar Mines Zipf-RK Jr.; Mark-C | Transactions of the Institution of Mining and Metallurgy 106(Sept-Dec), 1997; :A124-A132	1997	Publication	Ground control
Proceedings of the Second International Workshop on Coal Pillar Mechanics and Design Mark-C; Heasley-KA; Iannacchione-AT; Tuchman-RJ, eds. | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Pub No. 99-114, Information Circular 9448, 1999	1999	Publication	Ground control
Technology News 492 - Proceedings of the Second International Workshop on Coal Pillar Mechanics and Design NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 492, 2001 Aug; :1-2	2001	Publication	Ground control
Analysis of Retreat Mining Pillar Stability (ARMPS) NIOSH | NIOSH, 2003 Aug, :software	2003	Software	Ground control

Intermediate Outcome related to Reducing Fatalities and Injuries Due to Ground Failures

Reducing Rock Fall Injuries to Coal Miners

Description of Problem

Rock falls in coal mines cause serious injuries to miners nearly every working day. In recent years, about 500 injuries annually have resulted from rock falls. Often these injuries are quite serious, resulting in an average of 50 days of lost time. These injuries are not caused by major roof falls. Rather, they occur when small pieces of rock fall from between the primary roof supports (roof bolts) or around the automated temporary roof support. Small rock falls have also caused one or two fatalities in almost each of the past 5 years.

Research and Development Activities

NIOSH research has shown that most rock fall injuries can be prevented by using surface controls. These include straps, large plates, and, in particular, wire mesh (roof screen). To help increase the use of surface controls, NIOSH has conducted an intensive research/educational program aimed at:

- Making the coal mining community aware of the magnitude of the rock fall problem;
- Identifying and publicizing "best practices" for preventing rock falls through the use of surface controls; and
- Attempting to change the mining industry culture, which currently accepts a certain level of risk of rock fall injury beneath supported roof.

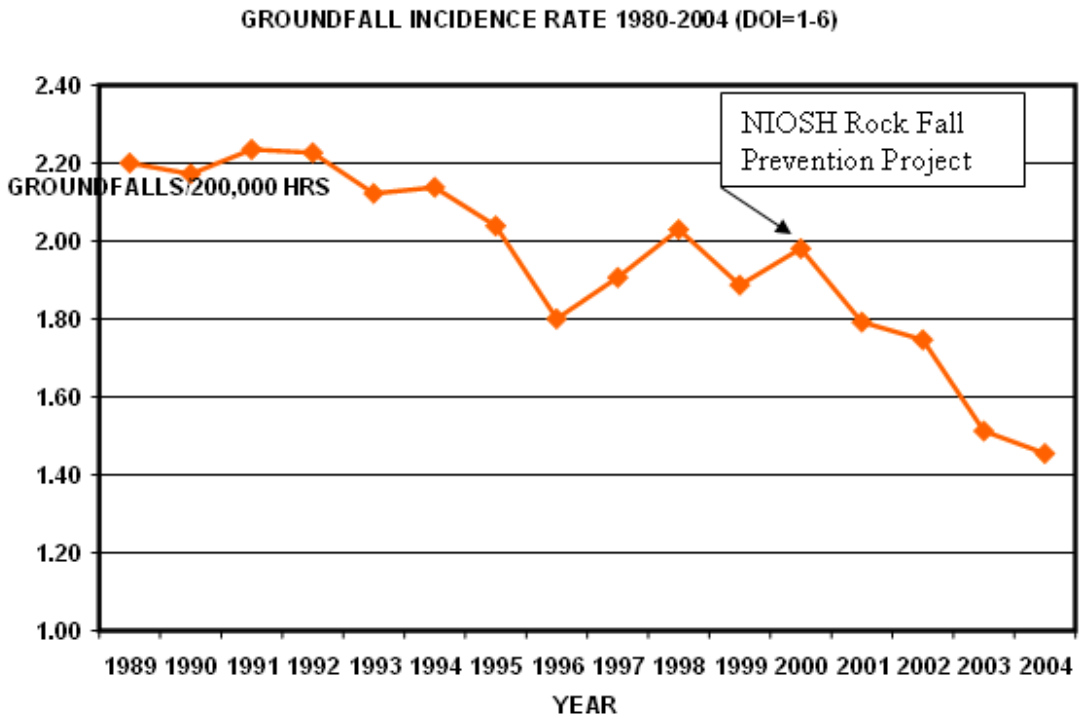
Research has included extensive analysis of rock fall injury data, in-mine studies of the effectiveness of different surface control techniques, and evaluations of the geologic conditions associated with rock falls. In addition, a new surface control called the personal bolter screen (PBS) was developed for thinner seams and other situations where traditional full screen might not be appropriate.

R&D Outputs and Transfer Activities

The educational effort began with a series of technical papers presented at a broad range of ground control, mining engineering, and mine safety audiences. Numerous visits were made to mines that were at particularly high risk for rock falls. An ongoing partnership with the Mine Safety and Health Administration, exemplified by NIOSH's co-sponsorship of the Preventative Roof/Rib Outreach Program (PROP) effort, has provided another crucial vehicle for information transfer. Most recently, a 7-minute video entitled Make It Safer With Roof Screen was developed. It has been very well received, with more than 200 copies requested in the United States. The PBS has been made commercially available by two major roof support manufacturers.

Description of Intermediate Outcome

Prior to 2000, when NIOSH initiated its rock fall prevention initiative, the rock fall injury rate in U.S. underground coal mines had held relatively steady for at least 6 years. It has now fallen in each of last 4 years to a level about 25% below its former plateau. The improvement can be attributed in part to an increased awareness of the rock fall problem and an increased use of surface control systems. NIOSH believes that further major improvements in the rock fall injury rate can still be obtained because the use of screen and of the PBS has not yet increased to its fullest potential.



Outputs

16 Outputs

Title	Year	Output Type	Strategic Goal
Application of Ground Penetrating Radar to Evaluate the Extent of Polyurethane Grout Infiltration for Mine Roof Control: A Case Study Monaghan-WD; Trevits-MA | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University; :197-204	2004	Publication	Ground control
Best Practices and Bolting Machine Innovations for Roof Screening Robertson-SB; Molinda-GM; Dolinar-DR; Pappas-DM; Hinshaw-GE | 2003 SME Annual Meeting, Feb 24-26, Cincinnati, Ohio, preprint 03-158. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.; :1-8	2003	Publication	Ground control
Best Practices to Mitigate Injuries and Fatalities from Rock Falls Mark-C; Iannoacchione-AT | In: Proceedings of the 31st Annual Institute of Mining Health, Safety and Research, Bockosh GR, Karmis M, Langton J, McCarter MK, Rowe B, eds., Blacksburg, VA: Virginia Polytechnic Institute and State University, Department of Mining and Minerals Engineering, 2000; :115-130	2000	Publication	Ground control
Covering the Roof Reduces Crippling Injuries Underground Molinda-GM; Robertson-SB; Mark-C; Dolinar-DR | Coal Age 108(11-12), 2003; :20-22, 26	2003	Publication	Ground control
Deep-cut Ground Control and Worker Safety in Coal Mines Bauer-ER; Bise-CJ | SME preprint 99-109. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 1999	1999	Publication	Ground control
Developments in Sealant Support Systems for Ground Control Pappas-DM; Barton-TM; Weiss-ES | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 21st International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2002 Aug; :344-353	2002	Publication	Ground control
Enhanced Surface Control for Roof and Rib Support Tadolini-SC; Dolinar-DR | In: Peng SS, Mark C, Khair AW, eds. Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2001 Aug; :173-179	2001	Publication	Ground control
Evaluation of Polyurethane Injection for Beltway Roof Stabilization in a West Virginia Coal Mine Molinda-GM | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining, August 3-5, 2004. Morgantown, WV: West Virginia University, 2004 Aug; :190-196	2004	Publication	Ground control
Factors Influencing Intersection Stability in U.S. Coal Mines Molinda-G; Mark-C; Bauer-E; Babich-D; Pappas-D | In: Proceedings of the 17th International Conference on Ground Control in Mining, Peng SS, ed., Morgantown, WV: University of West Virginia, 1998 Aug; pp. 267-275	1998	Publication	Ground control
Proceedings: New Technology for Coal Mine Roof Support Mark-C; Dolinar-DR; Tuchman-RJ; Barczak-TM; Signer-SP; Wopat-PF, eds. | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2000-151, IC 9453; :1-280	2000	Publication	Ground control
Roof Screening: Best Practices and Roof Bolting Machines Robertson-SB; Hinshaw-GE | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 21st International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2002; :189-194	2002	Publication	Ground control

Title	Year	Output Type	Strategic Goal
Safety Improvements for Roof Bolter Operators Robertson-SB; Cooper-DP; Wiehagen-WJ | In: Proceedings of the American Society of Safety Engineers Professional Development Conference (Las Vegas, NV, June 7-10, 2004). Des Plaines, IL American Society of Safety Engineers, 2004 Jun; :1-17	2004	Publication	Ground control
Skin Failure of Roof and Rib in Underground Coal Mines Bauer-ER; Pappas-DM; Dolinar-DR; McCall-FE; Babich-DR | In: Peng SS, Mark C, eds. Proceedings of the 18th International Conference on Ground Control in Mining, Morgantown, WV: West Virginia University, 1999; :108-114	1999	Publication	Ground control
Technology News 493 - Proceedings: New Technology for Coal Mine Roof Support NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 493, 2001 Aug :1-2	2001	Publication	Ground control
Technology News 508 - NIOSH Releases New Safety Video: Make It Safer With Roof Screen NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 508, 2005 Mar; :1-2	2005	Publication	Ground control
Make it Safer with Roof Screen NIOSH | NIOSH 2004 Jan; :Video (RealMedia format)	2004	Video	All

Intermediate Outcome related to Reducing Fatalities and Injuries Due to Ground Failures

Rock Burst Control in Deep Metal Mines

Description of Problem

Mines in the Coeur d'Alene Mining District have a fatality rate eight times greater than the mining industry average for all causes of death. Ore from the platinum mines in Montana is being extracted from greater depths, and conditions that favor rock bursts are being encountered. Currently, five underground hard-rock mines in the United States have geologic and mining conditions that could generate rock bursts. In 2003, these mines employed 2,205 (19%) of the 11,549 operators and contract workers in underground metal/nonmetal mining.

Research and Development Activities

The NIOSH mining program is continuing research that began under the U.S. Bureau of Mines to monitor, study, and control rock bursts in deep metal mines. Great strides have been made in understanding the basic mechanisms of different types of bursts. The development of seismic monitoring systems tailored to mine-scale events has provided mine personnel with a tool to measure how underground mines respond to stress changes brought on by excavation. This monitoring technology allows mine stability information to be conveyed to miners working underground, as well as to engineers and management, and incorporated into daily and long-term operations planning for worker safety. Monitoring data have also been used by NIOSH to guide the development of ways to reduce worker exposure to underground hazards. For example, this research led to adapting the underhand mining method and specialized support systems to decrease rock burst fatalities dramatically in deep-vein mines in Idaho.

R&D Outputs and Transfer Activities

During 1997-2005, this research was transferred to the mining industry through 31 technical papers and presentations. Eighty percent of the mines that are experiencing rock burst problems have cooperated in the research and adopted the technology.

Description of Intermediate Outcome

After the underhand mining method was first implemented at the Lucky Friday Mine in the late 1980´s not one rock burst fatality has occurred. Without this work, the mine would have been forced to close permanently because of the rock burst danger. Work continues to develop this method and assist mines in adopting these and other life-saving ground support measures. NIOSH recently assisted two burst-prone mines to adopt the underhand mining method in combination with a weakly cemented backfill as support. In 2001, the Galena Mine switched from overhand cut-and-fill

to underhand methods in burst-prone stopes, as recommended by NIOSH. In 2002, the Stillwater Mine adopted these methods for the more burst-prone parts of its mine. These and other NIOSH-recommended measures have greatly reduced the vulnerability of miners to rock burst collapse. These outcomes are the result of a long-standing research effort begun in the 1950s.

Proper application of rock burst safety measures, like any prescription, can only succeed where the problem is properly diagnosed. Researchers at NIOSH have built on a long-standing program of mine monitoring to advise mines on technology for diagnosing the nature of rock bursts as well as detecting incipient hazards. A number of rock burst-prone mines have installed these monitoring systems, including the Galena, Meikle, East Boulder and Stillwater mines. Regional sensors and the Stillwater Mine system set up by NIOSH have recently detected the onset of rock bursting at that mine.

The rock-burst problem and long-standing efforts by NIOSH researchers to reduce the risks of injuries and fatalities have been recognized on a number of occasions by the local press. Too often this coverage has been prompted by fatal accidents.

- Kramer B [1999]. Danger around every corner. Spokesman Review, Feb 21.
- The Olympian [2001]. Spokane lab puts miners' safety first, May 15 (this article highlighted rock burst and haul truck work).
- Silverman J [2001]. Silver valley mourns two miners. Spokesman Review, Jun 7.

Outputs

27 Outputs

Title	Year	Output Type	Strategic Goal
60 Years of Rockbursting in the Coeur D'Alene District of Northern Idaho, USA: Lessons Learned and Remaining Issues Whyatt-J; Blake-W; Williams-T; White-B | Presentation at 109th Annual Exhibit and Meeting, Society for Mining, Metallurgy, and Exploration, Feb. 25-27, 2002, Phoenix, AZ. Preprint 02-164; :10 pp	2002	Publication	Ground control
A Method for Modeling Variation of In Situ Stress Related to Lithology Whyatt-JK | In: Elsworth D, Tinnucci JP, Heasley KA, eds. Rock Mechanics in the Public Interest. Proc 38th U.S. Rock Mechanics Symposium, DC Rocks, Vol. 2 (Washington, DC, July 7-10, 2001), Rotterdam: Balkema, 2001 Jul; :1087-1094	2001	Publication	Ground control
Classification of Large Seismic Events at Lucky Friday Mine Whyatt-JK; Blake-W; Williams-TJ | Transactions of the Institution of Mining and Metallurgy (Section A: Mining Industry), vol. 106, Sept.-Dec. 1997; :A148-A162	1997	Publication	Ground control
Coeur d'Alene Mining District: Product of Preconcentrated Source Deposits and Tectonism Within the Lewis and Clark Line White-B | In: Roberts S, Winston D, eds. Geologic Field Trips, Western Montana and Adjacent Areas. University of Montana, Missoula, and Western Montana College of the University of Montana, Dillon, pp. 95-102	2000	Publication	Ground control
Comparison of Seismic Tomography, Strain Relief, and Ultrasonic Velocity Measurements to Evaluate Stress in an Underground Pillar Scott-DF; Girard-JM; Williams-TJ; Denton-DK | Society for Mining, Metallurgy, and Exploration, Inc. (SME) Annual Meeting (Mar 1-3, 1999; Denver, CO); SME Preprint 99-155	1999	Publication	Ground control
Differential Wall Rock Movements Associated with Rock Bursts, Lucky Friday Mine, Coeur d'Alene Mining District, Idaho, USA White-BG; Whyatt-JK | In: Armadei, Kranz, Scott & Smeallie, eds. Rock Mechanics for Industry. Proceedings of the 37th U.S. Rock Mechanics Symposium (Vail, CO, June 6-9, 1999), 1999 Balkema, Rotterdam, ISBN 90 5809 052 3, Balkema, 1999 Jun; :1051-1059	1999	Publication	Ground control
Diverse Tectonism in the Coeur d'Alene Mining District White-BG | Butte, MT: Montana Bureau of Mines and Geology, Spec. Pub. 112, pp. 254-265	1997	Publication	Ground control
Geomechanics of Reinforced Cemented Backfill in an Underhand Stope at the Lucky Friday Mine, Mullan, Idaho Williams-TJ; Denton-DK; Larson-MK; Rains-RL; Seymour-JB; Tesarik-DR | Spokane, WA: US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2001-138, Report of Investigations 9655, 2001 Jul :1-18	2001	Publication	Ground control
Ground Conditions and the May 13, 1994, Rock Burst, Coeur d'Alene Mining District, Northern Idaho Whyatt-JK.; Williams-TJ; White-BG | In: J. Girard, M. Leibman, C. Breeds, and T. Doe, eds. Pacific Rocks 2000. Rock Around the Rim: Proceedings of the Fourth North American Rock Mechanics Symposium (NARMS 2000) (July 31-Aug. 3, 2000; Seattle WA), Balkema, 2000; :313-318	2000	Publication	Ground control
Interaction Between Wall Rock Closure, Cemented Backfill Load, and Reinforcement Bolt Load in an Underhand Stope at the Lucky Friday Mine Williams, T.J., D. Denton, J.B. Seymour, D. Tesarik, C. Peppin, and D. Bayer | In: D Stone, ed., Minefill 2001: Proceedings of the 7th International Symposium on Mining with Backfill, Soc. For Min., Metall, and Explor., Littleton, CO, 2001; :117-125	2001	Publication	Ground control

Title	Year	Output Type	Strategic Goal
Investigation of a Rock-Burst Site, Sunshine Mine, Kellogg, Idaho Scott-DF; Williams-TJ; Friedel-MJ | In: Gibowicz SJ, Lasocki S, eds., Proceedings of the 4th International Symposium on Rockbursts and Seismicity in Mines, Balkema, 1997; :311-315	1997	Publication	Ground control
Mechanics of a Large, Strain-Type Rock Burst and Design for Prevention White-BG; Williams-TJ; Whyatt-JK | In: Hammah R, Bawden W, Curran J, Telesnicki M, eds. NARMS-TAC 2002: Mining and Tunnelling Innovation and Opportunity. Vol 2. Toronto, Ontario, Canada: Univ. of Toronto, Toronto, July 7-10, 2002; :1095-1100	2002	Publication	Ground control
Monitoring of Reinforced Cemented Backfill in an Underhand Stope Williams, T., D. Denton, C. Peppin, and D. Bayer | In: J. Girard, M. Leibman, C. Breeds, and T. Doe, eds. Pacific Rocks 2000. Rock Around the Rim: Proceedings of the Fourth North American Rock Mechanics Symposium (NARMS 2000) (July 31-Aug. 3, 2000; Seattle, WA), Balkema, 2000; :387-393	2000	Publication	Ground control
New Tricks for an Old Elephant: Revising Concepts of Coeur d'Alene Geology White-BG | Min Eng 1998 Jan; :50(8)27-35	1998	Publication	Ground control
New Tricks for an Old Elephant: Revising Concepts of Coeur d'Alene Geology White-BG | SME preprint 98-87. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., pp. 1-11	1998	Publication	Ground control
Origin of Mining-Induced Fractures Through Macroscale Distortion White-BG; Larson-M; Iverson-SR | Gulf Rocks 2004: Proceedings, Rock Mechanics Across Borders & Disciplines, s6th North American Rock Mechanics Conference, June 5-10, 2004, Houston, Texas. Report No. ARMA/NARMS 04-569. Alexandria, VA: American Rock Mechanics Association, 2004 Jun; :1-8	2004	Publication	Ground control
P-Wave Signal IDs Stressed Rock in Deep Mines Williams-TJ; Scott-DF | Sensors, The Journal of Applied Sensor Technology, vol. 15, no. 2, 1998 Feb; :12-13	1998	Publication	Ground control
Relative Stress Conditions in an Underground Pillar, Homestake Mine, Lead, SD Scott-DF; Williams-TJ; Freidel-MJ; Denton-DK | Proceedings of the 36th U.S. Rock Mechanics Symposium. New York, NY: Columbia University, Paper No. 278, 1997	1997	Publication	Ground control
Remote Monitoring of Mine Seismicity and Earthquakes Using Radio Telemetry, Computers, and the Internet Denton-D; Stickney-M; Williams-T; Langston-R | In: R.K. Singhal, K. Fytas, and C. Chiwetelu, eds., Computer Applications in the Minerals Industries, Proceedings of the Fourth International Conference on Computer Applications in the Minerals Industries (CAMI 2003) (Sept. 8-10, 2003; Calgary, AB), 2003 Sep	2003	Publication	Ground control
Rock Bursting and Seismicity During Ramp Development, Lucky Friday Mine, Mullan, Idaho Whyatt-JK; White-BG | In: Peng SS, ed. Proceedings of the 17th International Conference on Ground Control in Mining, 1998 Aug :317-325	1998	Publication	Ground control
Role of Fault Slip on Mechanisms of Rock Burst Damage, Lucky Friday Mine, Idaho, USA White-BG; Whyatt-JK | In: Hogan TO, ed. SARES 99 - Second Southern African Rock Engineering Symposium. Implementing Rock Engineering Knowledge September 13-15, Johannesburg, S. Africa. Lisboa, Portgual: International Society of Rock Mechanics 1999 Jan; :169-178	1999	Publication	Ground control

Title	Year	Output Type	Strategic Goal
Shear Mechanism for Mining-Induced Fractures Applied to Rock Mechanics of Coal Mines White-B | In: Peng SS, Mark C, Wahab A, and Heasley KA, eds. Proceedings of the 21st International Conference on Ground Control in Mining (Morgantown, WV, Aug. 6-8, 2002), West Virginia University, Morgantown, WV, 2002 Aug; :328-334	2002	Publication	Ground control
Shear Origin of Tension in Excavation-Induced Fractures White-BG; Iverson-S; Larson-M | In: Culligan PJ, Einstein HH, Whittle AJ, eds. Soil and Rock America 2003. 12th Panamerican Conference on Soil Mechanics and Geotechnical Engineering and the 39th U.S. Rock Mechanics Symposium, Vol. 1. Cambridge, MA: Massachusetts Institute of Technology, 2003 Jun; 1:909-916	2003	Publication	Ground control
Stratigraphic Subunits and Control of Ground in The Revett Formation, Coeur d'Alene Mining District, Idaho Whyatt-JK; White-BG | Proceedings of the 36th U.S. Rock Mechanics Symposium. New York, NY: Columbia University, paper No. 332, 1997	1997	Publication	Ground control
Stratigraphy of the Proterozoic Revett Formation and its Control on Ag-Pb-Zn Vein Mineralization in the Coeur d'Alene District, Idaho Mauk-JL; White-BG | Econ Geol 99:295-312	2004	Publication	Ground control
Structural Stress and Concentration of Mining-Induced Seismicity Whyatt-JK; White-BG; Blake-W | Trans SME, Vol. 300,1997; :74-82	1997	Publication	Ground control
The Lewis and Clark Line and Coeur d'Alene Mining District White-B; Winston-W; Lange-I | In: Roberts S, Winston D, eds. Geologic Field Trips, Western Montana and Adjacent Areas. University of Montana, Missoula, and Western Montana College of the University of Montana, Dillon, pp. 103-122	2000	Publication	Ground control

Strategic Program Outcome for Surveillance and Training

Improved Training Materials and Methods to Prevent Injuries and Illnesses

Mine safety and health professionals have long recognized training as a critical part of an effective safety and health program. Since 1977, federal regulations have required mine operators to provide safety and health training to all new miners, as well as a minimum of 8 hours of refresher training each year. Several major changes have taken place in the way mine safety and health training is conceived and practiced since 1977. We believe that our research has stimulated these changes. These include:

1. More emphasis on learning that requires collaboration and active problem-solving.
2. More integration of miners´ practical knowledge and experience with mandatory safety and health information they receive annually.
3. More realism in training scenarios and greater fidelity of visual illustrations.
4. Greater use of training materials that are thoroughly authenticated and field tested.

Our nation´s miners sit through millions of hours of mandatory safety and health training each year. Mining companies spend millions of dollars to provide this training. It is often unclear whether these miners are learning anything that can actually help them reduce their risk of occupational injury and illness. Many miners sit through the same training lectures and films year after year in order to fulfill the legal requirements. In these situations, their "training" ends up being an unfortunate waste of time and resources. However, when it is done well, training is valuable and worthwhile to both the miners and their employer.

With help from universities, mining companies, the Mine Safety and Health Administration (MSHA), and other providers of miners' training, NIOSH researchers have developed more than 80 training modules and products on a wide variety of safety and health topics. Most of these are intended to improve miners' ability to (1) recognize common workplace hazards or (2) handle nonroutine events such as fires and other types of mine emergencies. The main emphasis of the NIOSH Mining Program´s training research activity is not on producing training materials per se, but on finding better training processes and methods. Most of our training modules were developed during research studies to determine the feasibility and effectiveness of using innovative new methods to present occupational safety and health information to miners. These include computer simulations, interactive problem-solving stories, degraded stereoscopic (3-D) images of hazardous conditions, and videotaped interviews with miners.

According to MSHA records, NIOSH's mine training materials have been used extensively by the mining industry. During the past 20 years, trainers have obtained more than a half million copies through MSHA´s National Mine Health and Safety Academy. Numerous mining companies, mine trainers, and union officials have requested help from NIOSH mine training researchers. Several companies have provided financial support through Cooperative Research and Development Agreements. MSHA and state mining officials often request our help and advice on various matters related to miners´ safety and health training.

Intermediate Outcomes

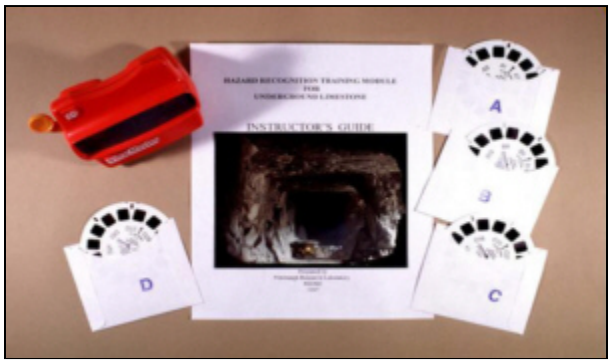
- 3-D Hazard Recognition Training: A New Approach to Preventing Injuries Associated With Construction, Maintenance and Repair Activities
- A Computer-based Training Simulation to Prevent Loss of Life During Mine Emergencies
- Interactive Problem Solving Stories: A New Approach to Preventing Miners' Occupational Injuries and Illnesses
- Mine Training Videos
- Western Train-the-Trainer (T3) Training Forum

Intermediate Outcome related to Improved Training Materials and Methods to Prevent Injuries and Illnesses

3-D Hazard Recognition Training: A New Approach to Preventing Injuries Associated With Construction, Maintenance and Repair Activities

Description of Problem

The U.S. aggregates and surface stone industry employs about 100,000 workers at 11,300 mine sites. Data collected during 1993-1997 showed that at least 40% of all injuries at these mining operations occurred during construction, maintenance and repair activities. It was determined that a training intervention was needed to ensure that surface miners are able to recognize and respond to the hazards linked with performing these types of activities.



Hazard recognition training materials

Research and Development Activities

An interactive training program was developed mainly for use with workers who perform construction, maintenance and repair work at surface mining operations, or the surface of underground mining operations. Trainees begin by viewing twenty 3-D images of various construction, maintenance and repair activities and workplace conditions. After viewing each slide, the instructor asks the trainees to list as many hazards as they can. They are then asked to explain what should be done to protect workers from these hazards. The instructor may also present additional information contained in the instructor's section of the training package. After viewing all of the slides, trainees are asked to take a 20-question true/false quiz. The instructor then leads a class discussion while reviewing the answers to the quiz.

The exercise addresses the following safety and health topics: confined space, electrical, ergonomics, excavation/trenching, falling materials, fire safety, general housekeeping, hand tools, hazard communication, health hazards, lockout/tagout, machine equipment guarding, material handling, mobile equipment, personal protective equipment, welding and cutting. This training exercise was developed in cooperation with aggregates mining companies and The Pennsylvania State University. It was authenticated with mine safety experts and extensively field tested with miners. The field test results suggest that this training leads to an increase in miners' knowledge. Those who took this training scored significantly higher on the 20-question true/false test than those who did not take the training.

R&D Outputs and Transfer Activities

The development and evaluation of this innovative training program has been the subject of several conference presentations and journal articles. Copies of this training program can be obtained from the Mine Safety and Health Administration's National Mine Health and Safety Academy. This training module can also be found by going to http://www.cdc.gov/niosh/mining/products/view-masterreeltrainingexercises.htm and clicking on "Hazard Rec. for CMR Activities" on the left.

Description of Intermediate Outcome

The training program has been very well received and widely adopted by those who train surface miners. Major aggregate producers, including Vulcan Materials and Hansen Aggregates, have incorporated the training into their Part 46 training classes. The program has been used at more than 1,500 mining operations throughout the United States. To date, more than 5,000 copies of the exercise have been requested. It is being used to train workers not only in the mining industry, but also in the construction, gas, and oil extraction industries. The Center to Protect Workers' Rights has recommended that it be used to train construction workers in many countries and has had it translated into Spanish. Copies of the program have been requested by trainers in 18 foreign countries.

Outputs

4 Outputs

Title	Year	Output Type	Strategic Goal
Construction/Maintenance and Repair Activities: Hazard Recognition Training Program Rethi-LL; Flick-JP; Kowalski-KM; Calhoun-RA | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 99-158, 1999 Oct :3-79	1999	Publication	Surveillance and training
Development and Evaluation of a Training Exercise for Construction, Maintenance and Repair Work Activities Rethi-LL; Barrett-EA | In: Bockosh-GR, Karmis-M, Langton-J, McCarter-MK, Rowe-B eds. Proceedings of the Thirty-First Annual Institute on Mining Health, Safety and Research (Blacksburg, VA; Aug 27-30, 2000). Virginia Polytechnic Institute and State University, Department of Mining and Minerals Engineering; :93-102	2000	Publication	Surveillance and training
Out-of-the-Box Approach to Mine Safety: Focus on Construction, Maintenance, and Repair Activities Kowalski-Trakofler-KM; Rethi-LL | Professional Safety 48(1), 2003; :21-27	2003	Publication	Surveillance and training
Hazard Recognition Training Program for CMR Activities Rethi-LL; Flick-JP; Kowalski-KM; Calhoun-RA; Barrett-EA; Cornelius-KM; Haggerty-JJ; Saksena-N | NIOSH, 1999 Oct :1-78	1999	Training	All

Intermediate Outcome related to Improved Training Materials and Methods to Prevent Injuries and Illnesses

A Computer-based Training Simulation to Prevent Loss of Life During Mine Emergencies

Description of Problem

When emergencies start to unfold, it is critical that decision-makers respond quickly and effectively to prevent or minimize loss of life. Many people in the mining industry could potentially be thrust into the role of leading the response to an emergency. However, as mines become safer and major disasters fewer, the number of people who have had real experience in dealing with mine emergencies continues to dwindle. The industry needs a feasible and effective way to give future emergency command center leaders the opportunity to practice information gathering, situation assessment, decision-making, and coordination skills without risk to personnel or property.

Participating in a training session

Research and Development Activities

NIOSH scientists have developed a new training tool for potential emergency command center leaders. The Mine Emergency Response Interactive Training Simulation (MERITS) is an Internet-delivered, computer-based simulation exercise. It was developed to give trainees the experience of operating a command center during a major mine emergency. The exercise can be used in settings with limited resources available for larger-scale mock drills and can be used to train small numbers of individuals cost-effectively. The simulation setting is a small underground coal mine. Field tests have also found MERITS useful for training mine rescue teams and emergency response personnel at underground stone and surface mines.

R&D Outputs and Transfer Activities

MERITS was introduced to the general public in June 2002 via NIOSH *Technology News* No. 496. It was also introduced through several papers and presentations at mine safety conferences. MERITS can be downloaded from http://merits.niosh.cdc.gov/merits/. In the fall of 2003, the Pennsylvania Bureau of Deep Mine Safety adapted MERITS for its annual refresher training to rank-and-file miners and for its training course for new miners. The agency reports that these uses have been very effective. A key part of emergency response and rescue and of MERITS is effective communication. A supplemental training tool called "The Emergency Communication Triangle" was developed to address this need. NIOSH researchers were assisted by the state of Pennsylvania, the state of Colorado, the United Mine Workers of America, and various private mining companies in developing and field testing these training exercises.

Description of Intermediate Outcome

In his testimony before the U.S. Senate Appropriations Subcommittee on Labor, Health and Human Services, and Education, David E. Hess, Secretary, Pennsylvania Department of Environmental Protection, stated that training, including MERITS, was a key factor in the success of the Quecreek mine disaster response. He reported that "the rescued miners have said the safety training they received helped them in several ways, first to warn the other miners to leave the rapidly flooding mine, how to share resources and protect themselves underground and to understand what rescuers above ground would be doing to rescue them. Training includes live action sessions, workshops and MERITS." Along with supporting the use of MERITS, the Pennsylvania Bureau of Deep Mine Safety said in its Quecreek Mine Inundation Status Report/Action Plan that it would "make the 'emergency communication triangle' training module widely available." Copies of the simulation have been requested from safety and emergency response professionals in 28 states, the District of Columbia, and 19 foreign countries.

Outputs

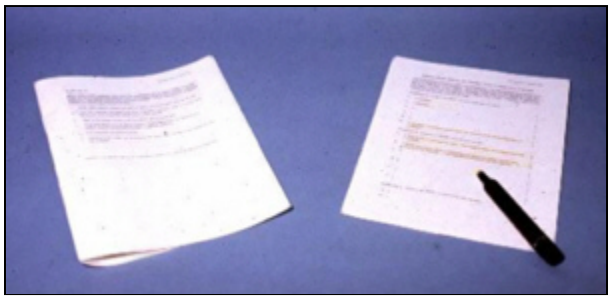
4 Outputs

Title	Year	Output Type	Strategic Goal
Emergency Response Command Center Training Using Computer Simulation Brnich-M; Mallett-L; Reinke-D; Vaught-C | In: 33rd Annual Institute on Mining Health, Safety, and Research Conference Proceedings, Roanoke, VA, August 11-13, 2002	2002	Publication	Mine disasters; Surveillance and training
Pennsylvania Incorporates Innovative Programs into Mine Rescue Training Eppley-D; Reinke-DC | MSHA Holmes Safety Association Bulletin, Feb/March 2002; :15-16	2002	Publication	Mine disasters; Surveillance and training
Technology News 496 - NIOSH Releases New Computer-Based Training Exercise Called MERITS Reinke-D; Mallett-L | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 496, 2002 June; :1-2	2002	Publication	Mine disasters; Surveillance and training
Mine Emergency Response Interactive Training Simulation (MERITS) NIOSH	2002	Training	Mine disasters; Surveillance and training

Intermediate Outcome related to Improved Training Materials and Methods to Prevent Injuries and Illnesses

Interactive Problem Solving Stories: A New Approach to Preventing Miners' Occupational Injuries and Illnesses

Description of Problem



Latent image training materials

The Federal Coal Mine Safety and Health Amendments Act of 1977 requires U.S. mine operators to provide formal safety and health training to all miners at least annually. The initial materials and methods used to conduct miners' training following passage of the 1977 Act were often found to be lacking in several ways. The training tended to be didactic, not interactive and engaging. Many instructors made no attempt to assess whether trainees remembered the information or were able to apply it. Trainees received little or no feedback. They only needed to be physically present in the classroom for a prescribed length of time.

Research and Development Activities

To help overcome these deficiencies, mine training experts at the NIOSH Pittsburgh Research Laboratory pioneered a new training method to improve miners' decision-making skills with respect to mine health and safety. The training is designed to teach judgment and decision-making skills within two broad domains: (1) how miners respond to mine emergencies (e.g., first aid, self-rescue, and escape) and (2) how miners integrate safety concepts within the context and performance of routine production work. The exercises are based on interviews and official reports of mine accidents, emergencies, and disasters. They reflect the problems and predicaments encountered by miners in these real-life events. Each problem-solving story is presented in a booklet as an unfolding story with a plot, characters, predicaments, goals, and obstacles. Trainees make a series of choices among good and bad action alternatives at critical decision points. Using a developing pen, they record their decision on a latent-image answer sheet and receive immediate feedback about the consequences of the action(s) they picked.

R&D Outputs and Transfer Activities

These exercises are available through the Mine Safety and Health Administration's (MSHA) National Mine Health and Safety Academy. They can also be viewed at http://www.cdc.gov/niosh/mining/products/invisibleinktrainingexercises.htm. MSHA is converting these simulations to a Web-based interactive format and is making them available through its website (http://www.msha.gov/interactivetraining.htm). These simulation exercises have also been the subject of several publications and presentations at mine safety conferences.

Description of Intermediate Outcome

The interactive problem-solving stories have been found to be very effective through field tests with thousands of miners. Mine trainers have purchased more than a half million copies of this type of training exercise. A detailed assessment of the use of our training simulations was published in NIOSH Information Circular (IC) 9459, "Use of Simulation Exercises for Safety Training in the U.S. Mining Industry". Researchers contacted 147 organizations that purchased the exercises from the National Mine Health and Safety Academy over a 2-year period. Feedback was obtained from 52 of these organizations. Sixty percent of the respondents rated the exercises as more useful than traditional instructional materials, 40% as equally useful, and 0% as less useful. Most trainers (79%) thought that the exercises helped them to make better use of workers' knowledge and experience during training. Fifty of the fifty-two respondents reported that they would like to have new simulations developed. Most showed an interest in helping to develop and field test new exercises. Ninety-four percent of the trainers judged the exercises as a good value; 92% planned to order more simulations in the future.

Outputs

63 Outputs

Title	Year	Output Type	Strategic Goal
Cripple Creek Deep Cut: An Exercise for Remote Control Miner Operators and Face Crews Steiner-LJ; Brnich-MJ; Duncan-J; Vaught-C; Calhoun-RA; Cornelius-KC; Rethi-LL; Rossi-EW; Turin-FC | National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 99-159, 1999 Oct :1-44	1999	Publication	Surveillance and training; Traumatic injuries
Decision Making During a Simulated Mine Fire Escape Cole-HP; Vaught-C; Wiehagen-WJ; Haley-JV; Brnich-MJ Jr. | IEEE Transactions on Engineering Management, 45(2), 1998; :153-162	1998	Publication	Mine disasters
Effective Hazard Recognition Training using a Latent-Image, Three-Dimensional Slide Simulation Exercise Barrett-EA; Kowalski-KM | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 9527. NTIS stock number: PB95-170379, 1995; :36 pp	1995	Publication	All
I Can't Get Enough Air! Proper Self-contained Self-rescuer Usage Brnich-MJ; Vaught-C; Calhoun-RA | National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 99-160, 1999 Oct; :1-43	1999	Publication	Mine disasters; Surveillance and training
Investigation of a Slip/Fall Accident Rethi-LL; Wiehagen-WJ; Calhoun-RA; Garry-D; Cole-HP; Brnich-MJ | National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 99-156, 1999 Oct; :1-43	1999	Publication	Surveillance and training; Traumatic injuries
The Concept of Degraded Images Applied to Hazard Recognition Training in Mining for Reduction of Lost-Time Injuries Kowalski-Trakofler-KM; Barrett-EA | J Saf Res 2003; 34(5):515-525	2003	Publication	Surveillance and training
Use of Simulation Exercises for Safety Training in the U.S. Mining Industry Cole-HP; Wiehagen-WJ; Vaught-C; Mills-BS | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2001-141, Information Circular 9459, 2001 Sep; :1-20	2001	Publication	Cumulative injuries; Surveillance and training
Apparent Diving Accident University of Kentucky | USBM research contract H0348040, 1987 Jul; :1-30	1987	Training	Surveillance and training; Traumatic injuries
Basics of Transformers & Monitors West Virginia University; USBM | NIOSH, 1994 Dec	1994	Training	Surveillance and training; Traumatic injuries
Belt Fire Exercise University of Kentucky; USBM | USBM research contract H0348040; 1989 Jul	1989	Training	Mine disasters; Surveillance and training
Belt Fire Injury USBM | USBM, 1996 May	1996	Training	Mine disasters; Surveillance and training
Belt Haulage Accident University of Kentucky | USBM research contract H0348040; 1987 Aug	1987	Training	Surveillance and training; Traumatic injuries
Belt Line Problem University of Kentucky; State of Arizona | USBM research contract H0348040; 1988 Sep	1988	Training	Surveillance and training; Traumatic injuries

Title	Year	Output Type	Strategic Goal
Bennie's Chest Pain University of Kentucky | USBM contract H0348040, 1988 Jan; :1-25	1988	Training	Surveillance and training; Traumatic injuries
Bernie's Feeder Accident University of Kentucky | USBM research contract H0348040; 1988 May	1988	Training	Surveillance and training; Traumatic injuries
Bob's Electrical Shock University of Kentucky | USBM research contract H0348040; 1987 Aug; :31 pages	1987	Training	Surveillance and training; Traumatic injuries
Bob's Loader Accident Illinois Eastern Community College; University of Kentucky | USBM research contract H0348040; 1988 Oct	1988	Training	Surveillance and training; Traumatic injuries
Bulls Double Header: Too Much Unsupported Roof Kentucky Department of Mines and Minerals; USBM | USBM Purchase order P0325350; :35 pages	1994	Training	Ground control; Surveillance and training; Traumatic injuries
Cleo's Longwall Accident (invisible ink) University of Kentucky | USBM research contract H0348040; 1987 Nov	1987	Training	Surveillance and training; Traumatic injuries
Coal Miner's Chest X-ray Program University of Kentucky; USBM; West Virginia University | USBM 1997 Jul	1997	Training	Respiratory diseases; Surveillance and training
Continuous Miner Accident (invisible ink) University of Kentucky | USBM research contract H0348040; 1987 Aug	1987	Training	Surveillance and training; Traumatic injuries
Continuous Miner Fire Southwest Virginia Community College; University of Kentucky | USBM research contract H0348040; 1989 Jul	1989	Training	Mine disasters; Surveillance and training; Traumatic injuries
Cripple Creek Deep Cut Steiner-LJ; Brnich-MJ Jr; Vaught-C; Duncan-J | NIOSH, 1999 Oct :1-44	1999	Training	All
Cutthrough Ventilation Arrangement University of Kentucky | USBM research contract H0348040; 1987 Sep	1987	Training	Mine disasters; Surveillance and training
Delta Mine Cutthrough University of Kentucky | USBM research contract H0348040; 1988 Jun	1988	Training	Mine disasters; Surveillance and training
Drill Rig Incident Barrett-EA; Calhoun-RA | NIOSH Information Circular IC 9473; 2005 Feb; :1-19	2005	Training	Hearing loss; Surveillance and training
Electrical Shock Victim University of Kentucky; Polk Community College | USBM research contract H0348040; 1988 Apr	1988	Training	Surveillance and training; Traumatic injuries
Escape from a Mine Fire University of Kentucky; USBM | USBM research contract H0348040; 1989 Jun	1989	Training	Mine disasters; Surveillance and training
Haul Truck Repair Accident University of Kentucky | USBM research contract H0348040; 1987 Nov	1987	Training	Surveillance and training; Traumatic injuries

Title	Year	Output Type	Strategic Goal
Highwall Rescue Exercise University of Kentucky; Illinois Eastern Community Colleges | USBM research contract H0348040; 1989 Jul	1989	Training	Ground control; Surveillance and training; Traumatic injuries
I Can't Get Enough Air! - Proper Self-contained Self-rescuer Usage Brnich-MJ Jr; Vaught-C; Cahoun-RA | NIOSH 1999 Oct; :1-43	1999	Training	Mine disasters; Surveillance and training
Injury Rate Problem at Maxmore Mine University of Kentucky; USBM | USBM research contract H0348040; 1989 Jun	1989	Training	Surveillance and training; Traumatic injuries
Investigation of a Slip/Fall Accident Rethi-LL; Wiehagen-WJ; Calhoun-RA; Garry-D; Cole-HP; Brnich-MJ Jr | NIOSH 1999 Oct; :1-43	1999	Training	All
Leroy's Feeder Accident University of Kentucky | USBM research contract H0348040; 1988 Oct	1988	Training	Surveillance and training; Traumatic injuries
Lingering Smoke Exercise University of Kentucky | USBM research contract H0348040; 1987 Nov	1987	Training	Mine disasters; Surveillance and training
Low Coal Fire University of Kentucky | USBM research contract H0348040; 1987 Jul	1987	Training	Mine disasters; Surveillance and training
Main Haulage Scaling Exercise USBM | USBM 1996	1996	Training	Surveillance and training; Traumatic injuries
Man In the Bin University of Kentucky; Southwest Virginia Community College | USBM research contract H0348040; 1989 Jul	1989	Training	Surveillance and training; Traumatic injuries
Pete's Predicament: Unsupported Roof Kentucky Department of Mines and Minerals; USBM | USBM research contract H0348040; 1994 Oct	1994	Training	Ground control; Surveillance and training; Traumatic injuries
Pipe Repair Problem University of Kentucky; Southwest Virginia Community College | USBM research contract H0348040; 1989 Jun	1989	Training	Surveillance and training; Traumatic injuries
Pit Distribution Troubleshooting Illinois Eastern Community Colleges; University of Kentucky | USBM research contract H0348040; 1989 Jun	1989	Training	Surveillance and training; Traumatic injuries
Prep Plant Belt Problem University of Kentucky; Mountain Empire Community College | USBM research contract H0348040; 1989 Jul	1989	Training	Surveillance and training; Traumatic injuries
Problem in the Shop Illinois Eastern Community Colleges; University of Kentucky | USBM research contract H0348040; 1989 Aug	1989	Training	Surveillance and training; Traumatic injuries
Problem on Dragline #1 Illinois Eastern Community Colleges; University of Kentucky; Polk Community College | USBM research contract H0348040; 1989 Jul	1989	Training	Surveillance and training; Traumatic injuries
Problem on the Belt Line University of Kentucky | USBM research contract H0348040, 1987 Jul; :32 pages	1987	Training	Surveillance and training; Traumatic injuries

Title	Year	Output Type	Strategic Goal
Problem on the Catwalk (coal) University of Kentucky | USBM research contract H0348040; 1987 Nov	1987	Training	Surveillance and training; Traumatic injuries
Problem on the Catwalk (phosphate) University of Kentucky | USBM research contract H0348040; 1988 Jun	1988	Training	Surveillance and training; Traumatic injuries
Raggs & Curly Guarding Exercise USBM | USBM; 1995-01	1995	Training	Surveillance and training; Traumatic injuries
Roof Control at Intersections University of Kentucky | USBM research contract H0348040; 1987 Sep	1987	Training	Ground control; Surveillance and training; Traumatic injuries
Roof Fall Entrapment University of Kentucky | USBM research contract H0348040; 1987 Aug	1987	Training	Ground control; Surveillance and training
Roof Support in a Primary Escapeway USBM | USBM; 1990 Nov	1990	Training	Ground control; Surveillance and training
Sammy's Loose Roof Decisions USBM; University of Kentucky | USBM research contract H0348040; 1989 Jun	1989	Training	Ground control; Surveillance and training
Scoop Accident, First Aid Problem University of Kentucky | USBM research contract H0348040; 1988 Mar	1988	Training	Surveillance and training; Traumatic injuries
Smoke on the Section University of Kentucky | USBM research contract H0348040; 1987 Jul	1987	Training	Mine disasters; Surveillance and training
Tipple Heater Exercise Coal Mining Technology Illinois Eastern Community Colleges; University of Kentucky | USBM research contract H0348040; 1989 Jun	1989	Training	Surveillance and training; Traumatic injuries
Trailing Cable Electrical Problem West Virginia University; University of Kentucky | USBM research contract H0348040; 1990 Sep	1990	Training	Surveillance and training; Traumatic injuries
Trailing Cable Repair University of Kentucky | USBM research contract H0348040; 1987 Jul	1987	Training	Surveillance and training; Traumatic injuries
Traumatic Head Injury University of Kentucky | USBM research contract H0348040; 1987 Aug	1987	Training	Surveillance and training; Traumatic injuries
Travel Through Smoke USBM | USBM 1994 Sep	1994	Training	Mine disasters; Surveillance and training
Unsupported Roof Rescue University of Kentucky | USBM research contract H0348040; 1987 Jul	1987	Training	Ground control; Surveillance and training; Traumatic injuries
Vulcan Mine Ignition University of Kentucky | USBM research contract H0348040; 1987 Jul	1987	Training	Mine disasters; Surveillance and training

Title	Year	Output Type	Strategic Goal
Vulcan Mine Recovery University of Kentucky | USBM research contract H0348040; 1987 Sep	1987	Training	Mine disasters; Surveillance and training; Traumatic injuries
Water Line Repair University of Kentucky | USBM research contract H0348040; 1987 Jul	1987	Training	Surveillance and training; Traumatic injuries

Intermediate Outcome related to Improved Training Materials and Methods to Prevent Injuries and Illnesses

Mine Training Videos

Description of Problem

Video poster

The need for effective training materials was identified to the NIOSH Spokane Research Laboratory (SRL) during a series of stakeholder meetings held throughout the West. Safety trainers reported that good-quality training tools specific to mining topics were either missing altogether or were too outdated to be of any use. In addition, annual refresher training was not viewed positively by miners. They resented having "nonminers" tell them how to do their jobs and were resistant to any safety messages delivered by people who didn't look and talk like miners. SRL worked with mine safety trainers in various segments of the industry, as well as with the Mine Safety and Health Administration (MSHA) and mining associations, to develop a list of topics that was perceived as critical needs and to begin filling the gaps in effective safety training materials.

Research and Development Activities

SRL has created a library of 10 mine safety and health training videos during 1999-2004. (Some titles are also available in DVD format.) The videos cover topics identified as needed by safety professionals from a range of mining sectors. These include handling explosives, installing ground supports, avoiding rock falls, working safely around highwalls or surface prep plants, and the long-term effects on workers impacted by disaster and tragedy at the workplace. The videos contain real miners working in real mines to bring their safety messages to life. In addition, they capture and hold the interest of miners by using stories to engage trainees. The videos were developed collaboratively with safety professionals working in the topic area with the full cooperation of mining operations. MSHA and the International Society of Mine Safety Professionals (ISMSP) were active partners in developing these materials. The videos have proven to be highly effective in transferring information to miners, who respond favorably to people they consider to be "master miners" acting as mentors.

R&D Outputs and Transfer Activities

The videos are continuously in demand. To date, about 12,000 of them have been shipped to mine safety and health trainers in more than 36 countries. (Videos are provided only upon demand. Every requestor is entered into a customer database to allow followup and to obtain user feedback information.)

Thirteen articles and papers have been published by SRL on this work since 2000. Two reports have been prepared by outside researchers under contract to evaluate the effectiveness of the videos as training tools. A total of 35 presentations have been given at national and international conferences since 2002. In addition, a 90-minute workshop on this research is scheduled for the National Safety Council/World Safety Congress in September 2005.

Description of Intermediate Outcome

The SRL training videos are widely used in the U.S. mining industry. Mining companies, MSHA, mining associations, and state agencies have all provided money or in-kind services so that the videos could be produced. However, the use of these training products has expanded beyond the mine site. Industries as diverse as insurance, tunnel building and construction, the military, and even university occupational safety and health programs have begun to use them in their training programs. They are held in such high regard that safety trainers have requested additional copies after their originals are kept by members of their training audiences.

The work has been recognized by safety and training professionals outside the U.S. mining industry as well. Five journal and media articles (written by others) have appeared in the past 3 years. These include:

- Smith S [2005]. Preaching or teaching: the use of narrative in safety training. Occup Hazards, April 13.
- Naso M [2005]. Tell me a story: how experience and people help teach safety. Saf Health Magazine. National Safety Council, May.
- SafetyWA Magazine [2003]. Workers are the stars. West Australia J Occup Saf Health, December.
- The Australian Mining Times [2003]. Storytelling as a safety tool. October.
- Kral S [2003]. Improved training reduces worker injuries. Min Eng, October.

The NIOSH videos have been recognized for their outstanding contribution to safety and health training and have earned several national awards. These include the NIOSH top honors for Educational Materials (Alice Hamilton Awards) in 2000 and 2001, CDC's Communicators' Roundtable Award for Electronic Media in 2002, a Guiding Light award from ISMSP in 2002, the ISMSP Highest Degree of Safety Award in 2000, and a Telly award (given to broadcast media such as TV, cable, and satellite programming) in 2003. Two of the videos have also been accepted for the International Film Festival competition held during the 2005 World Congress on Safety and Health at Work.

Outputs

23 Outputs

Title	Year	Output Type	Strategic Goal
Development of NIOSH Hard-Rock Safety Training Materials Cullen-ET | Presentation at 108th annual exhibit and meeting, Society for Mining, Metallurgy, and Exploration, Denver, CO, Feb. 26-28, 2001; :4 pp	2001	Publication	Surveillance and training
Feeding the Multitudes - How to Connect With Customers Cullen-ET | Presentation at 108th annual exhibit and meeting, Society for Mining, Metallurgy, and Exploration, Denver, CO, Feb. 26-28, 2001; :6 pp	2001	Publication	Surveillance and training
Getting to Zero-The Human Side of Mining Cullen-ET; Camm-TW; Jenkins-FM; Mallett-L | U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupatoinal Safety and Health, Spokane Research Laboratory, Spokane, WA, DHHS (NIOSH) Publication No. 2006-112, Information Circular # 9484, November, 2005; :1-32	2005	Publication	Surveillance and training
Mine Safety Training: Past, Present, and Future Cullen-E | Minesafe International 2000 (Perth, Australia, Sept. 3-8, 2000). Chamber of Minerals and Energy of Western Australia, Perth, Australia, 2000 Sep; :151-154	2000	Publication	Surveillance and training
Releasing the Energy of Workers to Create a Safer Workplace: The Value of Using Mentors to Enhance Safety Training Camm-TW; Cullen-ET; | In: Peters R, ed. Strategies for Improving Miners' Training. Pittsburgh, PA, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Information Circular 9463, 2002 Sep :35-38	2002	Publication	Surveillance and training
Teaching Miners: Breaking the Barriers to Learning Cullen-E | Minesafe International 2003. Perth, Western Australia: The Chamber of Minerals and Energy of Western Australia, Inc., 2003 Oct; :1-8	2003	Publication	Surveillance and training
Technology News 482 - Ground Support Safety Training Video NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 482, 2000 Jul :1-2	2000	Publication	Ground control; Surveillance and training
Technology News 491 - NIOSH Releases Two New Safety Training Videos NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 491, 2001 Jun :1-2	2001	Publication	Surveillance and training
Technology News 494 - Expert Miner Training Video Released by NIOSH NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 494, 2002 Mar :1-2	2002	Publication	Surveillance and training
Technology News 497 - "You Are My Sunshine": A New Video Release From NIOSH on the Sunshine Mine Fire NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 497, 2002 Aug; :1-2	2002	Publication	Mine disasters; Surveillance and training

Title	Year	Output Type	Strategic Goal
Technology News 502 - New Training Video for Aggregate Operators: Aggregate Training for the Safety Impaired Cullen-E | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 502, January 2003	2003	Publication	Surveillance and training; Traumatic injuries
Tell Me a Story: Why Stories are Essential to Effective Safety Training Cullen-ET | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Pub. No. 2005-152, Report of Investigations 9664	2005	Publication	Surveillance and training
Tell Me a Story: Using Narrative to Teach Safety to Skilled Blue-Collar Workers Cullen-E | In: Proceedings, Risk and Safety Management in Industry, Logistics, Transport, and Military Service: New Solutions for the 21st Century. London: U.S. Navy, Office Of Naval Research, International Field Office, 2003 Mar; :1-4	2003	Publication	Surveillance and training
Aggregate Training for the Safety Impaired Cullen-ET | NIOSH 2003 Dec; :Video (VHS format, 35 minutes)	2003	Video	Surveillance and training; Traumatic injuries
Aggregate Training for the Safety Impaired, Spanish version Cullen-ET | NIOSH 2003; :Video (VHS format, 35 minutes)	2003	Video	Surveillance and training; Traumatic injuries
Handling Explosives in Underground Mines Cullen-ET | NIOSH 1998 Jan; :Video (VHS format, 15 minutes)	1998	Video	Surveillance and training; Traumatic injuries
Hazards In Motion Cullen-ET | NIOSH 2001; :Video (VHS format, 30 minutes)	2001	Video	Surveillance and training; Traumatic injuries
Hidden Scars Cullen-ET | NIOSH 2001 Jan; :Video (VHS format, 25 minutes)	2001	Video	Ground control; Traumatic injuries
Miner Mike Saves the Day! or Ground Support... It's Important! Cullen-ET | NIOSH 2000 Jan; :Video (VHS format, 33 minutes)	2000	Video	Ground control; Surveillance and training
Rock Falls - Preventing Rock Fall Injuries in Underground Mines Miller-A | NIOSH 1999 Jan; :Video (VHS format, 20 minutes)	1999	Video	Ground control
The Sky Is Falling Cullen-ET | NIOSH 2004 Aug; :Video (VHS format, 38 minutes)	2004	Video	Ground control; Surveillance and training; Traumatic injuries
You Are My Sunshine Cullen-ET | NIOSH 2002 :Video (VHS format, 69 minutes)	2002	Video	Mine disasters
Zen and the Art of Rockbolting Cullen-ET | NIOSH 2002 Jan; :Video (VHS format, 33 minutes)	2002	Video	Ground control

Intermediate Outcome related to Improved Training Materials and Methods to Prevent Injuries and Illnesses

Western Train-the-Trainer (T3) Training Forum

Description of Problem

A series of focus group meetings were held with members of the minerals industry beginning in 1998 and continued at several Critical Issues conferences sponsored by the International Society for Mine Safety Professionals (ISMSP). Through these meetings, the Spokane Research Laboratory (SRL) became aware of the need for a western version of the Mine Safety and Health Administration's (MSHA) popular TRAM (Training Resources Applied to Mining) mine safety training program held annually to train trainers in Beckley, WV. Trainers in the Western United States did not believe they had a forum where they could gather, share ideas and best practices, and find solutions to safety problems. Because of the geographical and economic barriers preventing western safety trainers from attending the TRAM Conference in Beckley, few of the western trainers got involved. Most felt isolated from their peers and from new, innovative training methods and materials. The western trainers believed that the miners for which they were responsible were being impacted by this lack of access to each other and the collective wisdom they had to share. SRL researchers began working with industry and government partners to remedy the situation.

Research and Development Activities

The first Western TRAM Conference was held in Reno, NV, in June 2003. SRL took advantage of the planned meeting of the Joseph A. Holmes Association, a nonprofit, safety-oriented organization supported by MSHA, but not a well-known entity in the West, and added a "train-the-trainer" forum to it. The list generated from the database of customers of SRL's training videos was used to contact safety trainers in the West and to invite them to attend the first-ever western conference specifically for safety trainers. A total of 340 mine safety and health experts from both industry and government participated. More than 50 safety professionals from government and industry provided practical training programs and materials. Feedback was very positive, and there was an immediate demand by safety and health trainers to make this an annual event. Since that time, SRL has organized and coordinated the western equivalent of TRAM. It is called Train-the-Trainer (T^3) and has provided more than a dozen presenters to augment the list of topics available to attendees. In 2004, T^3 was held in Salt Lake City, UT, in conjunction with the conference of the Institute on Mining Health, Safety and Research and the ISMSP Critical Issues Conference. It drew more than 400 safety and health trainers from the United States, Canada, Mexico, Venezuela, United Kingdom, Australia, and other countries. This has become an annual event.

R&D Outputs and Transfer Activities

The T^3 conference is an excellent opportunity for NIOSH to share the materials and information it has developed with western safety trainers. These trainers will take the information directly to miners and discover the major concerns and issues in the mine safety arena. Thirty-one researchers from SRL and the Pittsburgh Research Laboratory (PRL) have presented their work at T^3, covering a wide variety of topics. Of particular interest has been the work done at both SRL and PRL on developing training materials for coal and metal/nonmetal mining. The exposure to safety professionals provided by the conference has greatly expanded the potential customer base for both labs.

Description of Intermediate Outcome

NIOSH has played a major role in organizing three international train-the-trainer conferences in the Western United States. The T^3 conferences have become the largest gathering of mine safety professionals in the West. They offer trainers the opportunity to meet and share ideas and solutions. Without NIOSH's efforts to create and organize T^3, western safety trainers would not have access to NIOSH training materials or the collective wisdom of their peers. Agency researchers have benefited from the opportunity to work with several hundred safety and health specialists from many countries, representing a wide array of expertise and topical knowledge. The T^3 conference provides an invaluable opportunity to trainers. It also leads to recognition of agency research, visibility for its researchers, expanded contacts in the industry for future collaborative efforts, and an opportunity to provide training materials and methods to hundreds of trainers in the mining industry. These trainers, in turn, can now provide the benefits of these better practices to much of the western U.S. mining workforce.

Outputs

4 Outputs

Title	Year	Output Type	Strategic Goal
Coaching Skills for On-the-Job Trainers Mallett-LG; Kowalski-Trakofler-K, Vaught-C; Wiehagen-WJ; Peters-RH; Keating-P | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-146, Information Circular 9479	2005	Publication	Surveillance and training
2003 Western TRAM Conference NIOSH | Held jointly with the Joseph A. Holmes Safety Association meeting (Reno, NV; June 2003)	2003	Workshop, Seminar, or OIB	Surveillance and training
2004 Train-the-Trainer (T3) Conference NIOSH | Held jointly with the Institute on Mining Health, Safety and Research meeting and ISMSP's Critical Issues Conference (Salt Lake City, UT; May 2004)	2004	Workshop, Seminar, or OIB	Surveillance and training
2005 Train-the-Trainer (T3) Conference NIOSH | Held jointly with the ISMSP's Critical Issues Conference (Reno, NV; May 2005)	2005	Workshop, Seminar, or OIB	Surveillance and training

Strategic Program Outcome for Surveillance and Training

Reducing the Hazards of Mining's Emerging Issues

Emerging issues in miner health are driven by deeper and more complex mines; shifting work organization; changing airborne particles from advancing technologies; bigger, faster, and more sophisticated machinery; and new chemical exposures. Miners and emergency responders face extreme heat and cold stresses as mines become more remote or go deeper. Increasingly complex mines challenge miners´ ability to navigate through everyday work processes but more critically, under emergency situations. Miners are exposed to chemicals, metals, and trace toxic substances that continue to evolve due to technological or environmental changes. Improving health outcomes will require both the use of emerging technologies to solve health hazards as well as attention to the hazards introduced by new technologies.

A specific example of an emerging health issue is mine workers´ exposures to chemicals, dusts, mine gases, and industrial fumes. Overexposure to these substances may cause acute or chronic health problems. A NIOSH study inventoried 2,570 different chemical substances and 84,939 trade name substances at 491 selected mine sites. The results show potential exposures to a variety of chemical hazards in U.S. mines. The effects of these chemical and environmental hazards are hard to quantify. Traditional occupational health surveillance data, such as those from the Bureau of Labor Statistics, significantly underestimate injuries and illnesses, and special filters must be used to supplement the numbers. The Mine Safety and Health Administration also requires injury, illness, and disease documentation, but only those that are most obviously work-related may actually be reported. For instance, because most diseases take time to become symptomatic, the ability to directly link the disease to work exposure is reduced.

The health hazards emphasis is relatively new for the NIOSH mining program compared with other programs that have a longer history and a record of impressive influence on the industry. Potential outcomes of the health hazards program are expected to improve the health and safety of miners. However, there are specific outcomes in the intermediate stage that are already beginning to influence the reduction of chemical and environmental exposures.

- The HazCom Helper software program provided an enhanced communication tool for mine companies, thus raising awareness of chemical hazards in the workplace beyond minimal compliance requirements.
- Mine rescue teams are more aware of and are using procedures such as forced rest and body temperature monitoring to maintain optimum activity levels while working in hot environments.

The transfer of key findings has occurred in conferences among scientific peers and at seminars and workshops for mining safety and health professionals, as well as through publications, CDs, and other products.

Intermediate Outcomes

- Reducing Hazards through Better Communications
- Reducing Heat Strain Health Hazards

Intermediate Outcome related to Reducing the Hazards of Mining's Emerging Issues

Reducing Hazards through Better Communications

Description of Problem

In 2002, the Mine Safety and Health Administration (MSHA) enacted a new regulation-30 CFR 47 (HazCom rule). This requires all mines to develop a written hazard communication program that includes tracking hazardous chemicals at their sites. All mines with six or more workers were to comply by September 23, 2002; those with fewer than five workers were to comply by March 21, 2003. NIOSH personnel met with representatives from several mining companies and MSHA administrators to discuss what NIOSH could do to help small- to medium-sized mines that lack the resources to successfully comply with the MSHA HazCom rule. NIOSH determined that companies would need assistance with writing the required HazCom plan and developing a list of all hazardous chemicals at their mine.

Following many requests for the HazCom Helper from companies regulated by OSHA, NIOSH revised the program to create the HazCom Helper-OSHA version to be more compatible with the specific needs of these nonmining companies.

Research and Development Activities

To meet this need, NIOSH developed the HazCom Helper to assist individuals in writing a HazCom plan in a step-by-step fashion. The NIOSH HazCom Helper is approved by both MSHA and OSHA and can be downloaded from the NIOSH Web site at (http://www.cdc.gov/niosh/mining/topics/chemicalhazards). Both MSHA and OSHA inspectors accept the HazCom Helper written plan as complying with their respective HazCom rules.

R&D Outputs and Transfer Activities

Mining companies, MSHA, training consultants, and universities have requested more than 3,600 copies of the HazCom Helper. The product was the second most downloaded software from NIOSH's Web site in 2003 and 2004. In an effort to raise awareness of the hazardous chemicals to which miners are exposed, the mining program also developed hands-on workshops ("A Layman's Guide to HazCom Compliance") and seminars ("Overview of Hazards and Controls associated with Common Chemicals Found in Mining"). These were presented at six locations throughout the United States during 2003-2004. Also, MSHA requested that a workshop be held to explain the use of the HazCom Helper at the 22nd Annual South Central

Joint Mine Health and Safety Conference in Albuquerque, NM (March 2004). MSHA trainers use the HazCom Helper in regional workshops for miner training and as a training tool at its inspector training facility. More than 1,000 CD versions of the HazCom Helper have been used in MSHA-hosted training seminars and workshops.

Description of Intermediate Outcome

This project has helped both the mining community and nonmining companies by providing a tool that (1) aids in reducing the administrative burden of preparing a written HazCom plan, (2) improves the quality of information in the HazCom plan, and (3) increases worker awareness of hazardous chemicals in the workplace. Testimonials from returned evaluations include the following: "Good product! We had a program, but used it [HazCom Helper] to enhance what we already had."; "Very useful and beneficial to operators!"; "I am glad I found your program; it has made this step much easier for me!"; and, "I have looked at the NIOSH HazCom helper. It is slick and helpful for the in-plant hazard communication program, especially for small businesses."

Outputs

4 Outputs

Title	Year	Output Type	Strategic Goal
Technology News 503 - HAZCOM Helper: Compliance Tool for MSHA Rule 30 CFR Part 47 Scott-D; Drake-P | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 503, 2003 Mar; :1-2	2003	Publication	Surveillance and training
Technology News 510 - HazCom Helper - OSHA Version: Compliance Tool For OSHA Rule 29 CFR 1910.1200 NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 510, 2005 Oct; :1-2	2005	Publication	Surveillance and training
HazCom Helper - MSHA Version Scott-DF; Drake-PL; Brady-TM | NIOSH Pub. No. 2003-18. 2003; CD-ROM	2004	Software	Surveillance and training
HazCom Helper - OSHA Version Scott-DF; Drake-PL; Brady-TM | NIOSH Pub. No. 2003-18. 2003; CD-ROM	2005	Software	Surveillance and training

Intermediate Outcome related to Reducing the Hazards of Mining's Emerging Issues

Reducing Heat Strain Health Hazards

Description of Problem

In October 2002, two mine rescuers died from heat exposure during training exercises in an underground gold mine. Deep underground metal mines experience extreme environmental conditions due to the thermal gradient of the rock at depth and the contribution of heat from diesel powered equipment. During mine emergencies there is the potential of additional heat load from a fire while ventilation systems used to remove this heat burden could be compromised.

Research and Development Activities

Research conducted under conditions similar to those of the October 2002 accident identified pre-rescue-activity body temperature as a significant predictor of an individual's tolerance for heat exposure during the activity. The use of pre-rescue-activity body temperature to identify at-risk individuals in mine rescue activities would reduce the risk to the individual and the team mission due to failure of an individual to perform. The research also identified a forced-rest regimen based on resting heart rate that can greatly reduce the risk of heat strain-related injuries by limiting the metabolic heat load. The research identified the need to limit work-rest regimens beyond the recommendations of the current NIOSH Recommended Standard in order to protect this special class of worker.

R&D Outputs and Transfer Activities

Study findings were published in the 2005 Transactions of the Society for Mining, Metallurgy, and Exploration, Inc. Three presentations were given targeting a range of audiences, including mining professionals and mine safety trainers. One of these was at the 2005 Mines and Aggregates Safety and Health Association (MASHA) safety conference in Ontario, Canada.

Description of Intermediate Outcome

The results from monitoring core temperatures and heart rate of mine rescue teams during underground training exercises led 16 US and Canadian mine rescue teams who work in hot environments to alter their procedures. These teams now pre-screen participants for baseline body temperatures in order to identify individuals at high risk of injury from working in a hot

environment. In addition, eight teams have altered their procedures to provide adequate rest periods during mine rescue activities. This outcome is continuing to gain acceptance in the affected parts of the mining industry, as evidenced by requests for information on the application of the methods in Australia and the United Kingdom.

Outputs

1 Output

Title	Year	Output Type	Strategic Goal
A Study of Heat Stress Exposures and Interventions for Mine Rescue Workers Varley-F | Trans Soc Min Metal Explor 2004 Dec; 316:133-142	2004	Publication	Surveillance and training

3.3 Outputs

A total listing of 1428 **Outputs** under the Mining Program since 1996 is presented in this section. This listing includes the outputs that, when used and implemented by customers, led to Intermediate Impacts. The majority of outputs in the Mining Program are publications (84.1%), followed in smaller numbers by workshops, videos, and other output types.

At the end of this section is a series of tables and pie charts showing outputs broken down by strategic goal, year produced (1996 through 2005), and output types. There is also an explanation of how outputs are categorized.

1428 Outputs

Title	Year	Output Type	Strategic Goal
100 Years of Improvement in Aggregate Worker Safety Iannacchione-A; Mucho-T | Stone, Sand and Gravel Review 2003 Mar; :28-34	2003	Publication	Surveillance and training
60 Years of Rockbursting in the Coeur D'Alene District of Northern Idaho, USA: Lessons Learned and Remaining Issues Whyatt-J; Blake-W; Williams-T; White-B | Presentation at 109th Annual Exhibit and Meeting, Society for Mining, Metallurgy, and Exploration, Feb. 25-27, 2002, Phoenix, AZ. Preprint 02-164; :10 pp	2002	Publication	Ground control
A 20-Liter Furnace Test Method to Determine the Combustion Gas Toxicity of Conveyor Belts De Rosa-MI | Pittsburgh, PA: U.S. Department of Energy, Report of Investigations 9626. NTIS stock number: PB96-202619, 1996	1996	Publication	Mine disasters
A Case Study Examining Cumulative Trauma Exposure of Coal Mine Workers Cornelius-KM; Turin-FC | In: Das B, Karwoski W, eds. Advances in Occupational Ergonomics and Safety II, IOS Press and Ohmsha: 1997; :569-572	1997	Publication	Cumulative injuries
A Case Study of Bolt Loads in a Trona Mine Retreat Section Signer-S; Rains-R | Roofbolting in Mining (Aachen, Germany, June 6-7, 2001). Aachen International Mining Symposia, Institut für Bergbaukunde I, Aachen, Germany, 2001 Jun; :481-494	2001	Publication	Ground control
A Case Study of Bolt Performance in a Two-entry Gate Road Signer-SP; Lewis-JL | 17th Conference on Ground Control in Mining, West Virginia University, August, 1998; :249-256	1998	Publication	Ground control
A Case Study of Roof Bolting Tasks to Identify Cumulative Trauma Exposure Cornelius-KM; Turin-FC | Proc IIE Annual Research Conference, 2001 Institute of Industrial Engineers (CD-ROM)	2001	Publication	Cumulative injuries
A Checklist for Evaluating Cab Design of Construction Equipment Kittusamy-NK | Applied Occupational and Environmental Hygiene 18, 2003; :721-723	2003	Publication	Cumulative injuries
A Comparative Evaluation of the Differential-Pressure-Based Respirable Dust Dosimeter with the Personal Gravimetric Respirable Dust Sampler in Underground Coal Mines Ramani-RV; Mutmansky-JM; Honglin-H; Volkwein JC; Marple-VA; Olson-BA; Luna-PC | Proc Seventh Intl Mine Ventilation Congress. Krakow, Poland: Research and Development Center for Electrical Engineering and Automation in Mining - EMAG, 2001 Jan; :243-251	2001	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
A Comparison of a Directional Spray System and a Flooded-Bed Scrubber for Controlling Respirable Dust Exposures and Face Gas Concentrations Goodman-GVR; Pollock-DE; Beck-TW | In: Ganguli R, Bandopadhyay S, eds. Mine ventilatation: Proceedings of the 10th U.S./North American Mine Ventilation Symposium (Anchorage, AK, May 16-19, 2004). Leiden, Netherlands: Balkema, 2004; :241-248	2004	Publication	Respiratory diseases
A Comparison of Longwall & Continuous Mining Safety in U.S. Coal Mines 1988-1997 Gallagher-S; Llewellyn-R; Mattos-J | Proceedings of Longwall USA International Exhibition & Conference, 1998 :91-101	1998	Publication	Surveillance and training
A Compendium of NIOSH Mining Research 2000 NIOSH | NIOSH Publication No. 2000-109, 2000 Feb :1-75	2000	Publication	All
A Compendium of NIOSH Mining Research 2001 NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2001-114, 2001 Jan:1-68	2001	Publication	All
A Compendium of NIOSH Mining Research 2002 NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2002-110, 2001 Dec; :1-84	2001	Publication	All
A Complexity Assessment Methodology for Programmable Electronic Mining Systems Sammarco-JJ | Proc 20th Int System Safety Conf (Aug. 5-9, 2002; Denver, CO), 2002 Aug :177-186	2002	Publication	Traumatic injuries
A Computer Software Program that Estimates Air Quantity Requirements in Large Opening Stone Mines Robertson-SB; Grau-RH; Dolgos-JG; Mucho-TP | In: Ganguli R, Bandopadhyay S, eds. Mine ventilation: Proceedings of the 10th U.S./North American Mine Ventilation Symposium (Anchorage, Alaska, May 16-19, 2004). Leiden, Netherlands: Balkema, 2004 May; :363-369	2004	Publication	Mine disasters
A Correlation Between Seismic Tomography, Seismic Events and Support Pressure Westman-EC; Heasley-KA; Swanson-PL; Peterson-S | In: Elsworth D, Tinucci JP, Heasley KA, eds. Rock mechanics in the national interest, Proc 38th U.S. Rock Mechanics Symposium, Washington, DC, 2001 Jul; :319-326	2001	Publication	Ground control
A Distinct Element Parametric Study of Failure Modes Around an Underground Opening in Rock Masses of Varying Quality MacLaughlin-MM; Pakalnis-R; Brady-TM | American Rock Mechanics Association, 40th U.S. Symposium of Rock Mechanics, Anchorage, Alaska June 25-29, 2005, ARMA/USRMS 05-747	2005	Publication	Ground control
A General Framework for Prioritizing Research To Reduce Injuries and Diseases in Mining Levens-R | Human and Ecological Risk Assessment, Vol. 4, No. 6, 1998; :1285-1290	1998	Publication	Surveillance and training
A GPS Based System for Minimizing Jolts to Heavy Equipment Operators Miller-RE; Lowe-NT; Thompson-R | SAE Commercial Vehicle Engineering Congress and Exhibition, October 26-28, 2004, Chicago, IL. Warrendale, PA: Society of Automotive Engineers International, 2004 Oct; :1-4	2004	Publication	Cumulative injuries; Traumatic injuries
A Guidance Sensor for Continuous Mine Haulage Sammarco-JJ | Proc 1996 IEEE Industry Applications Society 31st Annual Meeting, Vol 4, 1996, San Diego, California, 1996; :2465-2472	1996	Publication	Traumatic injuries

Title	Year	Output Type	Strategic Goal
A Human Component to Consider in Your Emergency Management Plans: The Critical Incident Stress Factor Kowalski-KM | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin, 1998 Aug; :3-8	1998	Publication	Mine disasters
A Hybrid Statistical-Analytical Method for assessing Violent Failure in U.S. Coal Mines Maleki-HM; Zahl-EG; Dunford-JP | Proc Second International Workshop on Coal Pillar Mechanics and Design. Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 99-114, IC 9448, :139-144	1999	Publication	Ground control
A Method for Evaluating System Interactions in a Dynamic Work Environment Steiner-LJ; Turin-FC; Cornelius-KM | Advances in Occupational Ergonomics and Safety II. Amsterdam, Netherlands: IOS Press and Ohmsha, 1997 Jan; :603-606	1997	Publication	Cumulative injuries
A Method for Modeling Variation of In Situ Stress Related to Lithology Whyatt-JK | In: Elsworth D, Tinnucci JP, Heasley KA, eds. Rock Mechanics in the Public Interest. Proc 38th U.S. Rock Mechanics Symposium, DC Rocks, Vol. 2 (Washington, DC, July 7-10, 2001), Rotterdam: Balkema, 2001 Jul; :1087-1094	2001	Publication	Ground control
A Method for the Selection of Rock Support Based on Bolt Loading Measurements Signer-SP; Cox-DJ; Johnston-JL | Proceedings of the 16th International Conference on Ground Control in Mining, Peng SS, ed., Morgantown, West Virginia: West Virginia University, 1997; :183-190	1997	Publication	Ground control
A Method for the Selection of Rock Support Based on Bolt Loading Measurements Signer-SP; Cox-D; Johnston-JL | In: Broch E, Myrvang A, Stjern G, eds. Proceedings of the International Symposium on Rock Support: Applied Solutions for Underground Structures, 1997; :388-399	1997	Publication	Ground control
A Method of Measuring Continuous Detonation Rates Using Off-the-Shelf Items Santis-LD; Cortese-RA | In: Proceedings of the 22nd Annual Conference on Explosives and Blasting Technique. Orlando, FL: International Society of Explosive Engineers, 1996; :154-164	1996	Publication	Traumatic injuries
A Miniature Data Acquisition System with LED Warning Lights Sunderman-C; Signer-S; Johnson-J | In: R.K. Singhal, K. Fytas, and C. Chiwetelu, eds., Computer Applications in the Minerals Industries, Proceedings of the Fourth International Conference on Computer Applications in the Minerals Industries (CAMI 2003) (Sept 8-10, 2003; Calgary, AB), 2003 Sep	2003	Publication	Traumatic injuries
A Model for the Structure of Round-Strand Wire Ropes Wang-RC; McKewan-WM | Organisation Internationale pour l'Etude de l'Endurance des Cables (OIPEEC) (International Organization for the Study of the Endurance of Ropes) Bulletin 81. Reading, U.K.: Reading Rope Research, Departmetn of Engineering, University of Reading, 2001 Jun; :15-42	2001	Publication	Traumatic injuries
A Model Hearing Conservation Program for Coal Miners Bise-CJ; Frank-T | Cincinnati, OH: Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Final Report.- Cooperative Agreement U60/CCU315855	2004	Publication	Hearing loss
A New Look at the Uniaxial Compressive Strength of Coal Mark-C; Barton-TM | In: Aubertin M, Hassani F, Mitri H, eds. Proceedings of the Second North American Rock Mechanics Symposium: NARMS '96. Montreal, Quebec, Canada, 1996; : 405-412	1996	Publication	Ground control
A New Technology for Respirable Coal Mine Dust Measurement Williams-KL; Vinson-RP | Appl Occupational and Environmental Hyg 11(7), 1996; :618-623	1996	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
A Noise Control for Continuous Miners Kovalchik-PG; Johnson-M; Burdisso-R; Duda-F; Durr-M | Tenth International Meeting on Low-Frequency Noise and Vibration and its Control (Sept. 11-13, 2002; York, United Kingdom)	2002	Publication	Hearing loss
A Passive Means to Detect Hot Trolley Insulators Yenchek-M; Hudson-A | Min Eng 2000 Jan; 52(1):43-47	2000	Publication	Traumatic injuries
A PC Based Ergonomic Analysis Software Package for Underground Mining Equipment Unger-RL | In: Thompson SD, Grayson RL, Wang YJ, eds. Proceedings of the Fifth Conference on the Use of Computers in the Coal Industry. Morgantown, WV: West Virginia University,1996; :83-91	1996	Publication	Cumulative injuries; Traumatic injuries
A PC-Based Visibility Analysis Software Package for Underground Mining Equipment Unger-RL | In: Dhar BB, Bhowmick BC, eds. Proceedings of the 27th International Conference of Safety in Mines Research Institutes. Vol. 2, New Delhi, India: Oxford & IBH Publishing Co. Pvt. Ltd., 1997; :983-993	1997	Publication	Cumulative injuries; Traumatic injuries
A Performance Approach to Training Research Vaught-C; Wiehagen-WJ; Barrett-EA; Brnich-MJ Jr.; Kowalski-KM; Mallett-L; Rethi-LL; Randolph-R | Proceedings of Minesafe International 2000 (Perth, Western Australia, September 3-8, 2000). Perth, Australia, 2000 Sep; :155-164	2000	Publication	Surveillance and training
A Portable Spectro-Polarimetric Imager: Potential Mine Safety and Geologic Applications Sabine-C; Denes-LJ; Gottlieb-M; Kaminsky-B; Metes-P; Maycrle-RT; Girard-JM | Proceedings of the Thirteenth International Conference, Applied Geologic Remote Sensing, Vancouver, British Columbia, Canada, 1-3 March 1999; 1:I190-I194	1999	Publication	Ground control
A Profile of Workers' Experience and Preparedness in Responding to Underground Mine Fires Vaught-C; Fotta-B; Wiehagen-WJ; Conti-RS; Fowkes-RS | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 9584. NTIS stock number: PB96-147848, 1996	1996	Publication	Mine disasters
A Project to Evaluate the Role Positive and Negative Emotion Plays in Promoting Hearing Conservation Behaviors Among Coal Miners Witte-K; Vaught-C; Stephenson-M | Proceedings of the Sixth International Conference of the Scientific Committee on Education and Training in Occupational Health, 2002; :81-82	2002	Publication	Hearing loss
A Radar-based Highwall Rib-Thickness Monitoring System Mowrey-GL; Ganoe-CW; Monaghan-WD | Trans Soc Min Eng, Vol. 298,1996; :1865-1869	1996	Publication	Ground control
A Review of Occupational Silica Exposures on Continuous Mining Operations Goodman-GVR; Listak-JM; Organiscak-JA | Proc 31st Annual Inst Min Health Saf Research, Blacksburg, VA, Bockosh GR, Karmis M, Langton J, McCarter MK, Rowe B, eds., Virginia Polytechnic Institute and State University, Dept of Mining and Minerals Engineering, 2000 Jan; :105-113	2000	Publication	Respiratory diseases
A Second-Generation Remote Optical Methanometer Franks-RA; Opferman-JJ; Friel-GF; Edwards-JC | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Publication No. 97-126, Report of Investigations 9640, 1997 May; :1-9	1997	Publication	Mine disasters
A Second-Generation Remote Optical Methanometer Franks-RA; Opferman-JJ; Friel-GF; Edwards-JC | In: Proceedings of the 43rd International Instrumentation Symposium. ISA, 1997; :527-536	1997	Publication	Mine disasters
A Simulation Approach Analyzing Random Motion Events Between a Machine and its Operator Ambrose-DH | In: Proceedings of the Digital Human Modeling for Design and Engineering Conference and Exposition, Dearborn, Michigan, June 6-8, 2000. Paper No. 2000-01-2160. Warrendale, PA: SAE International, 2000 Jun; :1-11	2000	Publication	Traumatic injuries

Title	Year	Output Type	Strategic Goal
A Sociotechnical Approach to the Unintended Consequences of Technical Design in Mining Vaught-C; Wiehagen-WJ; Steiner-LJ; Cornelius-KM; Turin-FC; Mallett -LG, et al | In: Proceedings of the 28th International Conference of Safety in Mines Research Institutes (Sinaia, Romania), Vol. II, 1999; :687-697	1999	Publication	Surveillance and training
A Sound Power Level Study of a Roof Bolter Peterson-JS; Kovalchik-PG; Matetic-RJ | SME Preprint No. 05-72, 2005 SME Conference, Salt Lake City, Utah, 2005; :8 pp	2005	Publication	Hearing loss
A Static Fatigue Constitutive Law for Joints in Weak Rock Larson-MK | Proc Third Intl Conf on Mechanics of Jointed and Faulted Rock, Vienna, Austria; April 6-9, 1998; :171-177	1998	Publication	Ground control
A Statistical Overview of Retreat Mining of Coal Pillars in the United States Mark-C; McCall-FE; Pappas-DM | In: Peng SS, ed., Proceedings of the 16th International Conference on Ground Control in Mining, Morgantown, WV: West Virginia University; 204-210	1997	Publication	Ground control; Surveillance and training
A Study of Burnout in Accident Investigators in the US Mining Industry Kowalski-K; Podlesny-A | International Journal of Emergency Management 1(2), 2002 Jan; :155-169	2002	Publication	Mine disasters; Surveillance and training
A Study of Heat Stress Exposures and Interventions for Mine Rescue Workers Varley-F | Trans Soc Min Metal Explor 2004 Dec; 316:133-142	2004	Publication	Surveillance and training
A Study of Heat Stress Exposures and Interventions for Mine Rescue Workers Varley-F | 2004 SME Annual Meeting (Feb 23-25, 2004; Denver, CO), Preprint No. 04-107. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2004 Feb; :1-11	2004	Publication	Surveillance and training
A Study of Logger Fatalities from 1992-2000 Scott-DF | Injury Prevention, vol. 10, 2004; :239-243	2004	Publication	Surveillance and training
A Study of the Ground Control Effects of Mining Longwall Faces Into Open or Backfilled Entries Oyler-DC; Mark-C; Dolinar-DR; Frith-RC | Geotech Geol Eng 2001 Jan; 19(2):137-168	2001	Publication	Ground control
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A Systematic Comparison of Different Seats on Shuttle Cars Used in Underground Coal Mines Kittusamy-NK; Mayton-AG; Jobes-CC; Ambrose-DH | In: Proceedings of Inter-Noise 2003, the 32nd International Congress and Exposition on Noise Control Engineering (Seogwipo, Korea, Aug. 25-28, 2003). 2003 Aug; :2025-2032	2003	Publication	Cumulative injuries; Traumatic injuries
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A Technique For Measuring Toxic Gases Produced by Blasting Agents Mainiero-RJ | Proc 23rd Annual Conference on Explosives and Blasting Technique. Cleveland, OH: International Society of Explosives Engineers, 1997 Jan; :595-604	1997	Publication	Traumatic injuries

Title	Year	Output Type	Strategic Goal
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A Workplace Safety Device for Operators of Remote-Controlled Continuous Mining Machines Schiffbauer-WH | American Journal of Indus Med, Vol 36, Sup 1, 1999 Sep; :69-71	1999	Publication	Traumatic injuries
Acceleration and GPS Data Monitor Truck-Haulage Jolts Miller-RE; Boman-P; Walden-J; Rhoades-S; Gibbs-R | Min Eng, 52(8):20-22	2000	Publication	Cumulative injuries; Traumatic injuries
Accurate Navigation and Control of Continuous Mining Machines for Coal Mining Schiffbauer-WH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSHss, DHHS (NIOSH) Publication No. 98-101, Report of Investigations 9642, 1997 Nov; :1-33	1997	Publication	Traumatic injuries
Acoustical Considerations in the Design of Minerals Processing Plants Burks-JA; Rider-JP; Cecala-AB | In: Proceedings of the 1998 National Conference on Noise Control Engineering (Noise-Con 98), 1998; :443-448	1998	Publication	Hearing loss; Respiratory diseases
Active Promixity Warning Systems for Surface and Underground Mining Applications Schiffbauer-WH | Min Eng 54(12):40-48	2002	Publication	Traumatic injuries
Addressing Small Mine Issues in the NIOSH Mine Safety and Health Research Program Grayson-RL | In: Proceedings of the Third Health and Safety Seminar for Small Mines (Somerset, PA). University Park, PA: The Pennsylvania State University, 1998	1998	Publication	Surveillance and training
Addressing the Safety of Programmable Electronic Mining Systems: Lessons Learned Sammarco-JJ | Proc 2002 IEEE 37th Industry Applications Society Ann Meet, Pittsburgh, Pennsylvania, 2003 :692-698	2003	Publication	Traumatic injuries
Administrative Controls for Reducing Worker Noise Exposures Bauer-ER; Babich-DR | SME preprint 04-09. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2004; :1-9	2004	Publication	Hearing loss
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Advances in Remote Sensing Techniques for Monitoring Rock Falls and Slope Failures Girard-JM; Mayerle-RT; McHugh-EL | Proc 17th Intl Conference on Ground Control in Mining, 1998 Aug :326-331	1998	Publication	Ground control
Airborne Dust Liberation During Coal Crushing Organiscak-JA; Page-SJ | Coal Prep, 2001 Jun 21:423-453	2001	Publication	Respiratory diseases
Alarm System for Detecting Hazards Due to Power Transmission Lines Sacks-HK; Yenchek-MR; Homce-GT; Cawley-JC | U.S Patent #6,600,426 (granted July 29, 2003)	2003	Patent	Traumatic injuries

Title	Year	Output Type	Strategic Goal
Alternative Methodologies for Evaluating Explosion-resistant Mine Ventilation Seals Sapko-MJ; Weiss-ES; Harteis-SP | In Proceedings of the 30th International Conference of Safety in Mines Research Institutes. Johannesburg, Republic of South Africa: South African Institute of Mining and Metallurgy, 2003 Oct; :615-640	2003	Publication	Mine disasters
An Active Proximity Warning System for Surface and Underground Mining Applications Schiffbauer-WH | SME Annual Meeting (Denver, CO; Feb 26-28, 2001), Preprint No. 01-117, SME, Inc., 2001 Feb; :1-8	2001	Publication	Traumatic injuries
An Alarm to Warn of Overhead Power Line Contact by Mobile Equipment Homce-GT; Cawley-JC; Yenchek-MR; Sacks-HK | Conference Record of the 2001 IEEE Industry Applications Conference, 36th IAS Annual Meeting (Chicago, Illinois, September 30-October 4, 2001); :8 pp	2001	Publication	Traumatic injuries
An Analysis and Prevention of Flyrock Accidents in Surface Blasting Operations Bajpayee-TS; Verakis-HC; Lobb-TE | Proc 30th Ann Conf Explos Blasting Tech, New Orleans, LA, February 1-4, 2004, 2004 Feb; :1-10	2004	Publication	Traumatic injuries
An Analysis of Rock Failure Around a Deep Longwall Using Microseismics Heasley-KA; Ellenberger-JL; Jeran-PW | 20th Intl Conf on Ground Control in Mining. Morgantown, WV: West Virginia University, 2001 Aug; :280-286	2001	Publication	Ground control
An Analysis of Serious Injuries to Dozer Operators in the U.S. Mining Industry Wiehagen-WJ; Mayton-AG; Jaspal-JS; Turin-FC | NIOSH Publication No. 2001-126, IC 9455, 2001 Apr :1-23	2001	Publication	Surveillance and training; Traumatic injuries
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An Approach to Identifying Geological Properties from Roof Bolter Drilling Parameters Finfinger-GL; Peng-SS; Gu-Q; Wilson-G; Thomas-B | Proc 19th Intl Conf on Ground Control in Mining, 2000, Peng-SS, Mark-C, eds. Morgantown, WV: West Virginia University, 2000; :1-11	2000	Publication	Ground control
An Assessment of Occupational Silica Exposures on Continuous Mining Operations Goodman GVR, Listak J, Organiscak JA | SME Trans, Vol. 310. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2001	2001	Publication	Respiratory diseases
An Electromagnetic Spatial/Spectral Sensor for Geological Measurements Chufo-RL | Proc Sixth International Conference on Ground Penetrating Radar 1996 Sep 30 - Oct 3 Sendai, Japan Tohoku University, Dept. of Geoscience and Technology, 1996; :545-547	1996	Publication	Ground control
An Emissions-Assisted Maintenance Procedure for Diesel-Powered Equipment Schnakenberg-G | Web document, http://www.cdc.gov/niosh/mining/topics/diesel/eamp/eamp.htm	1997	Web document	Respiratory diseases
An Environmentally Robust Proximity Warning System for Hazardous Areas Schiffbauer-WH; Mowrey-GL | in: Proceedings of the ISA Emerging Technologies Conference. Research, 2001, Triangle Park, North Carolina, Instrumentation, Systems, and Automation Society, Paper No. 2091; 2001; :10 pp	2001	Publication	Traumatic injuries

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An Evaluation of Cab Filtration and Pressurization Systems: Two Case Studies Chekan-GJ; Cecala-AB; Colinet-JF | In: Proceedings of the Environment, Safety & Health Forum and Expo (Phoenix, AZ, Sept. 22-24, 2003). Alexandria, VA: National Stone, Sand & Gravel Association, 2003; :114-129	2003	Publication	Respiratory diseases
An Evaluation of Methods for Controlling Silica Dust Exposures on Roof Bolters Goodman-GVR; Organiscak-JA | 2002 SME Annual Meeting, Feb 25-27, Phoenix, Arizona, preprint 02-163. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2002 Feb; :1-5	2002	Publication	Respiratory diseases
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An Evaluation of Strata Behavior and Tailgate Support Performance of Eagle Nest Mine Mucho-TP; Compton-CS; Oyler-DC; Zelanko-JC; Horvath-S | In: Ozdemir L, Hanna K, Haramy KY, Peng S, eds. Proceedings of the 15th International Conference on Ground Control in Mining. Golden, CO: Colorado School of Mines,1996; :523-526	1996	Publication	Ground control
An Examination of the Loyalhanna Limestone's Structural Features and their Impact on Mining and Ground Control Practices Iannacchione-AT; Coyle-PA | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 21st International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2002 Aug; :218-227	2002	Publication	Ground control
An Experimental Study of the Relationship Between Bearing Vibrations and Deterioration of Induction Machine Stator Windings Trutt-FC; Kohler-JL; Sottile-J | In: Proceedings of the 26th National Technical Training Symposium of the Vibration Institute (Pittsburgh, PA), 2002; :135-141	2002	Publication	Traumatic injuries
An Instrumented Cable Martin-L | Sensors, The Journal of Applied Sensor Technology, 1999 Apr; :1 p	1999	Publication	Ground control
An Investigation of Longwall Gob Gas Behavior and Control Methods Schatzel-SJ; Diamond-WP; Garcia-F; Mucho-TP; LaScola-JC; McCall-FE; Jeran-PW | In: Tien JC, ed. Proceedings of the Eighth U.S. Mine Ventilation Symposium, Rolla, MO: University of Missouri-Rolla Press, 1999; :43-51	1999	Publication	Mine disasters
An Oral History Analysis of Mine Emergency Response Vaught-C; Brnich-MJ; Mallett-LG | NIOSH Publication No. 2004-145, IC 9471, 2004 Apr :1-77	2004	Publication	Mine disasters
An Ounce of Prevention: Training Workers to Prevent a Crisis Mallett-L; Brnich-MJ, Jr; Vaught-C | Proc Contingency Planning & Management Conference (CPM '99). Flemington, New Jersey, Witter Publishing Corp., 1999 Apr; :21-27	1999	Publication	Surveillance and training
An Overview of Geomechanics Safety Research on Mobile Roof Supports Maleki-H; Owens-J | System Safety at the Dawn of a New Millennium. Proceedings, 17th International System Safety Conference, Orlando, FL, Aug 16-21, 1999. Unionville, VA: System Safety Society, 1999 Jan; :554-563	1999	Publication	Ground control
An Overview of Groundfall Injuries and Worker Activity in Underground Stone Mines Pappas-DM; Prosser-LJ Jr | MSHA Holmes Safety Association Bulletin, 2001 Aug:8-14	2001	Publication	Ground control

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An Overview of Standing Roof Support Practices and Developments in the United States Barczak-TM | Proceedings of the Third South African Rock Engineering Symposium, Johannesburg, Republic of South Africa: South African Institute of Mining and Metallurgy, October 10-12, 2005; :301-334	2005	Publication	Ground control
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An Overview of the Evaluation Process for Mine Trainers Mallett-L; Reinke-D | In: Peters R, ed. Strategies for Improving Miners' Training. Pittsburgh, PA, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2002-156, Information Circular 9463, 2002 Sep :13-17	2002	Publication	Surveillance and training
An Underground Coal Mine Fire Preparedness and Response Checklist: The Instrument Conti-RS; Chasko-LL; Lazzara-CP; Braselton-G | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Publication No. 2000-144, IC 9452, 2000 Aug; :151 pp	2000	Publication	Mine disasters
An Update on Face Ventilation Research for Improved Longwall Dust Control Jankowski-RA; Colinet-JF | SME preprint 98-82. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 1998	1998	Publication	Respiratory diseases
Analyses of Mobile Equipment Fires for All U.S. Surface and Underground Coal and Metal/Nonmetal Mining Categories, 1990-1999 De Rosa-MI | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevetnion, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publicaion No. 2004-105, IC 9467, 2004 Jan; :1-53	2004	Publication	Mine disasters; Surveillance and training
Analysis and Design of Rib Support (ADRS): A Rib Support Design Methodology for Australian Collieries Colwell-M; Mark-C | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 24th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2005; :12-22	2005	Publication	Ground control
Analysis and Prediction of Longwall Methane Emissions: A Case Study in the Pocahontas No. 3 Coalbed, VA Diamond-WP; Garcia-F; Aul-GN; Ray-RE | In: Ramani RV, ed. Proceedings of the 6th International Mine Ventilation Congress, Chapter 35. Society for Mining, Metallurgy, and Exploration, Inc.: Littleton, CO, 1997; :223-229	1997	Publication	Mine disasters
Analysis of Bench Crest Performance at the Yellowstone Mine: A Case Study Whyatt-J; McLaughlin-M; Miller-S | Proceedings of the 39th Symposium on Engineering Geology and Geotechnical Engineering: Research to Practice, May 18-19, 2004. M. McLaughlin and R. McNearny, eds., Butte, MT: Montana Tech of the University of Montana, 2004 May; :149-163	2004	Publication	Ground control
Analysis of Extensometer Data from a Room Widening Experiment Designed to Induce a Roof Fall Dolinar-DR; Oyler-DC; Compton-CS | In: Peng SS, ed. Proceedings of the 16th International Conference on Ground Control in Mining, Morgantown, WV: West Virginia University, 1997; :289-295	1997	Publication	Ground control

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Analysis of Mine Fires for All U.S. Metal/Nonmetal Mining Categories, 1990-2001 De Rosa-MI | Pittsburgh, PA: U.S. Department of Heatlh and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-105, IC 9476, 2004 Nov; :1-52	2004	Publication	Mine disasters
Analysis of Mine Fires for All U.S. Underground and Surface Coal Mining Categories: 1990-1999 De Rosa-MI | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health , DHHS (NIOSH) Publication No. 2004-167, 2004 Sep; IC 9470; :1-36	2004	Publication	Mine disasters
Analysis of Non-Fatal and Fatal Injury Rates for Mine Operator and Contractor Employees and the Influence of Work Location Karra-VK | Journal of Safety Research, Vol 36 No 5; :413-421	2005	Publication	Cumulative injuries; Surveillance and training; Traumatic injuries
Analysis of Pillar Design Practices and Techniques for U.S. Limestone Mines Iannacchione-AT | In Trans Inst Min Metall, (Sec A: Mining Industry), 1999 Dec 108(Sept-Dec):A152-A160	1999	Publication	Ground control
Analysis of Practical Ground Control Issues in Highwall Mining Zipf Jr-RK; Bhatt-SK | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining. Morgantown, WV, August 3-5, 2004: West Virginia University, 2004 Aug; :210-219	2004	Publication	Ground control
Analysis of Roof Bolt Systems Mark-C; Molinda-GM; Dolinar-DR | 20th Intl Conf on Ground Control in Mining. Morgantown, WV: West Virginia University, 2001 Aug; :218-225	2001	Publication	Ground control
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Analysis of Sampling Line Bias on Respirable Mass Measurement Peters-TM; Volkwein-JC | Appl Occup Environ Hyg 18(6); :458-465	2003	Publication	Respiratory diseases
Analysis of the Interaction Between Mobile Roof Supports and Mine Strata Maleki-H; Owens-J | Design and Construction in Mining, Petroleum and Civil Engineering, 1998, Nov :287-293	1998	Publication	Ground control
Anchorage Pull Testing for Fully Grouted Roof Bolts Mark-C; Compton-CS; Oyler-DC; Dolinar-DR | Proc 21st Intl Conf on Ground Control in Mining. Morgantown, WV: West Virginia University, 2002 Aug; :105-113	2002	Publication	Ground control
Apparatus and Method for Generating Power Onboard a Hoist Conveyance Beus-MJ; Sunderman-C; Rains-R; Lazenga-N | U.S. Patent # 6626267 (granted Sept. 2003)	2003	Patent	Traumatic injuries

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Application of Computers and Operations Research in the Mineral Industry: Proceedings of the 32nd International Symposium on the Application of Computers and Operations Research in the Mineral Industry Dessureault-S; Kecojevic-V, Ganguli-R; Dwyer-J (eds.) | Tucson, USA, 30 March-1 April, 2005. A.A. Balkema Publishers; 648 pp.	2005	Publication	Surveillance and training
Application of Field Measurements and Computer Modeling to Evaluate Deep Mine Shaft Stability in Northern Idaho Beus-MJ; Orr-TJ; Whyarr-JK | Spokane, WA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 9600. NTIS stock number: PB96-140181, 1996	1996	Publication	Ground control; Traumatic injuries
Application of Ground Penetrating Radar to Assess Ground Control Problems in Two Underground Limestone Mines Trevits-MA; Monaghan-WD; Mucho-TP | In: Proceedings of the Symposium on the Application of Geophysics to Environmental and Engineering Problems (SAGEEP 2004). Denver, CO: Environmental and Engineering Geophysical Society 2004; :788-805	2004	Publication	Ground control
Application of Ground Penetrating Radar to Evaluate the Extent of Polyurethane Grout Infiltration for Mine Roof Control: A Case Study Monaghan-WD; Trevits-MA | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University; :197-204	2004	Publication	Ground control
Application of Numerical Models to Investigate Permeability Changes and Gas Emissions Around Longwall Mining Panels Esterhuizen-G; Karacan-CO | Proceedings of the 40th US Rock Mechanics Symposium (Anchorage, Alaska), CD-ROM, paper 05-744; :13 pp	2005	Publication	Mine disasters
Application of Online Voltage Mismatch Condition Monitoring of Induction Motor Stator Windings in a Mining Environment Sottile-J; Trutt-F; Kohler-JL | In: Proceedings of the 38th Annual IEEE - IAS Meeting, October 13-17, Salt Lake City, UT, 2003, 2003; :1637-1644	2003	Publication	Traumatic injuries
Application of Particle Flow Code To Evaluate a Concept for Detecting Hazardous Voids in Surge Piles Using Profile Scanning Larson-MK; Iverson-SR | In: D. Elsworth, J.P. Tinnucci, and K.A. Heasley, eds. Rock Mechanics in the Public Interest. Proceedings of the 38th U.S. Rock Mechanics Symposium, DC Rocks, Vol 1, (July 7-10, 2001; Washington, DC), Balkema, 2001 Jul; :459-465	2001	Publication	Ground control
Application of Physical Modelling and Particle Flow Analysis to Evaluate Ore-pass Design Beus-MJ; Iverson-S; Stewart-B | Inst Min Metall, Trans, Sect A: Min Ind, 1998 Sep 106():A110-A117	1997	Publication	Ground control; Traumatic injuries
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Application of Radio-Frequency Identification Systems to Collision Avoidance in Metal/Nonmetal Mines Ruff-TM; Hession-Kunz-D | IEEE Transactions on Industry Applications, 37(1), 2001; :112-116	2001	Publication	Traumatic injuries

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Application of Seismic Tomography in Underground Mining Scott-DF; Williams-TJ; Friedel-MJ | In: Ozdemir L, Hanna K, Haramy KY, Peng S, eds. Proceedings of the 15th International Conference on Ground Control in Mining. Golden, CO: Colorado School of Mines, 1995; :647-659	1996	Publication	Ground control
Application of the Coal Mine Roof Rating (CMRR) to Extended Cuts Mark-C | SME preprint 98-190. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 1998	1998	Publication	Ground control
Application of the Coal Mine Roof Rating (CMRR) to Extended Cuts Mark-C | Min Eng 51(4); :52-56	1999	Publication	Ground control
Application of Tomographic Imaging to Stability Assessment Maleki-H; Johnston-JL | In: Ozdemir L, Hanna K, Haramy KY, Peng S, eds. Proceedings of the 15th International Conference on Ground Control in Mining. Golden, CO: Colorado School of Mines, 1996; :369-383	1996	Publication	Ground control
Applications of Ground-Based Radar to Mine Slope Monitoring McHugh-EL; Long-DG; Sabine-C | Presentation at annual conference of American Society for Photogrammetry and Remote Sensing, Denver, May 23-28, 2004; :12 pp	2004	Publication	Ground control
Applications of the Point Estimation Method for Stochastic Rock Slope Engineering Miller-S; Whyatt-J; McHugh-E | Gulf Rocks 2004: Proceedings, Rock Mechanics Across Borders & Disciplines, 6th North American Rock Mechanics Conference, June 5-10, 2004, Houston, Texas. Report No. ARMA/NARMS 04-517. Alexandria, VA: American Rock Mechanics Association, 2004 Jun; :1-12	2004	Publication	Ground control
Are You Operating an Air Rotary Drilling Rig? Is It Loud? Ingram-DK; Matetic-RJ | Water Well Journal, 57(7), 2003; :18-22	2003	Publication	Hearing loss
Assessing and Monitoring Open Pit Mine Highwalls Girard-JM	2001	Publication	Ground control
Assessing Mercury Health Effects in Gold Workers Near El Callao, Venezuela Rojas-M; Drake-PL; Roberts-SM | Journal of Occupational and Environmental Medicine, vol. 43, no. 2, 2001; :158-165	2001	Publication	Surveillance and training
Assessment of Ergonomic Risk Factors Among Operators of Heavy Earthmoving Machinery Kittusamy-NK | In: Proceedings of the 2003 ASSE Professional Development Conference (Denver, CO, June 22-26, 2003), American Society of Safety Engineers, 2003 Jun; :11 pp	2003	Publication	Cumulative injuries
Assessment of Noise Controls Commonly Used on Jumbo Drills and Bolters in Western Underground Metal Mines Reeves-ER | SME preprint 04-112. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.; :7 pp	2004	Publication	Hearing loss
Assessment of Noise Controls Commonly Used on Jumbo Drills and Bolters in Western United States Underground Metal Mines Reeves-ER | Min Eng 57(1), 2005; :41-47	2005	Publication	Hearing loss
Assessment of Respirable Quartz Dust Explosures at Roof Bolters In Underground Coal Mining Goodman-GVR; Organiscak-JA | Journal of the Mine Ventilation Society S Afr 56(2), 2003; :50-54	2003	Publication	Respiratory diseases
Automated-PC-Networked-Based Seismic Monitoring Systems Applied to Mining Hazards Research Swanson-P | Seismological Research Letters, 71(1), 2000; :234	2000	Publication	Ground control
Bag and Belt Cleaner Reduces Employee Dust Exposure Cecala-AB; Timko-RJ; Prokop-AD | Rock Prod 100 (3),1997 Mar; :41-43	1997	Publication	Respiratory diseases

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Barricading Makes a Comeback? Brnich-MJ Jr.; Vaught-C | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin, 1997 Nov; :14	1997	Publication	Mine disasters
Behavior of a Limestone Roof Supported by Spot Bolting Dolinar-DR; Mucho-TP | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin 1999 Mar; :19	1999	Publication	Ground control
Behavioral and Organizational Dimensions of Underground Mine Fires Vaught-C; Brnich-MJ; Mallett-LG; Cole-HP; Wiehagen-WJ; Conti-RS; Kowalski-KM; Litton-CD | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Publication No. 2000-126, Information Circular 9450, 2000 May :1-240	2000	Publication	Mine disasters
Belt Fires and Mine Escape Problems Kovac-JG; Kravitz-JH; Lazzara-CP | In: Proceedings of Longwall USA. Pittsburgh, PA, 1995; :65-75	1996	Publication	Mine disasters
Best Practices and Bolting Machine Innovations for Roof Screening Robertson-SB; Molinda-GM; Dolinar-DR; Pappas-DM; Hinshaw-GE | 2003 SME Annual Meeting, Feb 24-26, Cincinnati, Ohio, preprint 03-158. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.; :1-8	2003	Publication	Ground control
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Biomechanics of a Cable Hanging Task Gallagher-S | In: Kumar S, ed. Advances in Occupational Ergonomics and Safety - Proceedings of the XIIIth Annual International Occupational Ergonomics and Safety Conference 1998, IOS Press, 1998; :244-247	1998	Publication	Cumulative injuries
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Title	Year	Output Type	Strategic Goal
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Characteristics of Fugitive Dust Generated from Unpaved Mine Haulage Roads Organiscak-JA; Reed-WR | Int J Surface Min Reclam Envirom 18(4)2004; :236-252	2004	Publication	Respiratory diseases
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Title	Year	Output Type	Strategic Goal
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Clothes Cleaning Process: Instructional Materials NIOSH | NIOSH 2004; :1-16	2004	Publication	Respiratory diseases; Surveillance and training
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Coaching Skills for On-the-Job Trainers Mallett-LG; Kowalski-Trakofler-K, Vaught-C; Wiehagen-WJ; Peters-RH; Keating-P | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-146, Information Circular 9479	2005	Publication	Surveillance and training
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Coal Operator Mining Facts - 2002 NIOSH | NIOSH Publication No. 2004-123, 2004 Jan; :1 pp	2004	Publication	Surveillance and training
Coal Operator Mining Facts - 2003 NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-114, 2005 Feb; :1	2005	Publication	Surveillance and training
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Comparison of Ground Conditions and Ground Control Practices in the United States and Australia Mark-C | Proc 17th Intl Conf on Ground Control in Mining, Peng SS, ed., Morgantown, WV: West Virginia University, 1998 Aug :63-71	1998	Publication	Ground control
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Controlling Roof Beam Failures From High Horizontal Stresses in Underground Stone Mines Iannacchione AT, Dolinar DR, Prosser LJ Jr., Marshall TE, Oyler DC, Compton CS | In: Aziz NI, Indraratna B, eds. Proceedings of the International Conference on Geomechanics/Ground Control in Mining and Underground Construction, Wollongong, New South Wales, Australia: University of Wollongong, Vol. 2, 1998; :525-541	1998	Publication	Ground control
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Title	Year	Output Type	Strategic Goal
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Cripple Creek Deep Cut: An Exercise for Remote Control Miner Operators and Face Crews Steiner-LJ; Brnich-MJ; Duncan-J; Vaught-C; Calhoun-RA; Cornelius-KC; Rethi-LL; Rossi-EW; Turin-FC | National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 99-159, 1999 Oct :1-44	1999	Publication	Surveillance and training; Traumatic injuries
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Current Research on Slope Movement in Mines: Use of Hyperspectral Imagery McHugh-EL; Girard-JM; Denes-LJ; Metes-P; Sabine-C | 14th International Conference on Applied Geologic Remote Sensing, 2000 Nov Las Vegas, NV :1-8	2000	Publication	Ground control
Current State of Insert-Type Hearing Protector Fit-Testing: Follow-On Measurements in the Steel Industry and Fit-Testing in a Mobile Environment Byrne-DC; Michael-KL | Spectrum 19(1):14-16	2002	Publication	Hearing loss
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Title	Year	Output Type	Strategic Goal
Description of a Large Catastrophic Failure in a Southwestern Wyoming Trona Mine Zipf-RK; Swanson-P | Rock Mechanics for Industry. Proceedings of the 37th U.S. Rock Mechanics Symposium (Vail, CO, June 6-9, 1999), B. Amadei, R. L. Kranz, G. A. Scott, and P. H. Smeallie eds., Balkema, 1999 Jun; :293-298	1999	Publication	Ground control
Design Analysis of Underground Mine Ore Passes: Current Research Approaches Beus-MJ; Iverson-SR; Stewart-BM | Presentation at the 100th CIM Conference (Montreal, Quebec, Canada, May 3-7, 1998); 8 pp	1998	Publication	Ground control
Design and Demonstration of a Continuous Dust Control Parameter Monitoring System Spencer-ER; Kovscek-PD; Fields-KG | Pittsburgh, PA: U.S. Department of Energy, Report of Investigations 9623. NTIS stock number: PB96-188156, 1996	1996	Publication	Respiratory diseases
Design and Demonstration of a Continuous Dust Control Parameter Monitoring System Spencer-ER; Kovscek-PD; Fields-KG | In: Proceedings of Longwall USA. Pittsburgh, PA, 1996; :121-132	1996	Publication	Respiratory diseases
Design and Hazard Assessment of Mine Ore Passes Beus-MJ; Stewart-BM; Iverson-S | In: Ozdemir L, Hanna K, Haramy KY, Peng S, eds. Proceedings of the 15th International Conference on Ground Control in Mining. Golden, CO: Colorado School of Mines, 1996; :297-309	1996	Publication	Ground control; Traumatic injuries
Design and Instrumentation of a Large Reverberation Chamber Peterson-JS; Bartholomae-RC | NOISE-CON. Ames, IA: Institute of Noise Control Engineering of the USA, 2003 Jun; :1-8	2003	Publication	Hearing loss
Design and Testing of a Nondestructive Friction Bolt Tester Martin-L; Goris-J; Roberts-L | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2004-131, Information Circular 9469, 2004 Mar :1-6	2004	Publication	Ground control
Design Considerations for the Next Generation of Longwall Shields Barczak-TM | In: Proceedings of Longwall USA International Exhibition & Conference. Overland Park, KS: Intertec Publishing Corp., 2001; :17-38	2001	Publication	Ground control
Design in Weak Rock Masses: Nevada Underground Mining Operations Brady-T; Pakalnis-R; Clark-L | Presentation at annual meeting of SME, Salt Lake City, UT, Feb. 28-Mar. 2, 2005. Preprint 05-43, 2005; : 9 pp	2005	Publication	Ground control
Design Methodology for Standing Secondary Roof Support in Longwall Tailgates Mucho-TP; Barczak-TM; Dolinar-DR; Bower-J; Bryja-JJ | In: Proceedings of the 18th International Conference on Ground Control in Mining, Peng SS, Mark C, eds., Morgantown, WV: West Virginia University, 1999; :136-148	1999	Publication	Ground control
Design Methods to Control Violent Pillar Failures in Room-and-Pillar Mines Zipf-RK Jr.; Mark-C | Transactions of the Institution of Mining and Metallurgy 106(Sept-Dec), 1997; :A124-A132	1997	Publication	Ground control
Design Methods to Control Violent Pillar Failures in Room-and-Pillar Mines Zipf-RK Jr.; Mark-C | In: Ozdemir L, Hanna K, Haramy KY, Peng S, eds. Proceedings of the 15th International Conference on Ground Control. Golden, CO: Colorado School of Mines, 1996; :571-585	1996	Publication	Ground control
Design of Ore Passes Beus-MJ; Pariseau-WG; Stewart-BM Iverson-SR | Ch. 71 in Underground Mining Methods: Engineering Fundamentals and International Case Studies, William Hustrulid and Richard Bullock, eds., Society for Mining, Metallurgy, and Exploration, Littleton, CO, 2001; :627-634	2001	Publication	Traumatic injuries

Title	Year	Output Type	Strategic Goal
Design of Primary Roof Support Systems in U.S. Coal Mines Based on the Analysis of Roof Fall Rates Dolinar-DR; Mark-C; Molinda-GM | Proc Fourth Intl Symp on Roof Bolting in Mining, Aachen, Germany, Martens-PN ed., Druckerei Mainz GmbH; 2001; ::235-252	2001	Publication	Ground control
Design of U.S. Longwall Gate Entry Systems Mark-C | In: Milestones in Rock Engineering - The Bieniawski Jubilee Collection. Balkema, 1996; :s291-307	1996	Publication	Ground control
Design Parameters of Roof Support Systems for Pre-Driven Longwall Recovery Rooms Tadolini-SC; Barczak-TM | 2004 SME Annual Meeting, Feb 23-25, Denver, Colorado, preprint 04-54. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2004 Feb; :1-13	2004	Publication	Ground control
Design Spans: Underhand Cut-and-Fill Mining Pakalnis R, Caceres C, Clapp K, Morin M, Brady T, Williams T, et al. | Montreal, Quebec, Canada: Canadian Institute of Mining, Metallurgy, and Petroleum, pp. 1-9. [http://www.cim.org/meetings/techpapers/44/s44a2214p1883.pdf]	2005	Publication	Ground control
Designs for Rapid In-Situ Sealing Sapko-MJ; Weiss-ES; Trackemas-J; Stephan-CR | In: Proceedings of the Annual Meeting of the Society for Mining, Metallurgy, and Exploration, Inc (Feb 2003; Cincinnati, OH). Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc; :8 pp	2003	Publication	Mine disasters
Detecting Problems With Mine Slope Stability Girard-JM; McHugh-E | Presentation at 31st Annual Institute on Mining Health, Safety, and Research, Roanoke, VA, Aug. 27-30, 2000; :8 pp	2002	Publication	Ground control
Detection of A-C Machine Winding Deterioration Using Electrically Excited Vibrations Trutt-FC; Sottile-J; Kohler-JL | Proc IEEE Industry Applications Conference, 34th IAS Annual Meeting, 1999 Phoenix, AZ Oct 3-7 IEEE Standards Office1999 Oct; :1903-1907	1999	Publication	Traumatic injuries
Detection of A-C Machine Winding Deterioration Using Electrically Excited Vibrations Trutt-FC; Sottile-J; Kohler-JL | IEEE Transactions on Industry Applications Vol. 37-1, 2001; :10-14	2001	Publication	Traumatic injuries
Detection of A-C Machine Winding Deterioration Using Electrically Excited Vibrations Trutt-FC; Sottile-J; Kohler-JL | In: Proceedings of the Maintenance and Reliability Conference, 1999; :8.01-8.08	1999	Publication	Traumatic injuries
Detection of Downed Trolley Lines Using Arc Signature Analysis Peterson-JS; Cole-GP | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Publication No. 97-123, Report of Investigations 9639 1997 May :1-13	1997	Publication	Traumatic injuries
Detection of Electrical Winding Deterioration in Induction Motors Trutt-FC; Sottile-J; Kohler-JL | Electric Power Components and Systems, Taylor & Francis 29:1025-1033	2001	Publication	Traumatic injuries
Determination of In Situ Deformation Modulus for Cemented Rockfill Tesarik-DR; Seymour-JB; Jones-FM | Technology Roadmap for Rock Mechanics, 10th Congress, International Society for Rock Mechanics (Sandton [Johannesburg], S. Africa, Sept. 8-10, 2003), S. African Institute of Mining and Metallurgy Symp. Series, S33, Vol. 2, 2003 Sep; :1209-1220	2003	Publication	Ground control
Determination of Physical Properties of Cable Bolts in Cement Grout Pull Tests Using Instrumented King Wires Martin-L; Pakalnis-R; Milne-D | Presentation at Canadian Institute of Mining annual conference, Vancouver, BC, 2002 Apr; 8 pp.	2000	Publication	Ground control

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Developing a Rugged and Portable Data Acquisition System for the Field Cole-GP; Peterson-JS | Sensors 13(2), 1996; :33-36	1996	Publication	Traumatic injuries
Developing Random Virtual Human Motions and Risky Work Behaviors for Studying Anthropotechnical Systems Ambrose-DH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Pub No. 2004-130, Information Circular 9468, 2004 Mar; :1-26	2004	Publication	Cumulative injuries; Traumatic injuries
Developing Toolbox Training Materials for Mining Varley-FD; Boldt-CMK | In: Peters R, ed. Strategies for Improving Miners' Training. Pittsburgh, PA, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2002-156, Information Circular 9463, 2002 Sep :39-44	2002	Publication	Surveillance and training; Traumatic injuries
Development and Evaluation of a New Personal Dust Monitor for Underground Mining Applications Volkwein-JC; Thimons-ED; Dunham-D; Patashnick-H; Rupprecht-E | In: Sakkestad BA, ed. Proceedings of the 29th Internation Technical Conference on Coal Utilization and Fuel Systems (Clearwater, FL, April 18-22, 2004). Gaithersburg, MD: Coal Technology Assocation, 2004; :1-22	2004	Publication	Respiratory diseases
Development and Evaluation of a Training Exercise for Construction, Maintenance and Repair Work Activities Rethi-LL; Barrett-EA | In: Bockosh-GR, Karmis-M, Langton-J, McCarter-MK, Rowe-B eds. Proceedings of the Thirty-First Annual Institute on Mining Health, Safety and Research (Blacksburg, VA; Aug 27-30, 2000). Virginia Polytechnic Institute and State University, Department of Mining and Minerals Engineering; :93-102	2000	Publication	Surveillance and training
Development and Use of a High-pressure Packer for Measuring Horizontal Stress Using the Hydraulic Fracturing Method Oyler-DC | In: Elsworth D, Tinucci JP, Heasley KA, eds. Rock Mechanics in the National Interest. Vol. I. Lisse, Netherlands: Swets & Zeitlinger; :227-234	2001	Publication	Ground control
Development of a Dust Collector Inlet Hood for Enhanced Surface Mine Drill Dust Capture Organiscak-JA; Page-SJ | Int J Surface Min Reclam Environ 19(1):12-28	2005	Publication	Respiratory diseases
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Development of a Lower Pressure, Water-Powered Spot Scrubber for Mining Applications Organiscak-JA; Pollock-DE | SME preprint 05-103. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc, 2005; :1-9	2005	Publication	Respiratory diseases
Development of a Mine Hoist and Ore Pass Research Facility Beus-MJ; Ruff-TM | Spokane, WA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Publication No. 97-134, Report of Investigations 9637	1997	Publication	Traumatic injuries
Development of a Statistical-Analytical Approach for Assessing Coal Bump Potential Maleki-H; Zahl-EG; Dunford-JP | In Proc 16th Intl Conf on Ground Control in Mining, Peng SS, ed., Morgantown, WV; West Virginia University,1997; :304-310	1997	Publication	Ground control
Development of an Automated PC-Network-Based Seismic Monitoring System Swanson-P | Proceedings of the 5th International Symposium on Rockbursts and Seismicity in Mines (Johannesburg, S. Africa, Sept. 17-19, 2001), G. van Aswegen, R.J. Durrheim, and W.D. Orlepp, eds., S. African Institute of Mining and Metallurgy, Johannesburg, S. Africa, 2001 Dec; :11-17	2001	Publication	Ground control

Title	Year	Output Type	Strategic Goal
Development of an Overhead Power Line Contact Alarm for Mobile Equipment Homce-GT; Cawley-JC; Sacks-HK; Yenchek-MR | International Journal of Heavy Vehicle Systems, (12)4, 2005 Apr; :87-103	2005	Publication	Traumatic injuries
Development of NIOSH Hard-Rock Safety Training Materials Cullen-ET | Presentation at 108th annual exhibit and meeting, Society for Mining, Metallurgy, and Exploration, Denver, CO, Feb. 26-28, 2001; :4 pp	2001	Publication	Surveillance and training
Development of Numerical Models to Investigate Permeability Changes and Gas Emission around Longwall Mining Panel Esterhuizen-GS; Karacan-CO | Proceedings of the 40th U.S. Symposium on Rock Mechanics, ARMA/USRMS paper 05-744, Anchorage, AK, June 27-29, 2005; :13 pp	2005	Publication	Ground control
Development of Stress Measurement Techniques in Bump-Prone Coal for Safety Decisions Zahl-EG; Dunford-JP; Schissler-A; Larson-MK; Pierce-PA; Jones-FM | In: S. S. Peng and C. Mark, eds. Proceedings 19th International Conference on Ground Control in Mining (Aug. 8-10, 2000; Morgantown, WV), Dept. of Min. Eng., WV Univ., Morgantown, WV, 2000 Aug; :101-111	2000	Publication	Ground control
Development of Stress Measurements and Instrument Placement Techniques for Longwall Coal Zahl-EG; Dunford-JP; Tesarik-DR; Larson-MK | In: D. Elsworth, J.P. Tinnucci, and K.A. Heasley, eds., Rock Mechanics in the Public Interest. Proceedings of the 38th U.S. Rock Mechanics Symposium, DC Rocks, Vol 1, (July 7-10, 2001; Washington, DC), Balkema, 2001 Jul; :305-327	2001	Publication	Ground control
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Diesel Exhaust Aerosol, Review of Measurement Technology Cantrell-BK; Watts-WF Jr. | The Canadian Adhoc Committee Proceedings of the November 6-7, 1996, Plenary Conference in Toronto, Ontario, Diesel Emissions Exposure Reduction in Mines. Toronto, Ontario, Canada: Canada Centre for Mineral and Energy Technology (CANMET) :7.1-7.9	1996	Publication	Respiratory diseases
Diesel Exhaust Aerosol, Review of Occupational Exposure Cantrell-BK; Watts-WF Jr | Soc Min Eng preprint 96-126, 1996	1996	Publication	Respiratory diseases
Diesel Exhaust Aerosol: Review of Occupational Exposure Cantrell-BK; Watts-WF Jr | Appl Occup Env Hyg 12(12), 1997; :1019-1027	1997	Publication	Respiratory diseases
Diesel Exhaust Control Technology: a Review Schnakenberg-GH; Bugarski-AD | In: Proceedings of the Mining Diesel Emissions Conference (Markham, Ontario, Canada)	2001	Publication	Respiratory diseases
Diesel Listserver Schnakenberg-G | Email listserver, sign-up at http://www.cdc.gov/niosh/mining/topics/diesel/diesellistserver.htm	1997	Web document	Respiratory diseases
Diesel Particulate Matter Control Technologies and Measurements in US Mines Mischler-SE; Bugarski-AD; Schnakenberg-GH | In: Gillies ADS, ed. Proceedings of Eighth International Mine Ventilation Congress (Brisbane, Australia), AusIMM, Victoria, Australia, 2005; : 263-274	2005	Publication	Respiratory diseases
Diesel-Discriminating Mine Fire Sensors Litton-CD | In: Dhar BB, Bhowmick BC, eds. Proceedings of the 27th International Conference of Safety in Mines Research Institutes, Vol. 2. New Delhi, India: Oxford & IBH Publishing Co. Pvt. Ltd.,1997; :1013-1022	1997	Publication	Mine disasters

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Differential Pressure as a Means of Estimating Respirable Dust Mass on Collection Filters Dobroski-H Jr; Tuchman-DP; Vinson-RP | Applied Occupational and Environmental Hygiene 12(12), 1997 Dec; :1047-1051	1997	Publication	Respiratory diseases
Differential Pressure as a Measure of Particulate Matter Emissions from Diesel Engines Mischler-SE; Volkwein-JC | Environ Sci Technol 2005 Apr; 39(7):2255-2261	2005	Publication	Respiratory diseases
Differential Pressure Response of 25-mm-Diameter Glass Fiber Filters Challenged with Coal and Limestone Dust Mixtures Dobroski-H; Tuchman-D; Vinson-R; Timko-RJ | Appl Occup Environ Hyg, 2002 Feb 17(2); :96-103	2002	Publication	Respiratory diseases
Differential Wall Rock Movements Associated with Rock Bursts, Lucky Friday Mine, Coeur d'Alene Mining District, Idaho, USA White-BG; Whyatt-JK | In: Armadei, Kranz, Scott & Smeallie, eds. Rock Mechanics for Industry. Proceedings of the 37th U.S. Rock Mechanics Symposium (Vail, CO, June 6-9, 1999), 1999 Balkema, Rotterdam, ISBN 90 5809 052 3, Balkema, 1999 Jun; :1051-1059	1999	Publication	Ground control
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Discriminatory Mine Fire Source Detection Edwards-JC; Franks-RA; Friel-GF; Lazzara-CP; Opferman-JJ | In: Wasilewski S, ed. Proceedings of the Seventh International Mine Ventilation Congress (Jun 17-22, 2001; Krakow, Poland) Ch 91, 2001; :649-655	2001	Publication	Mine disasters
Disease and Illness in U.S. Mining, 1983-2001 McHugh-E; Girard-J | Journal of Occupational and Environmental Medicine, vol. 46, no. 12; :1272-1277	2004	Publication	Surveillance and training; Traumatic injuries
Distinguishing Motor Starts From Short Circuits Through Phase-Angle Measurements Yenchek-MR; Cawley-JC; Brautigam-AL; Peterson-JS | In: Conference Record No. 0-7803-6404 of the 2000 IEEE Industry Applications Conference, 35th IAS Annual Meeting and World Conference on Industrial Applications of Electrical Energy (Rome, Italy, October 1-3, 2000), 2000 Oct; :2695-2702	2000	Publication	Traumatic injuries
Distinguishing Motor Starts From Short Circuits through Phase-Angle Measurements Yenchek-MR; Cawley-JC; Peterson-JS; Kohler-JL | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Publication No. 97-120, Report of Investigations 9638, 1997 Mar :1-15	1997	Publication	Traumatic injuries
Distinguishing Motor Starts from Short Circuits through Phase-Angle Measurements Yenchek-MR; Cawley-JC; Peterson-JS; Kohler-JL | IEEE Trans Ind Appl, 2002 Jan/Feb 38(1):195-202	2002	Publication	Traumatic injuries
Distributed Measurement of Conductor Temperatures in Mine Trailing Cables Using Fiber-Optic Technology Dubaniewicz-TH Jr; Kovalchik-PG; Scott-LW; Fuller-MA | IEEE Transactions on Industry Applications, Institute of Electrical & Electronics Engineers, Inc., 34(2), 1998 Mar; :395-398	1998	Publication	Mine disasters; Traumatic injuries
Distributed Measurement of Conductor Temperatures in Mine Trailing Cables Using Fiber-Optic Technology Dubaniewicz-TH Jr; Kovalchik-PG; Scott-LW; Fuller-MA | In: Proceedings of the 1996 IEEE Industry Applications Society 31st Annual Meeting, Vol. 4, San Diego, CA, 1996; :2480-2483	1996	Publication	Traumatic injuries
Diverse Tectonism in the Coeur d'Alene Mining District White-BG | Butte, MT: Montana Bureau of Mines and Geology, Spec. Pub. 112, pp. 254-265	1997	Publication	Ground control

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Drill Monitor With Strata Strength Classification in Near-Real Time Utt-WK; Miller-GG; Howie-WL; Woodward-CC | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2002-141, Report of Investigations 9658, 2002 Jul :1-14	2002	Publication	Ground control; Traumatic injuries
Drill Rig Incident Barrett-EA; Calhoun-RA | DHHS (NIOSH) Publication No. 2005-108, IC 9473, 2005 Feb; :1-51	2005	Publication	Hearing loss; Surveillance and training
Dust Control at Yucca Mountain Project Kissell-FN; Juran-R; Dresel-R; Reaux-C | In: Proceedings of the Eighth U.S. Mine Ventilation Symposium, Tien JC, ed., Rolla, MO, University of Missouri-Rolla Press, 1999; :203-208	1999	Publication	Respiratory diseases
Dust Control Considerations for Deep-Cut Faces when Using Exhaust Ventilation and a Flooded-Bed Scrubber Colinet-JF; Jankowski-RA | SME preprint 97-48, 1997	1997	Publication	Respiratory diseases
Dust Control Considerations for Deep-Cut Mining when Utilizing Exhaust Ventilation and a Scrubber Colinet-JF; Jankowski-RA | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 9615. NTIS stock number: PB96-147798, 1996	1996	Publication	Respiratory diseases
Dust Control Methods in Tunnels and Underground Mines Kissell-FN | J Mine Vent Soc S Afr 55(4), 2002; :129-137	2002	Publication (guidelines)	Respiratory diseases
Dust Detector Tube Volkwein-J; Page-S; Dobroski-H | U.S. Patent #6,401,520 EP 0 993 599 B1 (granted June, 2002), Australia Patent #738972 (granted January 16, 2002)	2002	Patent	Respiratory diseases
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Dust Underfoot: Enclosed Cab Floor Heaters Can Significantly Increase Operator's Respirable Dust Exposure Cecala-AB; Organiscak-JA; Heitbrink-WA | Rock Products 2001 Apr; 104(4):39-44	2001	Publication	Respiratory diseases
Dusting Off: NIOSH Develops a New Method to Clean Dust-Soiled Work Clothes Pollock DE, Cecala AB, O'Brien AD, Zimmer JA, Howell JL | Rock Prod 108(3), 2005; :30-34	2005	Publication	Respiratory diseases
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Dynamic Temperature Measurement of Overheated Shuttle Car Trailing Cables in Underground Coal Mines Kovalchik-PG; Scott-LW; Dubaniewicz-TH; Duda-FT | Trans Soc Min Metal Explor, 1999 306:1-4	1999	Publication	Traumatic injuries
Economic Consequences of Mining Injuries Camm-T; Dwyer-J | Presentation at annual meeting of Society for Mining, Metallurgy, and Exploration, Denver, CO, Feb. 23-25, 2004. Preprint 04-37, 2004 Feb; : 5 pp	2004	Publication	Surveillance and training
Economic Consequences of Mining Injuries Camm-T; Dwyer-J | Mining Engineering Magazine, Vol 57, No. 9, pp. 89-92, September 2005	2005	Publication	Surveillance and training
Economics of Safety at Surface Mine Spoil Piles Camm-TW | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2000-129, Report of Investigations 9653, 2000 Jul :1-14	2000	Publication	Surveillance and training

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Effect of the Dip and Excavation Orientation on Roof Stability in Moderately Dipping Stone Mine Workings Esterhuizen-GS; Iannacchione-AT | Proceedings of the 40th U.S. Symposium on Rock Mechanics, ARMA/USRMS paper 05-743, Anchorage, AK, June 27-29, 2005; :8 pp	2005	Publication	Ground control
Effect of Three-Winding Transformer Models on the Analysis and Protection of Mine Power Systems Oommen-MP; Kohler-JL | IEEE Trans Ind Appl, 35(3), 1999; :670-674	1999	Publication	Traumatic injuries
Effective Control of Respirable Dust in Underground Coal Mines in the United States Colinet-JF; Goodman-GVR; Listak-JM; Chekan-GJ; Rider-JP; Pollock-DE; Thimons-ED | In: Gillies ADS, ed. Proceedings of Eighth International Mine Ventilation Congress (Brisbane, Australia), AusIMM, Victoria, Australia, 2005; :129-134	2005	Publication	Respiratory diseases
Effective Prevention of Hearing Loss in Miners Grayson-RL | Holmes Safety Association Bulletin, 1999 Jan; :3-5	1999	Publication	Hearing loss
Effects of Alternative Fuels on Concentrations of Nanometer and Ultrafine Particles in Underground Mine Bugarski-AD; Mischler-S; Schnakenberg-GH Jr | In: Proceedings of the Ninth ETH Conference on Combustion-Generated Nanoparticles (Aug. 15-17, 2005; Zurich, Switzerland)	2005	Publication	Respiratory diseases
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Effects of Lifting in Four Restricted Postures Gallagher-S; Unger-RL; Rossi-EW | Ergonomics and Musculoskeletal Disorders: Research on Manual Materials Handling, 1983-1996, Karwowski-W; Wogalter-MS; Dempsey-PG, eds., Human Factors and Ergonomics Society, 1997; :56-60	1997	Publication	Cumulative injuries
Effects of Load and Posture on the Recruitment of Trunk Muscles Gallagher-S; Marras-WS; Davis-KG | In: Proceedings of the Human Factors and Ergonomics Society 46th Annual Meeting, September 30 - October 4, 2002, Baltimore, MD, 2002; :1071-1075	2002	Publication	Cumulative injuries
Effects of Mining Height on Injury Rates in U.S. Underground Nonlongwall Bituminous Coal Mines Fotta-B; Mallett-LG | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Publication No. 98-104, Information Circular 9447, 1997 Nov :1-32	1997	Publication	Surveillance and training
Effects of Posture on Back Strength and Lifting Capacity Gallagher-S; Bobick-TG | Ergonomics and Musculoskeletal Disorders: Research on Manual Materials Handling, 1983-1996, W Karwowski; MS Wogalter; PG Dempsey, eds., 1997 Sep; :37-41	1997	Publication	Cumulative injuries
Effects of Posture on Dynamic Back Loading During a Cable Lifting Task Gallagher-S; Marras-WS; Davis-KG; Kovacs-K | Ergonomics, 2002 45(5), 2002; :380-398	2002	Publication	Cumulative injuries
Effects of Water Sprays and Scrubber Exhaust on Face Methane Concentrations Taylor-CD; Zimmer-JA | In: S Wasilewski, ed. Proc Seventh Intl Mine Ventilation Congress, 2001, Krakow, Poland :465-470	2001	Publication	Mine disasters

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Effects of Water Sprays Used With a Machine-Mounted Scrubber on Face Methane Concentrations Taylor-CD; Zimmer-JA | Proc Seventh International Mine Ventilation Congress, 2001, S Wasilewski, ed. Krakow, Poland :465-470	2001	Publication	Mine disasters
Electrical Accidents in the Mining Industry, 1990-1999 Cawley-JC | IEEE Trans Ind Appl 2003 Nov/Dec, 39(6;):1570-1577	2003	Publication	Traumatic injuries
Electrical Accidents in the Mining Industry, 1990-1999 Cawley-JC | SME preprint 02-007. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc, 2002	2002	Publication	Traumatic injuries
Electrical Accidents in the Mining Industry, 1990-1999 Cawley-JC | In: Conference Record of the 2001 IEEE Industry Applications Conference, 36th IAS Annual Meeting (Chicago, IL), 2001	2001	Publication	Traumatic injuries
Electrical Fault Detection on Downed DC Trolley Lines Peterson-JS; Cole-GP | SME Preprint 97-38, 1997 :1-5	1997	Publication	Traumatic injuries
Electrical Safety for Water Well Drillers Homce-GT; Cawley-JC; Yenchek-MR | Water Well Journal, 59(8); :12,14	2005	Publication	Traumatic injuries
Electrically Excited Vibrations for Condition Monitoring of Synchronous Machine Windings: An Experimental Study Trutt-FC; Sottile-J; Kohler-JL | In: Proceedings of the 23rd Annual Meeting of the Vibration Institute,1999; :85-91	1999	Publication	Traumatic injuries
Elements from Comprehensive Safety Programs in General Industry Could Benefit Independent Contractors Working in the Mining Industry - Part I Barrett-EA; Rethi-LL; Fotta-B | Holmes Safety Association Bulletin, 1996 Mar; :1-6	1996	Publication	Surveillance and training
Elements from Comprehensive Safety Programs in General Industry Could Benefit Independent Contractors Working in the Mining Industry - Part II Barrett-EA; Rethi-LL; Fotta-B | Holmes Safety Association Bulletin, 1996 Apr; :1-6	1996	Publication	Surveillance and training
Emergency Response Command Center Training Using Computer Simulation Brnich-M; Mallett-L; Reinke-D; Vaught-C | In: 33rd Annual Institute on Mining Health, Safety, and Research Conference Proceedings, Roanoke, VA, August 11-13, 2002	2002	Publication	Mine disasters; Surveillance and training
Emergency Response Veterans Share the Lessons They've Learned Mallett-L; Vaught-C; Brnich-MJ Jr | Holmes Safety Association Bulletin, 1996 Oct; :5-8	1996	Publication	Mine disasters
Emerging Technologies and the Future of Geotechnical Instrumentation Girard-JM; McHugh-EL | Rock Mechanics in the National Interest. Vol. I, Lisse, Netherlands: A. A. Balkema, 2001 Jul; 1:445-450	2001	Publication	Ground control
Emerging Technologies in Underground Coal Mining Mitchell-Dubaniewicz-J | In: Chiang S, ed. Proceedings of the 15th Annual International Pittsburgh Coal Conference, Pittsburgh, PA: Pittsburgh Coal Conference, 1998	1998	Publication	Surveillance and training
Emerging Technologies: Aiding Responders in Mine Emergences and During the Escape From Smoke-Filled Passageways Conti-RS | Proc Northwest Mining Association 107th Annual Meeting, Exposition and Short Courses (December 3-7, 2001; Spokane, WA); :14 pp	2001	Publication	Mine disasters; Surveillance and training
Empirical and Analytical Design of Large Openings at a Proposed National Underground Science Laboratory Zipf-K Jr; Tesarik-D; Johnson-J | In: Syd S. Peng, Christopher Mark, A. Wahab, and Keith Heasley, eds., Proceedings, 21st International Conference on Ground Control in Mining (Aug 6-8, 2002; Morgantown, WV) WV University, Morgantown, WV, 2002 Aug; :318-327	2002	Publication	Ground control

Title	Year	Output Type	Strategic Goal
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Empirical Approaches for Weak Rock Mass Brady-T; Martin-L; Clark-L | CIM Mining Industry Conference and Exhibition, Montreal, Quebec, Canada: Canadian Institute of Mining, Metallurgy, and Petroleum	2003	Publication	Ground control
Employment, Production, and Fatality Trends in the U.S. Coal Mining Industry Bockosh-GR; Fotta-B; McKewan-WM | Coal Age 107(10), 2002; :18-20	2002	Publication	Surveillance and training
Enhanced Surface Control for Roof and Rib Support Tadolini-SC; Dolinar-DR | In: Peng SS, Mark C, Khair AW, eds. Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2001 Aug; :173-179	2001	Publication	Ground control
Enhancing the Safety of Remnant Pillar Recovery in Lignite by Numerical Modeling Aksoy-CO; Kose-H; Yalcin-E; Heasley-KA; Mark-C | CIM Bull 2004	2004	Publication	Ground control
Environmental Impacts of Cemented Mine Waste Backfill Levens-RL; Marcy-AD; Boldt-CMK | US Bureau of Mines, Report of Investigations 9599, 1996:1-22	1996	Publication	Ground control
Equipment Fires Cause Injuries De Rosa-MI | Coal Age 109(10), 2004; :28-31	2004	Publication	Mine disasters
Ergonomic and Existing Seat Designs Compared on Underground Mine Haulage Vehicles Mayton-A.J; Ambrose-DH; Jobes-CC; Kittusamy-NK | In: Proceedings of the Human Factors and Ergonomics Society 47th Annual Meeting (Denver, CO; Oct. 13-17, 2003). Santa Monica, CA: Human Factors and Ergonomics Society; :1256-1260	2003	Publication	Cumulative injuries; Traumatic injuries
Ergonomic Assessment of Musculoskeletal Risk Factors at Four Mine Sites: Underground Coal, Surface Copper, Surface Phosphate, and Underground Limestone Wiehagen-WJ; Turin-FC | NIOSH Publication No. 2004-159, Information Circular 9475, 2004 Aug :1-38	2004	Publication	Cumulative injuries
Ergonomic Issues in Mining Gallagher-S | In: Karwowski W, Marras WS, eds. The Occupational Ergonomics Handbook, Boca Raton, FL, CRC Press LLC, 1999; :1893-1915	1999	Publication	Cumulative injuries
Ergonomic Risk Factors: a Study of Heavy Earthmoving Machinery Operators Kittusamy-NK | Professional Safety: Journal of American Society of Safety Engineers, 2002 Oct	2002	Publication	Cumulative injuries
Ergonomic Seat With Viscoelastic Foam Reduces Shock on Underground Mobile Equipment Mayton-AG; Gallagher-S; Merkel-R | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin, 1998 Apr; :12-13	1998	Publication	Cumulative injuries; Traumatic injuries
Ergonomic Seat With Viscoelastic Foam Reduces Shock on Underground Mobile Equipment Mayton-AG; Gallagher-S; Merkel-R | In: B. Das; W. Karwoski, eds., Advances in Occupational Ergonomics and Safety II, IOS Press and Ohmsha, 1997 Jun; :177-180	1997	Publication	Cumulative injuries; Traumatic injuries
Ergonomics Considerations for Reducing Cumulative Trauma Exposure in Underground Mining Cornelius-KM; Turin-FC | In: W. Karwowski, ed. International Encyclopedia of Ergonomics and Human Factors, 2001, Vol. III, London, United Kingdom, Taylor & Francis, Inc. 2001; :1497-1500	2001	Publication (guidelines)	Cumulative injuries
Estimate of Technically Feasible DPM Levels for Underground Metal and Nonmetal Mines Schnakenberg-GH Jr | Min Eng, 53(9), Sep 2001:45-51	2001	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
Estimated Sound Power Radiated by Surfaces on a Continuous Miner Tail Section Using Vibration Measurements Yantek-DS | NOISE-CON 2003. Ames, IA: Institute of Noise Control Engineering of the USA, 2003 Jun; :1-9	2003	Publication	Hearing loss
Estimating Low Back Loads of Underground Mine Roof Bolter Operators Using Digital Human Simulations Ambrose-HD; Cole-GP; Gallagher-S | In : Proceedings of the Digital Human Modeling for Design and Engineering Symposium (Rochester, MI, June 15-17, 2004). Warrendate, PA: Society of Automotove Engineers, Inc., technical paper 2004-01-2148, 204; :1-6	2004	Publication	Cumulative injuries
Evaluating Factors Affecting the Performance of Three-Axis Ultrasonic Anemometers Taylor-CD; Chilton-JE; McWilliams-LJ; Senk-MJ | Mine ventilation: Proc 10th U.S./North American Mine Ventilation Symposium, Anchorage, Alaska, May 16-19, 2004. Leiden, Netherlands: Balkema, 2004 May; :465-470	2004	Publication	Mine disasters
Evaluating Longwall Dust Sources and Controls Rider-JP; Colinet-JF; Listak-JM; Chekan-GJ | World Coal, 2001 10(10), 2001; :71-76	2001	Publication	Respiratory diseases
Evaluating Performance Characteristics of Machine-Mounted Methane Monitors by Measuring Response Time Taylor-CD; Chilton-JE; Mal-T | In: De Souza E, ed. Proc North American/Ninth U.S. Mine Ventilation Symposium. Lisse, The Netherlands: Balkema, 2002; :315-321.	2002	Publication	Mine disasters
Evaluating Techniques for Monitoring Rock Falls and Slope Stability McHugh-E; Girard-J | 21st Intl Conf on Ground Control in Mining. Morgantown, WV: West Virginia University, 2002 Aug; :335-343	2002	Publication	Ground control
Evaluating the Ventilation of a 40-Foot Two-Pass Extended Cut Thimons-ED; Taylor-CD; Zimmer-JA | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 99-138, Report of Investigations 9648, 1999	1999	Publication	Mine disasters
Evaluating Ventilating Air Movement in Underground Limestone Mines by Monitoring Respirable Dust Generated from Production Shots Chekan-GJ; Colinet-JF; Grau-RH III | In: Ganguli R, Bandopadhyay S, eds. Mine ventilation: Proceedings of the 10th U.S./North American Mine Ventilation Sympsoim (Anchorage, AK, May 16-19, 2004). Leiden, Netherlands: Balkema,2004; :221-232	2004	Publication	Mine disasters; Respiratory diseases
Evaluating Ventilation Parameters For Extended-Cut Mining Rider-JP; Taylor-CD; Zimmer-JA | SME preprint 97-148, 1997	1997	Publication	Mine disasters
Evaluation of a Continuous Haulage Guidance Sensor Sammarco-JJ | In: Gurgenci H, Hood M, eds. Proceedings of the Fourth International Symposium on Mine Mechanisation and Automation, Vol. 2, Brisbane, Queensland, Australia, 1997; :B6-21 to B6-32	1997	Publication	Traumatic injuries
Evaluation of a Local Exhaust Ventilation System for Controlling Refractory Ceramic Fibers During Disc Sanding Dunn-KH; Shulman-SA; Cecala-AB; Venturin-DE | J Occup Environ Hyg 2004. 2004 Oct 1(10):D107-111	2004	Publication	Mine disasters
Evaluation of a Signaling and Warning System for Underground Mines Conti-RS; Yewen-RG | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Publication No. 97-127, Report of Investigations 9641 1997 May :1-21	1997	Publication	Mine disasters
Evaluation of a Soybean Oil Based Diesel Fuel in an Underground Gold Mine McDonald-JF; Cantrell-BK; Watts-WF Jr.; Bickel-KL | CIM Bulletin 90(1015); :91-95	1997	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
Evaluation of Barclay Mowlem Cementitious Seals, Stoppings, and Overcast: Final report for memorandum of agreement 98BPRLB03 between NIOSH and Barclay Mowlem Construction Ltd., Moorooka, Queensland, Australia Weiss-ES; Cashdollar-KL; Kohli-DR; Slivensky-WA | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, Pittsburgh Research Laboratory, 1999 Sep	1999	Publication	Mine disasters
Evaluation of Devices to Prevent Construction Equipment Backing Incidents Ruff-TM | SAE Commercial Vehicle Engineering Congress and Exhibition (Oct. 26-28, 2004; Chicago, IL). Paper 2004-01-2725; :10 pp	2004	Publication	Traumatic injuries
Evaluation of Diesel Emission Control Technologies Used in U.S. Underground Coal and Non-Coal Mines Schnakenberg-GH; Bugarski-AD; Mischler-SE; Noll-JD | Proceedings of the 31st Intl Conf of Safety in Mines Res Institutes, Brisbane, Australia, Oct 2-5, 2005; :277-280	2005	Publication	Respiratory diseases
Evaluation of Diesel Particulate Filter Systems and Biodiesel Blends in an Underground Mine Bugarski-A; Schnakenberg-GH Jr; Noll-JD; Mischler-S; Crum-MW; Anderson-R | SME preprint 04-24. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2004; :1-13	2004	Publication	Respiratory diseases
Evaluation of Diesel Particulate Filter Systems and Biodiesel Blends in an Underground Mine Bugarski-A; Schnakenberg-GH Jr; Noll-JD; Mischler-S; Crum-MW; Anderson-R | Trans Soc Min Metal Explor. Vol 318. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.; :27-35	2005	Publication	Respiratory diseases
Evaluation of Dust Exposure to Truck Drivers Following the Lead Haul Truck Reed-WR; Organiscak-JA | SME preprint 05-10. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2005; :1-9	2005	Publication	Respiratory diseases
Evaluation of Engineering Noise Controls for a Continuous Miner Conveyer System Durr-TM; Kovalchik-P; Kwait-E | NOISE-CON. Ames, IA: Institute of Noise Control Engineering of the USA, 2003 Jun; :1-11	2003	Publication	Hearing loss
Evaluation of Explosion-Resistant Seals, Stoppings, and Overcast for Ventilation Control in Underground Coal Mining Weiss-ES; Cashdollar-KL; Sapko-MJ | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centrs for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2003-104, Report of Investigations 9659, 2002	2002	Publication	Mine disasters
Evaluation of Instrumented Cable and Rebar Bolts as Ground Support at a Trona Mine Martin-LA; Dreesbach-CA; Pakalnis-R | 20th Intl Conf on Ground Control in Mining. Morgantown, WV: West Virginia University, 2001 Aug; :309-316	2001	Publication	Ground control
Evaluation of Instrumented Cable Bolts in Cement Grout to Determine Physical and Numerical Modeling Properties Martin-L; Milne-D; Ruest-M; Pakalnis-R | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2004-133, Report of Investigations 9662, 2004 Apr :1-14	2004	Publication	Ground control
Evaluation of IYONI II Methanometers Chilton-JE; Taylor-CD; Timko-RJ | 30th International Conference of Safety in Mines Research Institutes. Johannesburg, Republic of South Africa: South African Institute of Mining and Metallurgy, 2003 Oct; :579-594	2003	Publication	Mine disasters

Title	Year	Output Type	Strategic Goal
Evaluation of Methods for Controlling Silica Dust Exposures on Roof Bolters Goodman-GVR; Organiscak-JA | 2002 Transactions, Society for Mining, Metallurgy, and Exploration, Vol. 312; :133-137	2002	Publication	Respiratory diseases
Evaluation of Mine Seals Using Ground Penetrating Radar Monaghan-WD; Trevits-MA; Sapko-MJ | In: Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Proglems (SAGEEP 2005). Denver, CO: Environmental and Engineering Geophysical Society, 2005; :1-14	2005	Publication	Mine disasters
Evaluation of Mining Activities Using a Scenario Interview Approach Turin-F; Steiner-L; Cornelius-K | Proceeding of the Human Factors and Ergonomics Society 42nd Annual Meeting, vol 2,1998 Oct; :1108-1112	1998	Publication	Cumulative injuries
Evaluation of New Methods and Facilities to Test Explosion-Resistant Seals Sapko-MJ; Weiss-ES | In: Proceedings of the 29th International Conference of Safety in Mines Research Institutes. Vol. 1. Katowice, Poland: Central Mining Institute, 2001; :157-166	2001	Publication	Mine disasters
Evaluation of Pillar Recovery in Southern West Virginia Mark-C; Karabin-G; Zelanko-JC; Hoch-MT; Chase-F | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 21st International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2002 Aug; : 81-89	2002	Publication	Ground control
Evaluation of Polymer Construction Material and Water Trap Designs for Underground Coal Mine Seals Weiss-ES; Slivensky-WA; Schultz-MJ; Stephan-CR; Jackson-KW | Pittsburgh, PA: U.S. Department of Energy, Report of Investigations 9634. NTIS stock number: PB96-123392, 1996	1996	Publication	Mine disasters
Evaluation of Polyurethane Injection for Beltway Roof Stabilization in a West Virginia Coal Mine Molinda-GM | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining, August 3-5, 2004. Morgantown, WV: West Virginia University, 2004 Aug; :190-196	2004	Publication	Ground control
Evaluation of Reinforced Cementitious Seals Weiss-ES; Cashdollar-KL; Mutton-IVS; Kohli-DR; Slivensky-WA | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Publication No. 99-136, Report of Investigations 9647, 1999	1999	Publication	Mine disasters
Evaluation of Systems to Monitor Blind Areas Behind Trucks Used in Road Construction and Maintenance: Phase 1 Ruff-TM | NIOSH Report of Investigations 9660, 2003 Feb; :1-15	2003	Publication	Traumatic injuries
Evaluation of Techniques for Protecting Dust Sampling Equipment in Harsh Environments Goodman-GVR; Spencer-ER | Pittsburgh, PA: U.S. Department of Energy, Report of Investigations 9627. NTIS stock number: PB96-210810, 1996	1996	Publication	Respiratory diseases
Evaluation of the Bagged Stone Dust Barrier Effectiveness in a Bord and Pillar Mine Du Plessis-JJL; Weiss-ES; Cashdollar-KL | In: Wasilewski S, ed., Proceedings of the Seventh International Mine Ventilation Congress (June 17-22, 2001, Crakow, Poland), chapter 81, :573-580	2001	Publication	Mine disasters
Evaluation of the Impact of Standing Support on Ground Behavior in Longwall Tailgates Barczak-TM; Esterhuizen-GS; Dolinar;DR | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 24th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2005; :23-32	2005	Publication	Ground control

Title	Year	Output Type	Strategic Goal
Evaluation of the Respirable Dust Dosimeter for Real-Time Assessment if Airborne Respirable Coal Mine Dust Exposures Ramani-JM; Mutmansky-JM; He-H; Marple-VA; Olson BA; Luna-PC; Volkwein-JC | In: De Souze E, ed. Proceedings of the North American/Ninth U.S. Mine Ventilation Symposium (Kingston, Ontario, Canada). Lisse, Netherlands: Balkema, 2002; : 579-586	2002	Publication	Respiratory diseases
Evaluation of the SKC® DPM Cassette for Monitoring Diesel Particulate Matter in Coal Mines Noll-JD; Birch-E | J Environ Monit 2004 Dec; 6(12):973-978	2004	Publication	Respiratory diseases
Evaluation of Two Portable Lead-Monitoring Methods at Mining Sites Drake-PL; Lawryk-NJ; Ashley-K; Sussell-A; Hazelwood-KJ; Song-R | Journal of Hazardous Materials, 2003, 102(1), 2003; :29-38	2003	Publication	Surveillance and training
Evaluation of Two-Phase Spray System for Airborne Dust Control in a Longwall Gallery Belle-GK; Ramani-RV; Colinet-JF | Proc 12th Intl Conf on Coal Research, Sandton, Republic of South Africa, Sep 12-15, 2000 Wash, DC International Conference on Coal Research, 2000 Sep; :113-119	2000	Publication	Respiratory diseases
Evaluation of Water Trap Designs and Alternative Mine Seal Construction Materials Weiss-ES; Slivensky-WA; Schultz-MJ; Stephan-CR | In: Dhar BB, Bhowmick BC, eds. Proceedings of the 27th International Conference of Safety in Mines Research Institutes Vol. 2, New Delhi, India: Oxford & IBH Publishing Co. Pvt. Ltd., 1997; :973-981	1997	Publication	Mine disasters
Examination of Person-Wearable Methane Monitors Chilton-JE; Taylor-CD; Hall-EE; Yantek-DS | In: Gillies ADS, ed. Proceedings of Eighth International Mine Ventilation Congress (Brisbane, Australia), AusIMM, Victoria, Australia, 2005; :189-195	2005	Publication	Respiratory diseases
Expectations versus Experience: Training Lessons Based Upon Miners' Difficulties when Using Emergency Breathing Apparatus Vaught-C; Mallett-LG; Brnich-MJ Jr; Peters-RH | J Int Soc Respir Prot 21 (Spring/Summer), 2004; :49-59	2004	Publication	Mine disasters; Surveillance and training
Experimental and Modeling Investigation of the Effect of Ventilation on Smoke Rollback in a Mine Entry Edwards-JC; Franks-RA; Friel-GF; Yuan-L | 2005 SME Annual Meeting, February 28 - March 2, Salt Lake City, Utah, preprint 05-14. Littleton, CO, Society for Mining, Metallurgy, and Exploration, Inc., 2005 Feb; :1-6	2005	Publication	Mine disasters
Experimental Investigation of On-Line Methods for Incipient Fault Detection Sottile-J; Trutt-FC; Kohler-JL | Conference Record of the 2000 IEEE Industry Applications Conference--35th IAS Annual Meeting and World Conference on Industrial Applications of Electrical Energy, Rome, Italy, Oct 1-3 2000 Pitscataway, New Jersey IEEE., 2000 Oct; :2682-2687	2000	Publication	Traumatic injuries
Experimental Mine and Laboratory Dust Explosion Research at NIOSH Sapko-MJ; Weiss-ES; Cashdollar-KL; Zlochower-IA | J Loss Prev Process Ind 2000 May; 13(3) :229-242	2000	Publication	Mine disasters
Experimental Mine and Laboratory Dust Explosion Research at NIOSH Sapko-MJ; Weiss-ES; Cashdollar-KL; Zlochower-IA | In: Proceedings of the International Symposium on Hazards, Prevention, and Mitigation of Industrial Explosions; Eighth International Colloquium on Dust Explosions. Schaumburg, IL: Safety Consulting Engineers, Inc., 1998; :120-142	1998	Publication	Mine disasters
Exposure-Related Health Effects of Silver and Silver Compounds: A Review Drake-PL; Hazelwood-KJ | The Annals of Occupational Hygiene, Vol. 49, No. 7; :575-585	2005	Publication	Surveillance and training
Factors Affecting ANFO Fumes Production Rowland-JH, III; Mainiero-RJ | In: Proceedings of the 26th Annual Conference on Explosives and Blasting Technique (Anaheim, CA, Feb. 13-16, 2000). Vol. 1. Cleveland, OH: International Society of Explosives Engineers, 2000 Feb; :163-174	2000	Publication	Traumatic injuries

Title	Year	Output Type	Strategic Goal
Factors Affecting Fumes Production of an Emulsion and ANFO/Emulsion Blends Rowland-JH III; Mainiero-R; Hurd-DA Jr. | Proc 27th Ann Conf Explos Blasting Tech. Vol. II. Cleveland, OH: International Society of Explosives Engineers, 2001; :133-141	2001	Publication	Traumatic injuries
Factors Affecting the Location of Methanometers on Mining Equipment Taylor-CD; Thimons-ED; Zimmer-JA | In: Proc 7th Intl Mine Ventilation Congress, Kracow, Poland, June 17-22, 2001; :683-687	2001	Publication	Mine disasters
Factors Affecting the Location of Methanometers on Mining Equipment Taylor-CD; Thimons-ED; Zimmer-JA | J Mine Vent Soc S Africa 56(1), 2003; :25-29	2003	Publication	Mine disasters
Factors Impacting Respirable Dust Entrainment and Dilution in High-Velocity Airstreams Chekan-GJ; Listak-JM; Colinet-JF | SME preprint 04-10. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2004; : 1-7	2004	Publication	Respiratory diseases
Factors Impacting Respirable Dust Entrainment and Dilution in High-Velocity Airstreams Chekan-GJ; Listak-JM; Colinet-JF | Society for Mining, Metallurgy, and Exloration, Inc., Littleton, CO, Transactions 2004, Vol. 316 2004	2004	Publication	Respiratory diseases
Factors Influencing Intersection Stability in U.S. Coal Mines Molinda-G; Mark-C; Bauer-E; Babich-D; Pappas-D | In: Proceedings of the 17th International Conference on Ground Control in Mining, Peng SS, ed., Morgantown, WV: University of West Virginia, 1998 Aug; pp. 267-275	1998	Publication	Ground control
Failure Characteristics of Roof Falls at an Underground Stone Mine in Southwestern Pennsylvania Iannacchione-AT; Marshall-TE; Prosser-LJ, Jr | In: Peng SS, Mark C, Khair AW, eds. Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2001 Aug; :119-125	2001	Publication	Ground control
Failure Mechanics of Multiple Seam Mining Interactions Zipf-RK | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 24th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University; :93-106	2005	Publication	Ground control
Fatal Accidents Due to Flyrock and Lack of Blast Area Security and Working Practices in Mining Bajpayee-TS; Bhatt-SK; Rehak-TR; Mowrey-GL; Ingram-DK | J Mines Met Fuels 2003 Nov-Dec; 51(11/12), 2003; :344-350	2003	Publication	Traumatic injuries
Feasibility of Using Laser-Based Vibration Measurements to Detect Roof Fall Hazards in Underground Mines Swanson-P | In: Proceedings of the Fifth International Conference on Vibration Measurement by Laser Techniques: Advances and Applications. Bellingham, WA: International Society for Optical Engineering (SPIE), Vol. 4827, 2002 :541-552	2002	Publication	Ground control
Feasibility Study to Reduce Injuries and Fatalities Caused by Contact of Cranes, Drill Rigs, and Haul Trucks with High-Tension Lines Sacks-HK; Cawley-JC; Homce-GTR; Yenchek-MR | IEEE Trans Ind Appl, 37(3), 2001; :914-919	2001	Publication	Traumatic injuries
Feasibility Study to Reduce Injuries and Fatalities Caused by Contact of Cranes, Drill Rigs, and Haul Trucks with High-Tension Lines Sacks-HK; Cawley-JC; Homce-GT; Yenchek-MR | In: Proceedings of the IEEE Industry Applications Conference, 34th IAS Annual Meeting (Phoenix, AZ, October 3-7, 1999); :240-248	1999	Publication	Traumatic injuries
Feeding the Multitudes - How to Connect With Customers Cullen-ET | Presentation at 108th annual exhibit and meeting, Society for Mining, Metallurgy, and Exploration, Denver, CO, Feb. 26-28, 2001; :6 pp	2001	Publication	Surveillance and training

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Field Assessment of Control Techniques and Long-Term Dust Variability for Surface Coal Mine Rock Drills and Bulldozers Organiscak-JA; Page-SJ | International Journal of Surface Min Reclam Environ, 13 1999; :165-172	1999	Publication	Respiratory diseases
Field Assessment of Retrofitting Surface Coal Mine Equipment Cabs with Air Filtration Systems Organiscak-JA; Cecala-AB; Heitbrink-WA; Thimons-ED; Schnitz-M; Ahrenholtz-E | Proc 31st Annual Institute of Mining Health, Safety and Research, 2000, Aug 27-30 Virginia Polytechnic Institute and State University, Department of Mining and Minerals Engineering, 2000 Aug; :57-68	2000	Publication	Respiratory diseases
Field Evaluation of Diesel Particulate Filters: Size-Selective Measurements of Aerosols in Mine Air and Engine Exhaust Bugarski-AD; Schnakenberg-GH Jr | In: Proceedings of the Mining Diesel Emissions Conference (Markham, Ontario, Canada)	2001	Publication	Respiratory diseases
Field Evaluation of Mobile Roof Support Technologies Maleki-H; Owens-J; Endicott-M | Paper in Proceedings: 20th International Conference on Ground Control in Mining, ed. By Syd S. Peng, Christopher Mark, and A. Wahab Khair (Morgantown WV, Aug. 7-9, 2001). WV University, Morgantown, WV, 2001; :67-77	2001	Publication	Ground control
Field Method for the Determination of Insoluble Hexavalent Chromium in Workplace Air Hazelwood-K; Drake-P; Ashley-K; Marcy-AD | Journal of Occupational and Environmental Hygiene, 2004, Vol. 1; :613-619	2004	Publication	Surveillance and training
Field Performance Testing of Fully Grouted Roof Bolts Mark-C; Compton-CS; Dolinar-DR; Oyler-DC | 2003 SME Annual Meeting, Feb 24-26, Cincinnati, Ohio, preprint 03-138. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2003 Feb; :1-8	2003	Publication	Ground control
Field Portable Measurement of Airborne Beryllium, Chromium, Lead and Other Metals: Instruments, Methods and Future Direction Lawryk-NJ; Ashley-K; Drake-PL | The Synergist, 2005, 16(5):54-61	2005	Publication	Surveillance and training
Field Studies of Carbon Monoxide Migration from Blasting Harris-ML; Sapko-MJ; Mainiero-RJ | Proc 31st Ann Conf Explos Blasting Tech, Orlando, FL, February 6-9, 2005, 2005 Feb; :21 pp	2005	Publication	Traumatic injuries
Field Study to Evaluate the Effectiveness of a Continuous Passive Lumbar Motion System Kittusamy-NK; Viswanathan-M; Jorgensen-MJ | XIX Annual International Occupatonal Ergonomics and Safety Conference 2005, Las Vegas, NV; :1-6	2005	Publication	Cumulative injuries; Traumatic injuries
Field Test with Strain-Gauged Friction Bolts at the Gold Hunter Mine, Mullan, Idaho, USA Johnson-J; Williams- T; Sunderman-C; Signer-S; Bayer-D | In: S. S. Peng, C. Mark, A. Wahab Khair, and K. Heasley, eds., Proceedings: 22nd International Conference on Ground Control in Mining (Aug. 5-7, 2003; Morgantown WV), Dept. of Mining Engineering, West Virginia University, 2003 Aug; :233-239	2003	Publication	Ground control
Field Tests of Cable Bolts Using Instrumented King Wires Martin-L; Pakalnis-R; Curtin-R | Presentation at the Canadian Institute of Mining, Metallurgy, and Petroleum--CIM 2000 Meeting, 2000, Mar 5-10 Toronto, Ontario, Canada :1-10	2000	Publication	Ground control
Field-Scale Void Detection in Coal Piles Using Resistivity Imaging Rodriguez-R; Rodriguez-H; Lhamond-M; Johnson-JJ; Iverson-S | In: Hammah R, Bawden W, Curran J, Telesnicki M, eds. NARMS-TAC 2002: Mining and Tunnelling Innovation and Opportunity, Vol. 1 (Toronto, ON, July 7-10, 2002). Toronto, ON: University of Toronto; :415-419	2002	Publication	Ground control
Filtered Recirculation: A Critical Component to Maintaining Acceptable Air Quality in Enclosed Cabs for Surface Mining Equipment Cecala-AB; Zimmer-JA | In: Ganguli R, Bandopadhyay S, eds. Mine ventilation: Proceedings of the 10th U.S./North American Mine Ventilation Symposium (Anchorage, AK, May 16-19, 2004). Leiden, Netherlands: Balkema, 2004 May; :377-387	2004	Publication	Respiratory diseases

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Fire Protection Provided by Detonator Containers Santis-LD | Proceedings of the 23rd Annual Conference on International Society of Explosives Engineers, 1997 :487-498	1997	Publication	Mine disasters
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Ignition of Methane-Air Mixtures by Laser-Heated Small Particles Dubaniewicz-TH Jr.; Cashdollar-KL; Gregory-GM; Chaiken-RF | In: Proceedings of ISA - Expo 98, International Conference and Exposition for Advancing Measurement and Control Technologies, Products, and Services	1998	Publication	Traumatic injuries
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Impact of Control Parameters on Shearer-Generated Dust Levels Rider-JP; Colinet-JF; Prokop-AE | Society for Mining, Metallurgy, and Exploration, Inc, SME preprint 01-184. Littleton, CO, 2001	2001	Publication	Respiratory diseases
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In Mine Evaluation of Discriminating Mine Fire Sensors Edwards-JC; Franks-RA; Friel-GF; Lazzara-CP; Opferman-JJ | In: E. DeSouza, ed. Proceedings of the North American/Ninth U.S. Mine Ventilation Symposium (June 8-12, 2002, Kingston, Ontario, Canada). A. A. Balkema Publishers, Lisse, Netherlands; :527-532	2002	Publication	Mine disasters
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Inflatable Devices for Use in Combating Underground Mine Fires Weiss-ES; Conti-RS; Bazala-EM; Pro-RW | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 9614. NTIS stock number: PB96-162367, 1996; :1-18	1996	Publication	Mine disasters
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Influence of Intermediate Principle Stress on Rock Mass Quality Li-G; Vongpaisal-S; Pakalnis-R; Brady-T | CAMI 2005 (Fifth International Conference on Computer Applications In Mineral Industries, November 1-3, 2005, Banff, Alberta, Canada	2005	Publication	Ground control
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Initiating an Ergonomics Process at a Surface Coal Mine Unger-RL; Turin-FC; Wiehagen-WJ; Steiner-LJ; Cornelius-KM; Torma-Krajewski-J | In: Bockosh GR, Kohler JL, Langton JF, Novak T, McCarter MK, Biviano A, eds. Proceedings of the 33nd Annual Institute on Mining Health, Safety and Research (Aug 27-30, 2002; Roanoke, VA), Blacksburg, VA: Virginia Polytechnic Institute and State University, Department of Mining and Minerals Engineering, 2002; :39-47	2002	Publication (guidelines)	Cumulative injuries
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In-Mine Evaluation of Discriminating Mine Fire Sensors Edwards-JC; Franks-RA; Friel-GF; Lazzara-CP; Opferman-JJ | In: De Souze E, ed. Proceedings of the North American/Ninth U.S. Mine Ventilation Symposium (Kingston, Ontario, Canada). Lisse, Netherlands: Balkema, 2002; :527-532	2002	Publication	Mine disasters

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Innovative Alternatives to Traditional Classroom Health and Safety Training Brnich-MJ, Jr; Derick-RL; Mallett-L; Vaught-C | In: Peters R, ed. Strategies for Improving Miners' Training. Pittsburgh, PA, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2002-156, Information Circular 9463, 2002 Sep :19-25	2002	Publication	Surveillance and training
Innovative Secondary Support Systems for Gate Roads Barczak-TM; Zelanko-JC; Molinda-GM | In: Proceedings of Longwall USA. Pittsburgh, PA; :21-43	1996	Publication	Ground control
Innovative Secondary Support Technologies for Western Mines Barczak-TM; Molinda-GM | In: Ozdemir L, Hanna K, Haramy KY, Peng S, eds. Proceedings of the 15th International Conference on Ground Control in Mining. Golden, CO: Colorado School of Mines, 1996	1996	Publication	Ground control
Innovative Strategies for Mine Fire Preparedness Brnich-MJ Jr; Conti-RS; Mallett-LG, Vaught-C; Wiehagen-WJ; Derick-RL | In: Proceedings of Longwall USA International Exhibition & Conference, 1999; :113-122	1998	Publication	Mine disasters
Insights on Technology Transfer from the Bureau of Mines Kissell-FN | Journal of Technology Transfer, 25(1), 2000 Mar; :5-8	2000	Publication	All
Installation and Safety Practices for Cable Bolts in Underground Mines Martin LA, Girard JM, Goris JM | Spokane, WA: U.S. Department of the Interior, Bureau of Mines, Information Circular 9441. NTIS stock number: PB96-140165, 196	1996	Publication	Ground control
Interaction Between Wall Rock Closure, Cemented Backfill Load, and Reinforcement Bolt Load in an Underhand Stope at the Lucky Friday Mine Williams, T.J., D. Denton, J.B. Seymour, D. Tesarik, C. Peppin, and D. Bayer | In: D Stone, ed., Minefill 2001: Proceedings of the 7th International Symposium on Mining with Backfill, Soc. For Min., Metall, and Explor., Littleton, CO, 2001; :117-125	2001	Publication	Ground control
International Experience with Longwall Mining into Pre-Driven Rooms Oyler-D; Frith-R; Dolinar-D; Mark-C | In: Proc 17th Conference on Ground Control in Mining, S. S. Peng. C. T. Holland, eds., 1998 Aug, Morgantown, WV, West Virginia University, 1998; :44-53	1998	Publication	Ground control
Intrinsically-Safe Roof Hazard Alert Module Mayercheck-W; Brautigam-A | U.S. Patent #6,469,619 (granted Oct. 22, 2002); Australia Patent #747632 (granted Aug. 29, 2002); UK Patent #GB0027883.8 (granted June 3, 2003)	2002	Patent	Ground control
Investigation of a Large-Scale Catastrophic Collapse in a Wyoming Trona Mine Swanson-PL | 28th International Conference of Safety in Mines Research Institutes, Proceedings of the Conference, Sinaia, România, June 7-11, 1999. Nat. Institute For Min. Safety and Explosion Proof Protection, PetroÕani, România, vol. 1, sessions A-1. 1999 Jun; :343-358	1999	Publication	Ground control
Investigation of a Rock-Burst Site, Sunshine Mine, Kellogg, Idaho Scott-DF; Williams-TJ; Friedel-MJ | In: Gibowicz SJ, Lasocki S, eds., Proceedings of the 4th International Symposium on Rockbursts and Seismicity in Mines, Balkema, 1997; :311-315	1997	Publication	Ground control
Investigation of a Slip/Fall Accident Rethi-LL; Wiehagen-WJ; Calhoun-RA; Garry-D; Cole-HP; Brnich-MJ | National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 99-156, 1999 Oct; :1-43	1999	Publication	Surveillance and training; Traumatic injuries
Investigation of Ampacity Derating Factors for Shuttle Cars Using Fiber Optics Technology Kovalchik-PG; Scott-LW; Duda-FT; Dubaniewicz-TH | IEEE Industry Applications Society 32nd Annual Meeting, Lindsay PA, ed., New Orleans, Louisiana, 1997 Oct; :1-4	1997	Publication	Traumatic injuries

Title	Year	Output Type	Strategic Goal
Investigation of Bulk Solids Engineering Properties and Application of PFC2D to Ore Pass Flow Problems Iverson-SR | In: H. Konietzky, ed., Numerical Modeling in Micromechanics via Particle Methods. Proceedings of the 1st International PFC Symposium (Gelsenkirchen Germany, Nov. 6-8, 2002), Balkema, Rotterdam, Netherlands, 2002; :252-258	2002	Publication	Traumatic injuries
Investigation of Coal Properties and Airborne Respirable Dust Generation Organiscak-JA; Page-SJ | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Publication No. 98-160, Report of Investigations 9645, 1998 Oct; :1-16	1998	Publication	Respiratory diseases
Investigation of Electromagnetic Emissions in a Deep Underground Mine Scott-DF; Williams-T; Knoll-S | Proceedings: 23rd International Conference on Ground Control in Mining, Morgantown, West Virginia, August 3-5, 2004, S.S. Peng, C. Mark, G. Finfinger, S. Tadolini, A.W. Khair, and K. Heasley, eds., Morgantown, WV: West Virginia University, 2004 Aug; :125-132	2004	Publication	Ground control
Investigation of Electromagnetic Emissions in a Deep Underground Mine Scott-DF; Williams-TJ; Knoll-SJ | In: Potvin Y, Hudyma M, eds. Controlling Seismic Risk: Sixth International Symposium on Rockburst and Seismicity in Mines, Proceedings (Perth Australia, March 9-11, 2005). Australian Centre for Geomechanics, W. Australia, Australia, 2005; :593-599	2005	Publication	Ground control
Investigation of Fully Grouted Roof Bolts Installed Under In Situ Conditions Compton-C; Oyler-D | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 24th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University; :302-312	2005	Publication	Ground control
Investigation of Intermittency in the Noise Exposure Pattern of Longwall Coal Miners Burks-JA; Bartholomae-RC | In: Proceedings of the 16th International Congress on Acoustics and 135th Meeting of the Acoustical Society of America, 1998; :1523-1524	1999	Publication	Hearing loss
Investigation of Longwall Face Ventilation Air-Splitting Methods for Improved Dust Control Organiscak-JA | Society for Mining, Metallurgy, and Exploration Annual Meeting, SME preprint 99B5. Littleton, CO, 1999 :1-14	1999	Publication	Respiratory diseases
Investigation of Pillar-Roof Contact Failure in Northern Appalachian Stone Mine Workings Esterhuizen-GS; Iannacchione-AT | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2004 Aug; :320-326	2004	Publication	Ground control
Investigation of the Jacking Force Capability of Tunnel Liners Barczak-TM; Smith-R | 2002 SME Annual Meeting, Feb 25-27, Phoenix, Arizona, preprint 02-186. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2002 Feb; :1-13	2002	Publication	Ground control
Isometric, Isoinertial, and Psychophysical Strength Testing: Devices and Protocols Gallagher-S; Moore-JS; Stobbe-TJ | In: Kumar S, ed. Muscle strength, Boca Raton, FL: CRC Press, 2004; :129-156	2004	Publication	Cumulative injuries
Issues for Training an Evolving Emergency Management Workforce: A View from the U.S. Mining Community Kowalski-K; Vaught-C; Mallett-L; Brnich-MJ | Int Emerg Mgmt Soc 9th Ann Conf Proc, May 14-17, 2002, R. T. Newkirk, ed., University of Waterloo, Canada, 2002 May; :430-438	2002	Publication	Surveillance and training
Issues Regarding the Safety and Health of Emergency Workers Kowalski-KM; Vaught-C | In: Proceedings of the Sixth Annual Conference of The International Emergency Management Society (TIEMS), Beroggi GEG, ed., Delft, Netherlands: Delft University of Technology, s1999; :286-292	1999	Publication	Mine disasters

Title	Year	Output Type	Strategic Goal
Jarring/Jolting Exposure and Musculoskeletal Symptoms among Farm Equipment Operators Mayton-AG; Kittusamy-NK; Ambrose-DH; Legault-M | In: Proceedings of the Summer Conference of the National Institute for Farm Safety, Inc. (Keystone Resort, CO, June 20-24, 2004). Madison, WI: National Institute for Farm Safety, Inc., paper No. 04-19, 2004; :1-15	2004	Publication	Cumulative injuries; Traumatic injuries
Judgment and Decision-Making Under Stress: An Overview for Emergency Managers Kowalski-KM; Vaught-C | In: Proceedings of The International Emergency Management Society (TIEMES) Conference (Oslo, Norway) (CD-ROM), 2001	2001	Publication	Mine disasters
Judgment and Decision-Making Under Stress: An Overview for Emergency Managers Kowalski-Trakofler-KM; Vaught-C; Scharf-T | Int J Emer Management 2003; 1(3):278-289	2003	Publication	Mine disasters
Laboratory Evaluation of a Canopy Air Curtain for Controlling Occupational Exposures of Roof Bolters Goodman-GVR; Organiscak-JA | Proc Seventh International Mine Ventilation Congress, (Krakow, Poland) 2001 Jun; :299-305	2001	Publication	Respiratory diseases
Laboratory Evaluation of Pressure Differential-based Respirable Dust Detector Tube Volkwein-JC; Schoeneman-AL; Page-SJ | Appl Occup Env Hyg, 15(1), 2000 Jan; :158-164	2000	Publication	Respiratory diseases
Laboratory Evaluation of Shield Dust Entrainment in High-Velocity Airstreams Listak JM; Chekan GJ; Colinet JF | SME preprint 01-144, 2001, Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.; :155-160	2001	Publication	Respiratory diseases
Laboratory Profile: The Spokane Research Center Cullen-E | News Link, The Federal Laboratory Consortium for Technology Transfer, 1997 Aug; :1 pp	1997	Publication	All
Laboratory Pull Tests of Resin-Grouted Cable Bolts Martin-LA; Girard-JM; Curtin-RP | In: Ozdemir L, Hanna K, Haramy KY, Peng S, eds. Proceedings of the 15th International Conference on Ground Control in Mining. Golden, CO: Colorado School of Mines, 1996; :455-468	1996	Publication	Ground control
Laboratory Testing To Quantify Dust Entrainment During Shield Advance Chekan-GJ; Listak-JM; Colinet-JF | Proc Seventh International Mine Ventilation Congress, 2001, (Krakow, Poland), S. Wasilewski, ed. :291-298	2001	Publication	Respiratory diseases
Ladder Simulation Exercise for Construction, Mining, and Other Industries Wiehagen-WJ; Calhoun-RA; Flick-J; Kowalsk-KM; Radomsky-M; Ramani-RV; et al | In: Proceedings of the Sixth International Conference of the Scientific Committee on Education and Training in Occupational Health, 2002; :63	2002	Publication	Surveillance and training
Lake Lynn Laboratory Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Publication No. 99-149	1999	Publication	All
LAMODEL - A Boundary Element Program for Coal Mine Design Heasley-KA; Zacharias-A | In: Proceedings of the Tenth International Conference on Computer Methods and Advances in Geomechanics. Tuscon, AZ; :1679-1682	2001	Publication	Ground control
Laser Ignition of Flammable Gas Dubaniewicz-TH Jr.; Cashdollar-KL; Monaghan-WD | Proc International Laser Safety Conference, 1999, Orlando, Florida: Laser Institute of America, 1999; :309-318	1999	Publication	Traumatic injuries
Laser Safety in Underground Coal Mines Dubaniewicz-TH | Web document, http://www.cdc.gov/niosh/mining/topics/electrical/lasersafety.htm	2001	Web document	Traumatic injuries

Title	Year	Output Type	Strategic Goal
Leadership Characteristics in Escape from Three Underground Mine Fires Kowalski-KM; Mallett-LG; Brnich-MJ Jr | In: Wybo JL, Therrien M-C, Guarnieri F, eds. Proceedings of the International Emergency Management and Engineering Conference. Montreal, Quebec, Canada, 1996; :317-326	1996	Publication	Mine disasters
Lighted Line Conti-RS; Chasko-LL | U.S. Patent #6,742,909	2004	Patent	Mine disasters
Lightning Propagation Through the Earth and its Potential for Methane Ignitions in Abandoned Areas of Underground Coal Mines Novak-T; Fisher-TJ | Conference Record of the 2000 IEEE Industry Applications Conference-35th IAS Annual Meeting and World Conference on Industrial Applications of Electrical Energy, Rome, Italy, 2000 Oct; :1-3, Pitscataway, New Jersey: IEEE 2002 Oct; :2674-2681	2002	Publication	Mine disasters; Traumatic injuries
Link-n-lock Cribs NIOSH | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin, 1998 Nov; :22	1998	Publication	Ground control
Load and Deflection Response of Ventilation Stoppings to Longwall Abutment Loading: A Case Study Oyler-DC; Hasenfus-G; Molinda-GM | In: Peng SS, Mark C, Khair AW, eds. Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2001 Aug; :34-41	2001	Publication	Ground control
Long-Term Evaluation of Diesel Particulate Filter Systems at Inco's Stobie Mine Stachulak-JS; Conard-BR; Bugarski-AD; Schnakenberg-GH | Proceeding of the Eighth International Mine Ventilation Congress, Brisbane, Queensland, Australia, July 6-8, 2005	2005	Publication	Respiratory diseases
Long-Term Evaluation of Diesel Particulate Matter Exposures in US Underground Metal and Non-Metal Mines Stachulak-JS; Conrad-BR; Bugarski-AD; Schnakenberg-GH | In: Gillies ADS, ed. Proceedings of Eighth International Mine Ventilation Congress (Brisbane, Australia), AusIMM, Victoria, Australia, 2005; :255-261	2005	Publication	Respiratory diseases
Long-Term Stability of a Backfilled Room-and-Pillar Mine Tesarik-D, Seymour-B, Yanske-T | Field Measurements in Geomechanics. Proceedings of the 5th International Symposium on Field Measurements in Geomechanics, Singapore, Dec. 1-3, 1999, C. F. Leung, S. A. Tan, and K. K. Phoon eds., Balkema, 1999 Dec; :431-435	1999	Publication	Ground control
Longwall Dust Control Potentially Enhanced by Surface Borehole Water Infusion Campoli-AA; McCall-FE; Finfinger-GL; Zuber-MD | Mining Engineering 48(7), 1996; :56-60	1996	Publication	Respiratory diseases
Longwall Dust Control: Issues and Possible Solutions Rider-JP;Colinet-JF; Chekan-G; Listak-J; Thimons-ED | In: Proceedings of Longwall USA International Exhibition & Conference. Overland Park, KS: Intertec Publishing Corp., 2001; :91-111	2001	Publication	Respiratory diseases
Longwall Dust Control: Review of Developments Effected in Mines in the U.S.A. over the Last Ten Years (In Polish) Jankowski-RA; Kissell-FN | Maszyny Gornicze J XIV(5), 1996; :51-56	1996	Publication	Respiratory diseases
Longwall Dust Control: Where We Are and Where We Need to Go in the 21st Century Jankowski-RA; Colinet-JF | In: Proceedings of Longwall USA International Exhibition & Conference, 1998; :123-138	1998	Publication	Respiratory diseases
Longwall Mine Noise and Recommendations to Reduce Worker Noise Exposure Bartholomae-RC; Burks-JA | In: Proceedings of Noise-Con 96. Seattle, WA, 1996; :949-954	1996	Publication	Hearing loss

Title	Year	Output Type	Strategic Goal
Longwall Operational Parameters and Dust Levels Measured in Poland's Coal Mines Organiscak-JA; Colinet-JF; Koziel-A | In: Proceedings of Longwall USA International Exhibition & Conference, 1999; :171-184	1999	Publication	Respiratory diseases
Longwall Tailgate Support: Consideration, Design, and Experience Barczak-TM; Mucho-TP; Dolinar-D; Bower-J; Bryja-J | In: Proceedings of Longwall USA International Exhibition & Conference, 1999; :79-104	1999	Publication	Ground control
Longwall Tailgates: the Technology for Roof Support has Improved, but Optimization is Still Not There Barczak-TM | In: Proceedings of Longwall USA (Pittsburgh, PA, June 3-5, 2003), 2003 Jun; :105-130	2003	Publication	Ground control
Look Up, Look Down, Look Out ESFI, OSHA, and NIOSH | Rosslyn, VA: Electrical Safety Foundation International, Inc.; :2 pp	2004	Publication	Traumatic injuries
Low Temperature Limits for Mixing Recycled Oil, Diesel Fuel, and Ammonium Nitrate to Make ANFO-Type Blasting Agents Ruhe-TC; Bajpayee-TS | In: Proceedings of the 22nd Annual Conference on Explosives and Blasting Technique (Orlando, FL, Feb. 4-8, 1996). Vol. 2. Cleveland, OH: International Society of Explosives Engineers, 1996; :232-243	1996	Publication	Traumatic injuries
Lowering Respirable Dust Exposures at Mineral Processing Facilities Cecala-AB; Timko-RJ; Thimons-ED | In: Proceedings of the Eighth U.S. Mine Ventilation Symposium, Tien JC, ed., Rolla, MO: University of Missouri-Rolla Press,1999; :221-227	1999	Publication	Respiratory diseases
Lowering Respirable Dust Exposures at Mineral Processing Facilities Cecala-AB; Timko-RJ; Thimons-ED | In: Proceedings of 104th Annual Northwest Mining Association Conference (Spokane, WA, December 1998)	1998	Publication	Respiratory diseases
Machine Injury Prediction by Simulation Using Human Models Ambrose-DH; Bartels-JR; Kwitowski-AJ; Helinski-RF; Gallagher-S | Warrendale, PA: Society of Automotive Engineers, Inc., technical paper 2003-01-2190, 2003; :1-11	2003	Publication	Traumatic injuries
Machine-Mounted Continuous Respirable Dust Monitor NIOSH | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin (reprint of Technology News 463), 1997 Oct:20-21	1997	Publication	Respiratory diseases
Maintainability Unger-RL | Web document, http://www.cdc.gov/niosh/mining/topics/machinesafety/equipmentdsgn/maintainability/mantainability.htm	2004	Web document	Cumulative injuries; Traumatic injuries
Maintainability Design Checklist Unger-RL; Conway-EJ | NIOSH 1996; http://www.cdc.gov/niosh/mining/products/checklists.htm#MDC	1996	Web document	Traumatic injuries
Make it Safer with Roof Screen - Instructional Materials Robertson-S; Mark-C	2005	Publication	Ground control
Mapping Hazards with Microseismic Technology to Anticipate Roof Falls - A Case Study Iannacchione-AT; Batchler-T; Marshall-TE | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University,2004 Aug; pp. 327-333	2004	Publication	Ground control
Material Properties Affecting the Stability of a 50-Year-Old Rock Dump in an Active Mine Tesarik-DR; McKibbin-RW | NIOSH Report of Investigations 9651, 1999 Dec; :1-28	1999	Publication	Ground control
Material Properties of Retested Specimens Composed of Tailings, Cement, and Blast-Furnace Slag Tesarik-DR; Seymour-JB; Lane-WL | Spokane, WA: U.S. Department of Energy, Report of Investigations 9636. NTIS stock number: PB97-133276; :16 pp	1996	Publication	Ground control

Title	Year	Output Type	Strategic Goal
Materials-Handling Accident Reduction in Underground Mines Stewart-BM; Clark-CC; Patton-PW | 6th International Symposium on Mine Mechanization and Automation (Sept. 25-28, 2001, Johannesburg, S. Africa). S. African Institute of Mining and Metallurgy, Johannesburg, S.Africa. Symposium Series S28, 2001; :159-166	2001	Publication	Traumatic injuries
Mathematics, Statistics, and Probability Zipf-RK Jr | Ch. 5. In: Raymond L. Lowrie, ed. SME Mining Reference Handbook, 2002; :103-126	2002	Publication	Surveillance and training
Measurement of Airflow in a Simulated Underground Mine Environment Using an Ultrasonic Anemometer Taylor-CD; Timko-RJ; Senk-MJ; Lusin-A | Transactions, Society for Mining, Metallurgy, and Exploration, Inc., Vol. 316, 2004, SME paper No. 03-065; :6 pp.	2004	Publication	Mine disasters
Measuring Low-Level Methane Concentrations with an Air Bag Sampling System Rider-JP; Taylor-CD; Thimons-ED | Journal of the Mine Ventilation Society of South Africa 50(2), 1997; :47-56	1997	Publication	Respiratory diseases
Measuring the Gas Content of Coal: A Review Diamond-WP; Schatzel-SJ | Int J Coal Geology 35, 1998; :311-331	1998	Publication	Mine disasters
Mechanics of a Large, Strain-Type Rock Burst and Design for Prevention White-BG; Williams-TJ; Whyatt-JK | In: Hammah R, Bawden W, Curran J, Telesnicki M, eds. NARMS-TAC 2002: Mining and Tunnelling Innovation and Opportunity. Vol 2. Toronto, Ontario, Canada: Univ. of Toronto, Toronto, July 7-10, 2002; :1095-1100	2002	Publication	Ground control
Metal and Nonmetal Diesel Particulate Filter Selection Guide Schnakenberg-GH; Bugarski-AD; Angel-J; Saseen-G | Web document, http://www.msha.gov/nioshmnmfilterselectionguide/dpmfilterguide.htm	2005	Web document	Respiratory diseases
Metal Mining Facts - 2001 NIOSH | NIOSH Publication No. 2003-131, 2003 Jul; :1-2	2003	Publication	Surveillance and training
Metal Operator Mining Facts - 2002 NIOSH | NIOSH Publication No. 2004-124, 2004 Jan; :1	2004	Publication	Surveillance and training
Metal Operator Mining Facts - 2003 NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-116, 2005 Feb; :1	2005	Publication	Surveillance and training
Method & Apparatus for Monitoring the Thickness of a Coal Rib During Rib Formation Mowrey-G | U.S. Patent #5,500,649 (granted March 19, 1996)	1996	Patent	Ground control
Method and Apparatus for Load Rate Monitoring Howie-WL; Owens-JK | U.S. Patent No. 6,957,166 (granted Oct. 18, 2005)	2005	Patent	Ground control
Method and Apparatus for Safety Testing Optical Systems for Hazardous Locations Dubaniewicz-TH; Green-GM | U.S Patent #6,667,801 (granted December 23, 2003)	2003	Patent	Traumatic injuries
Method for Characterization of Rock Strata in Drilling Operations Utt-W | Patent# 09/613/963	2001	Patent	Ground control
Method to Determine the Effects of Rotary Drilling Parameters and Overburden Rock on Silica Dust Generation Listak-JM | In: Yernberg WR, ed. Transactions of Society for Mining, Metallurgy, and Explorations, Inc. Vol. 314. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2003; :102-106	2003	Publication	Ground control
Methods and Apparatuses for Detecting a Temperature Increase in an Electrical Insulator Hudson-A | U.S. Patent #6,189,479 (granted Feb. 20, 2001)	2001	Patent	Traumatic injuries

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Methods for Dust Removal in Roadway Sections Frydel-W; Steindor-M; Jankowski-RA | In: Proceedings of the Eighth U.S. Mine Ventilation Symposium, Tien JC, ed., Rolla, MO: University of Missouri-Rolla Press, 1999; :237-240	1999	Publication	Respiratory diseases
Methods for Evaluating Explosion Resistant Ventilation Structures Sapko-MJ; Weiss-ES; Harteis-SP | In: Eighth International Mine Ventilation Congress (Brisbane, Australia); :211-219	2005	Publication	Mine disasters
Methods to Lower Dust Exposures at Mineral Processing Operations Cecala-AB; Thimons-ED | In: Proceedings of National Stone Association's 1997 Environmental Safety and Health Forum, 1997; :231-249	1997	Publication (guidelines)	Respiratory diseases
Methods to Lower Dust Exposures at Mineral Processing Operations Cecala-AB; Daniel-JH; Thimons-ED | Appl Occupational and Environmental Hygiene 11(7), 1996; :854-859	1996	Publication (guidelines)	Respiratory diseases
Methods to Lower the Dust Exposure of Bag Machine Operators and Bag Stackers Cecala-AB; Timko-RJ; Thimons-ED | Applied Occupational Environmental Hygiene 2000 Oct; 15(10):751-765	2000	Publication	Respiratory diseases
Methods To Minimize Injuries in Materials-Handling and Processes in Underground Mines Stewart-BM; Patton-PW; Clark-CC | Presentation at 109th annual exhibit and meeting, Society for Mining, Metallurgy, and Exploration, Feb. 25-27, 2002, Phoenix, AZ. Preprint 02-103, 2002 Feb; :8 pp	2002	Publication	Cumulative injuries; Traumatic injuries
Microseismic Activity Associated With a Deep Longwall Coal Mine Heasley-KA; Ellenberger-JL; Jeran-PW | 2002 SME Annual Meeting, Feb 25-27, Phoenix, Arizona, preprint 02-175. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2002 Feb; :1-5	2002	Publication	Ground control
Mine Aerosol Measurement Cantrell-BK; Volkwein-JC | In: Baron PA, Klaus W, eds. Aerosol Measurement: Principles, Techniques, and Applications, 2nd Edition, 2001 Sep; :801-820	2001	Publication	Respiratory diseases
Mine Design: Long-Term Effects of High-Extraction Mining Jeran-PW | In: Proceedings of the 13th Annual Meeting of the American Society for Surface Mining and Reclamation. Knoxville, TN, 1996; :217-233	1996	Publication	Ground control
Mine Emergency Response Command Center Training Using Computer Simulation Brnich-MJ Jr; Mallett-LG; Reinke-DC; Vaught-C | In: Bockosh GR, Kohler JL, Langton JF, Novak T, McCarter MK, Vibiano A, eds. Proceedings of the 33nd Annual Institute of Mining Health, Safety and Research. Blacksburg, VA: Virginia Polytechnic Institute and State University, Department of Mining and Minerals Engineering, 2002; 131-141	2002	Publication	Mine disasters
Mine Emergency Response Interactive Training Simulation Glowacki-AF; Brnich-MJ Jr; Mallett-LG; Unger-RL; Vaught-C | In: Proceedings of Minesim '96, the First International Symposium Via the Internet. University of Idaho, National Technical University of Athens, Greece, 1996	1996	Publication	Mine disasters
Mine Escapeway Multiuser Training with Desktop Virtual Reality Orr-TJ; Girard-JM | In: Bandopadhyay S, ed. Application of Computers and Operations Research in the Mineral Industry: Proceedings of the 30th International Symposium (APCOM 2002) (Phoenix, AZ, Feb. 25-27, 2002). Littleton, CO: Society of Mining, Metallurgy, and Exploration	2002	Publication	Surveillance and training
Mine Eyes: Proximity Alert for Monster Trucks Ruff-TM; Holden-TP | GPS World, 2002 Jul; :16-22	2002	Publication	Traumatic injuries
Mine Fire Detection by Ultrasonic Ranging Systems Friel-GF; Edwards-JC | Pittsburgh, PA: U.S. Department of Energy, Report of Investigations 9624. NTIS stock number: PB96-188149, 1996	1996	Publication	Mine disasters

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Mine Fire Detection in the Presence of Diesel Emissions Edwards-JC; Franks-RA; Friel-GF; Lazzara-CP; Opferman-JJ | Journal of the Mine Ventilation Society of South Africa. 2000 53(2); :66-71	2000	Publication	Mine disasters
Mine Fire Detection in the Presence of Diesel Emissions Edwards-JC; Franks-RA; Friel-GF; Lazzara-CP; Opferman-JJ | Chemical and Physical Process of Combusion. The Fall Technical Meeting of the Eastern States Section of the Combustion Institute (Oct 10-13, 1999; Raleigh, NC), North Carolina State University; :89-92	1999	Publication	Mine disasters
Mine Fire Detection in the Presence of Diesel Emissions Edwards-JC; Franks-RA; Friel-GF; Lazzara-CP; Opferman-JJ | Proc Eighth U.S. Mine Ventilation Symposium. Rolla, MO: University of Missouri-Rolla, Press, 1999 Jun; :295-301	1999	Publication	Mine disasters
Mine Fire Detection Under Zero Airflow Conditions Edwards-JC; Friel-GF; Franks-RA; Opferman-JJ | Proceedings of the 6th International Mine Ventilation Congress, Chapter 52, Ramani RV, ed., Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 1997 Feb; :331-336	1997	Publication	Mine disasters
Mine Fire Source Discrimination Using Fire Sensors and Neural Network Analysis Edwards-JC; Friel-GF; Franks-RA; Lazzara-CP; Opferman-JJ | Combustion Fundamentals and Applications - Proceedings of the 2000 Technical Meeting of the Central States Section of the Combustion Institute (April 17-18, 2000, Indianapolis, IN); :207-211	2000	Publication	Mine disasters
Mine Fire Source Discrimination Using Fire Sensors and Neural Network Analysis Edwards-JC; Friel-GF; Franks-RA; Lazzara-CP; Opferman-JJ | In: Proceedings of the 29th International Conference of Safety in Mines Research Institutes. Vol 2. Katowice, Poland: Central Mining Institute, 2001; :7-15	2001	Publication	Mine disasters
Mine Health and Safety Research at NIOSH Grayson-RL | In: Proceedings of the Mining Health and Safety Conference '98. Toronto, Ontario, Canada: Mines and Aggregates Safety and Health Association, tab 4, 1998	1998	Publication	All
Mine Health and Safety Research in the National Institute for Occupational Safety and Health Grayson-RL | In: Proceedings of the International Committee for Coal Research (ICCR) 1998 Meeting, 1998	1998	Publication	All
Mine Health and Safety: Industry's March Towards Continuous Improvement - The United States Experience Grayson-RL | In: Azcue JM, ed. Environmental impacts of mining activities: emphasis on mitigation and remedial measures, Berlin, Germany: Springer-Verlag,1999; :83-100	1999	Publication	All
Mine Health and Safety: Progress and Prospects for the Future Grayson-RL | Mining Engineer 51(6), 1999; :63-65	1999	Publication	All
Mine Rescue and Response Conti-RS | Proceedings of the 12th International Conference on Coal Research - Coal the Future (Sep 12-15, 2000; Sandton, Republic of South Africa). Symposium Series S26, International Committee for Coal Research, Washington, DC; :127-136	2000	Publication	Mine disasters
Mine Rescue Training Simulations and Technology Conti-RS; Chasko-LL; Stowinsky-LD | Disaster and Emergency Management: International Challenges for the Next Decade, 1998 May; :453-464	1998	Publication	Mine disasters
Mine Safety Training: Past, Present, and Future Cullen-E | Minesafe International 2000 (Perth, Australia, Sept. 3-8, 2000). Chamber of Minerals and Energy of Western Australia, Perth, Australia, 2000 Sep; :151-154	2000	Publication	Surveillance and training
Mine Shaft Conveyance Monitoring Beus MJ; Ruff TM; Iverson S; McCoy W | Min Eng, 2000, 53(10):55-58	2000	Publication	Traumatic injuries

Title	Year	Output Type	Strategic Goal
Miner Training Simulator: Users Guide and Scripting Language Documentation Ruff-TM | NIOSH Information Circular 9457, 2001 Jun; :1-21	2001	Publication	Surveillance and training; Traumatic injuries
Mining Kohler-JL | In: Rosenstock L, Cullen MR, Brodkin CA, Redlich, CA, eds. Textbook of clinical occupational and environmental medicine. 2nd ed. London: Elsevier, 2005; :201-214	2005	Publication	All
Mining Employees McWilliams-LJ; Podlesny-A | Web document, http://www.cdc.gov/niosh/mining/statistics/employees.htm	2004	Web document	Surveillance and training
Mining Fact Sheets McWilliams-LJ; Podlesny-A | Web document, http://www.cdc.gov/niosh/mining/statistics/facts.htm	2005	Web document	Surveillance and training
Mining Facts - 2001 NIOSH | NIOSH Publication No. 2003-105, 2003 Jun; :1 pp	2003	Publication	Surveillance and training
Mining Facts - 2002 NIOSH | NIOSH Publication No. 2004-122, 2004 Jan; :1 pp	2004	Publication	Surveillance and training
Mining Facts - 2003 NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-113, 2005 Feb; :1	2005	Publication	Surveillance and training
Mining Facts for 2000 NIOSH | NIOSH Publication No. 2002-145, 2002 May :1 pp	2002	Publication	Surveillance and training
Mining Fatalities McWilliams-LJ; Podlesny-A | Web document, http://www.cdc.gov/niosh/mining/statistics/fatalities.htm	2004	Web document	Surveillance and training
Mining Health and Safety on the Internet Randolph-RF; Steiner-LJ | In: Thompson SD, Grayson RL, Wang YJ, eds. Proceedings of the Fifth Conference on the Use of Computers in the Coal Industry. Morgantown, WV: West Virginia University, 1996; :178-184	1996	Publication	All
Mining Health and Safety Update: Vol. 1 No. 1 USDOE | Pittsburgh, PA: U.S. Department of Energy [1996]. Mining Health and Safety Update, 1995 Mar (this issue's focus is on ground control)	1996	Publication	Ground control
Mining Health and Safety Update: Vol. 2 No. 1 NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, (This issue's focus is on human factors, fires and explosions, life support, and equipment safety)	1997	Publication	Cumulative injuries; Mine disasters; Traumatic injuries
Mining Health and Safety Update: Vol. 2 No. 2 NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, (This issue's focus is on haulage, disaster prevention, and ground control)	1997	Publication	Ground control; Mine disasters; Traumatic injuries
Mining Health and Safety Update: Vol. 3 No. 1 NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, Vol 3, No. 1, (This issue's focus is on training and work design)	1998	Publication	Surveillance and training
Mining Illness and Disease McWilliams-LJ; Podlesny-A | Web document, http://www.cdc.gov/niosh/mining/statistics/illness.htm	2004	Web document	Surveillance and training

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Mining Injuries McWilliams-LJ; Podlesny-A | Web document, http://www.cdc.gov/niosh/mining/statistics/injuries.htm	2004	Web document	Surveillance and training
Mining Operations McWilliams-LJ; Podlesny-A | Web document, http://www.cdc.gov/niosh/mining/statistics/mines.htm	2004	Web document	Surveillance and training
Mining Publications List: 1995 - 1999 NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Publication No. 2000-107, 1999; :1-37	1999	Publication	All
Mining Publications List: 1995 - 2000 NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) 2001 Jan; :1-46	2001	Publication	All
Mining Roof Bolting Machine Safety: A Study of the Drill Boom Vertical Velocity Ambrose-DH; Bartels-JR; Kwitowski-AJ; Helinski-RJ; Gallagher-S; McWilliams-LJ; Battenhouse-TR Jr | Pittsburgh, PA: U.S. Department of Heatlh and Human Service,s Public Health Service, Centers for Disease Contorl and Prevention, NIOSH, DHHS (NIOSH) Pub No. 2005-128, Information Circular 9477, 2005	2005	Publication	Traumatic injuries
Mining Safety and Health Focus. Vol. 4, No. 1 NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH. (This issue's focus is on hearing loss prevention, dust and diesel exhaust measurement, and chemical hazards), 1999	1999	Publication	Hearing loss; Respiratory diseases; Surveillance and training
Mining Statistics McWilliams-LJ; Podlesny-A | Web document, http://www.cdc.gov/niosh/mining/statistics/	2004	Web document	Surveillance and training
Mining Surveillance Statistics and Research Support Activity NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 98-130	1998	Publication	Surveillance and training
Mining the Remaining Portion of the Ross Shaft Pillar Brady-TM; Johnson-JC; Laurenti-MA; Pariseau-WG; Stahl-M | In: D. Elsworth, J.P. Tinnucci, and K.A. Heasley, eds. Rock Mechanics in the Public Interest. Proceedings of the 38th U.S. Rock Mechanics Symposium, DC Rocks, vol 1, (Washington, D.C., July 7-10, 2001), Balkema, 2001 Jul; :395-399	2001	Publication	Ground control
Mining-Induced Seismic Events at the Lucky Friday Mine: Large Seismic Events (Magnitude >2.5), 1989-1994 Whyatt-JK; Williams-TJ; Blake-W; Sprenke-k; Wideman-C | Report prepared for Lawrence Livermore National Laboratory (Memorandum of Agreement B291533), 1996 Aug; :165 pp	1996	Publication	Ground control
Mist System - Technologically Achievable, Administratively Achievable, and Promising Noise Controls (30 CFR Part 62) NIOSH | Information Bulletin P04-18, 2005 (http://www.msha.gov/regs/complian/PIB/2004/pib04-18.pdf)	2005	Publication (guidelines)	Hearing loss
Mistakes, Misconceptions, and Key Points Regarding Secondary Roof Support Systems Barczak-TM | In: Peng SS, Mark C, Khair AW, eds. Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2001 Aug; :347-356	2001	Publication	Ground control
Mobile Machine Hazardous Working Zone Warning System Schiffbauer-WH; Ganoe-CW | U.S Patent #5,939,986 (granted Aug 17, 1999)	1999	Patent	Traumatic injuries
Mobile Roof Support Load Rate Monitoring System Howie-WL; Owens-JK | Proceedings of the IEEE Industry Applications Society (Phoenix, AZ, October 3-7, 1999). Vol. 1, :234-239	1999	Publication	Traumatic injuries

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Mobile Roof Support Safety Research - An Update Owens-J; Howie-W; Maleki-H | In: Jenkins FM, Langton J, McCarter MK, and Rowe B, eds. Proceedings: Thirtieth Annual Institute on Mining Health, Safety, and Research (Salt Lake City, UT, Aug. 8-11, 1999). Blacksburg, VA: Department of Mining and Minerals Engineering, Virginia Polytechnical Institute, 2001 Aug; :101-113	2001	Publication	Ground control; Traumatic injuries
Model for the Structure of Round-Strand Wire Ropes Wang-RC; Miscoe-AJ; McKewan-WM | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 98-148, Report of Investigations 9644, 1998 Sep; :1-19	1998	Publication	Traumatic injuries
Modern Shield Technology: Better Than Ever, But Still Not Perfect Barczak-TM | In: Peng SS, Mark C, eds. Proceedings of the 18th International Conference on Ground Control in Mining, Morgantown, WV: West Virginia University, 1999; :149-163	1999	Publication	Ground control
Moisture-Corrected Reflectance Rock Dust Meter Lucci-CE | Pittsburgh, PA: U.S. Department of Energy, Report of Investigations 9630. NTIS stock number: PB96-215017, 1996	1996	Publication	Mine disasters
Monitoring Air Flow through a Machine-Mounted Dust Scrubber Taylor-CD; Kovscek-PD; Thimons-ED | Appl Occupational and Environmental Hyg 11(7), 1996; :813-816	1996	Publication	Respiratory diseases
Monitoring Blind Spots: A Major Concern for Haul Trucks Ruff-TM | Engineering and Mining Journal, 202(12), 2001 Dec; :17-26	2001	Publication	Traumatic injuries
Monitoring Mining-Induced Stress Changes with the Biaxial Stressmeter Seymour-JB; Tesarik-DR; McKibbin-RW; Jones-FM | Paper in Field Measurements in Geomechanics. Proceedings of the 5th International Symposium on Field Measurements in Geomechanics, Singapore, Dec. 1-3, 1999. C. F. Leung, S. A. Tan, and K. K. Phoon eds., Balkema, 1999 Dec; :55-60	1999	Publication	Ground control
Monitoring Mobile Roof Supports Hay-KE; Signer-SP; King-ME; Owens-JK | In: Mark-C PhD, Tuchman-RJ, eds. Proceedings: New Technology for Ground Control in Retreat Mining, US Bureau of Mines, Report of Investigations 9446, 1997; :89-98	1997	Publication	Ground control; Traumatic injuries
Monitoring of Reinforced Cemented Backfill in an Underhand Stope Williams, T., D. Denton, C. Peppin, and D. Bayer | In: J. Girard, M. Leibman, C. Breeds, and T. Doe, eds. Pacific Rocks 2000. Rock Around the Rim: Proceedings of the Fourth North American Rock Mechanics Symposium (NARMS 2000) (July 31-Aug. 3, 2000; Seattle, WA), Balkema, 2000; :387-393	2000	Publication	Ground control
Motion Editing and Reuse Techniques and Their Role in Studying Events Between a Machine and its Operator Volberg-O; Ambrose-DH | In: Proceedings of the 2002 Society of Computer Simulation International, Advance Simulation Technologies Conference, 34(4), San Diego, California 2002 Apr; :181-186	2002	Publication	Cumulative injuries; Traumatic injuries
MSHA Data File Downloads McWilliams-LJ; Podlesny-A | Web document, http://www.cdc.gov/niosh/mining/data/	2005	Web document	Surveillance and training
MSHA Report, Summary of Explosive Testing Conducted Relative to the Accident at Material Service Quarry, Romeoville, IL Rowland-JH III; Mainiero-RJ	1999	Publication	Traumatic injuries
MSHA Report, Summary of Explosive Testing Conducted Relative to the Accident at Trapper Mining Inc., Craig CO Mainiero-RJ; Mytrysak-CA	1999	Publication	Traumatic injuries
MSHA Report, Summary of Testing Conducted Relative to Miller Quarry Accident Mainiero-RJ	1996	Publication	Traumatic injuries

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Multiple Seam Mining Interactions: Case Histories from the Harris No. 1 Mine Chase-FE; Worley-P; Mark-C | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 24th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University; :79-86	2005	Publication	Ground control
Multiple Type Discriminating Mine Fire Sensors Edwards-JC; Franks-RA; Friel-GF; Lazzara-CP; Opferman-JJ | Trans Soc Min Metal Explor, Transactions, Vol 314, 2003 Dec; :166-171	2003	Publication	Mine disasters
Multiple-seam Mining Chekan-GJ | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin, 1998 Sept :7-8	1998	Publication	Ground control
National Institute for Occupational Safety and Health, Pittsburgh Research Laboratory NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health	1998	Publication	All
Navigation and Control of Continuous Mining Systems NIOSH | NASA Tech Briefs 22(6), 1998; :10b-11b	1998	Publication	Traumatic injuries
Navigation and Control of Continuous Mining Systems for Coal Mining Schiffbauer-WH | In: Proceedings of the 1996 IEEE Industry Applications Society 31st Annual Meeting. Vol. 4. San Diego, CA: 1996; :2473-2479	1996	Publication	Traumatic injuries
Neural Network Application to Mine-Fire Diesel-Exhaust Discrimination Friel-GF; Edwards-JC | In: De Souze E, Ed. Proceedings of the North American/Ninth U.S. Mine Ventilation Symposium (Jun 8-12, 2002; Kingston, Ontario, Canada). A. A. Balkema Publishers, Lisse, Netherlands; :533-538	2002	Publication	Mine disasters
Neural Network Technology for Strata Strength Characterization Utt-W | Proc International Joint Conference on Neural Networks, Mount Royal, New Jersey. Middleton, WI: International Neural Network Society, 1999 Jan; :CD-ROM; 4pp	1999	Publication	Ground control
New Approach Controls Dust at the Collector Dump Point: NIOSH Finds a Simple, Cost-Effective Solution for Reducing Dust for Blasthole Drills Reed-WR; Organiscak-JA; Page-SJ | Coal Age 2004 109(6), 2004 Jun; :20-22	2004	Publication	Respiratory diseases
New Approach Controls Dust at the Collector Dump Point: NIOSH Finds a Simple, Cost-Effective Solution for Reducing Dust for Blasthole Drills Reed-WR; Organiscak-JA; Page-SJ | Eng Min J 204(7), 2004; :29-31	2004	Publication	Respiratory diseases
New Coal Mine Roof Rating (CMRR) Improves Safety in U.S. Underground Mines Molinda-GM; Mark-C | In: Proceedings of the 27th International Conference of Safety in Mines Research Institutes, Dhar BB, Bhowmick BC, eds., Vol. 2. New Delhi, India: Oxford & IBH Publishing Co. Pvt. Ltd., 1997; :1001-1011	1997	Publication	Ground control
New Design Approaches for Mine Ore Passes Based on Reduced Scale Laboratory Testing, Field Experiments, and Computer Modeling Beus-MJ; Iverson-S | In: G. N. Panagiotou and T. N. Michalakopoulos, eds. Mine Planning and Equipment Selection. Proceedings, 9th International Symposium on Mine Planning and Equipment Selection (Nov. 6-9, 2000; Athens, Greece). Balkema, 2000; :15-20	2000	Publication	Ground control; Traumatic injuries
New Developments with the Coal Mine Roof Rating Mark-C; Molinda-GM; Barton-TM | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 21st International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2002 Aug; :294-301	2002	Publication	Ground control
New Drill-monitoring System Evaluates Strata Strength in Real Time Utt-WK; Miller-GG; Howie-WL; Woodward-CC | Transactions of SME 312 2002; :87-92	2002	Publication	Ground control

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New Insight Into the Detection of High-Impedance Arcing Faults on DC Trolley Systems Li-J; Kohler-JL | IEEE Transactions on Industry Applications 35(5), 1999; :1169-1173	1999	Publication	Traumatic injuries
New Laminated Displacement-Discontinuity Program Heasley-KA; Salamon-MDG | In: Aubertin M, Hassani F, Mitri H, eds. Proceedings of the Second North American Rock Mechanics Symposium: NARMS '96. Montreal, Quebec, Canada, 1995; :1879-1886	1996	Publication	Ground control
New Laminated Displacement-Discontinuity Program: Fundamental Behavior Heasley-KA; Salamon-MDG | In: Ozdemir L, Hanna K, Haramy KY, Peng S, eds. Proceedings of the 15th International Conference on Ground Control in Mining. Golden, CO: Colorado School of Mines,1996; :111-125	1996	Publication	Ground control
New Techniques for Mining Thin-Seam Mountaintop Coal Reserves DuCarme-JP; Jaspal-JS; Kwitowski-AJ | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 9595. NTIS stock number: PB96-147863, 1996	1996	Publication	Ground control; Mine disasters; Surveillance and training
New Technology for Hoist Conveyance Monitoring and Analysis Beus-MJ, Ruest-M | CIM Bulletin 95(1065), 2002	2002	Publication	Traumatic injuries
New Technology To Monitor Blind Areas Near Surface Mining Equipment Ruff-T | Crossroads to Innovation, Conference Record of the 2003 Institute of Electrical and Electronics Engineers and 38th Annual Meeting of Industry Applications Society (Oct 12-16, 2003; Salt Lake City, UT), Available from the author and on CD-ROM from IEEE, Piscataway, NJ, 2003 Oct; :7 pp	2003	Publication	Traumatic injuries
New Tools for Roof Support Evaluation and Design Signer-S; Sunderman-C | In: S. S. Peng, C. Mark, A. Wahab Khair, and K. Heasley, eds., Proceedings: 22nd International Conference on Ground Control in Mining (Aug. 5-7, 2003; Morgantown WV), Dept. of Mining Engineering, West Virginia University, 2003 Aug; :114-118	2003	Publication	Ground control
New Tools To Monitor Personal Exposure To Respirable Coal Mine Dust Volkwein-JC; Thimons-ED | In: Proceedings of the Seventh International Mine Ventilation Congress, 2001, Krakow, Poland, 2001 Jan; :143-150	2001	Publication	Respiratory diseases
New Tricks for an Old Elephant: Revising Concepts of Coeur d'Alene Geology White-BG | Min Eng 1998 Jan; :50(8)27-35	1998	Publication	Ground control
New Tricks for an Old Elephant: Revising Concepts of Coeur d'Alene Geology White-BG | SME preprint 98-87. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., pp. 1-11	1998	Publication	Ground control
NIOSH Computer Programs for Bench Crest Failure Analysis in Fractured Rock Whyatt-J; Miller-S; Dwyer-J | In: Dessureault SD, Ganguli R, Kecojevic V, Dwyer JG, eds. Application of Computers and Operations Research in the Mineral Industry. Proceedings of the 32nd International Conference (APCOM) (Tucson, AZ, March 30-April 1, 2005). Balkema, 2005; :439-446	2005	Publication	Ground control
NIOSH Hazard Controls 27 - New Shroud Design Controls Silica Dust from Surface Mine and Construction Blast Hole Drills Page-SJ; Organiscak-JA; Flesch-JP; Hagedorn-RT | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 98-150, 1998 Nov; : 1-4	1998	Publication	Respiratory diseases

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NIOSH Hazard Controls 31: Dust Protection for Bag Stackers NIOSH | Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, HC 31, DHHS (NIOSH) Publication No. 2001-142, 2001 Jul :1-4	2001	Publication	Respiratory diseases
NIOSH Hazard ID - Carbon Monoxide Poisoning and Death After the Use of Explosives in a Sewer Construction Project NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication 98-122, 1998 Mar	1998	Publication	Traumatic injuries
NIOSH Hazard ID - Exposure to Silica Dust on Continuous Mining Operations Using Flooded-Bed Scrubbers Colinet-JF; Flesch-JP | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 97-147, 1997 Aug :1-2	1997	Publication	Respiratory diseases
NIOSH Hazard ID - Ignition Hazard from Drilling into Sealed Frames of Agricultural Equipment NIOSH | Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, HID 4, DHHS (NIOSH) Publication No. 98-146	1998	Publication	Traumatic injuries
NIOSH Hazard ID - Workers Exposed to Class B Biosolids During and After Field Application Hintz-P | NIOSH Hazard Identification 10. Dept. of Health and Human Services, Centers for Disease Control, NIOSH Pub. 2000-158, Aug. 2000	2000	Publication	Surveillance and training
NIOSH Health Hazard Evaluation Report: HETA #99-0283-2855: Yellowstone National Park, Yellowstone National Park, Wyoming Habes-DJ; Dick-RB; Tubbs-RL; Biggs-FR; Burt-SE | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, 2001 Aug; :23 pp	2001	Publication	Traumatic injuries
NIOSH Longwall Gob Gas Flow Characterization Studies: Pittsburgh Coalbed, PA Diamond-WP; Mucho-TP; Garcia-F; Jeran-PW; LaScola-JC; McCall-FE; Ulery-JP; Schatzel-SJ | In: Proceedings of Longwall USA International Exhibition & Conference, 1999; :105-118	1999	Publication	Mine disasters
NIOSH Mining Update - New Publications 1995-96 NIOSH	1997	Web document	All
NIOSH Pittsburgh Research Laboratory Visitor Information NIOSH | Caruso-DL, Brnich MJ, eds. Unpublished.	2005	Publication	Surveillance and training
NIOSH Program of Mining Research: 1998-1999 NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 99-103	1998	Publication	All
NIOSH Program of Mining Research: A Summary of Mining Research in Progress, 1998 NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 98-114	1998	Publication	All
NIOSH Research for Controlling Respirable Dust and Methane Gas on Continuous Miner Faces Goodman-GVR; Taylor-CD; Coliner-JF; Thimons-ED | Proc 12th International Conference on Coal Research, Sandton, Republic of South Africa. Johannesburg, South Africa: South Africa Institute of Mining and Metallurgy 2000 Sep; :151-154	2000	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
NIOSH Research in Coal Dust and Explosions Gurtunca-RG; Cashdollar-KL; Volkwein-JC; Rupprecht-E | In: Weitang F, ed. Proceedings of the 13th International Conference on Coal Research (Shanghai, China, October 26-29, 2004). Beijing, China: China National Coal Assocation, Department of International Cooperation,2004; :179-186	2004	Publication	Mine disasters
NIOSH Shield Hydraulics Inspection and Evaluation of Leg Data (Shield) Computer Program Barczak-TM; Conover-DP | 21st Intl Conf on Ground Control in Mining. Morgantown, WV: West Virginia University, 2002 Aug; :27-38	2002	Publication	Ground control
NIOSH Study Documents a Decade of Equipment Fires De Rosa-MI | Engineering and Mining Journal 206(3), 2005; :40-44	2005	Publication	Mine disasters
NIOSH Ventilation Research Addressing Diesel Emissions and Other Air Quality Issues in Nonmetal Mines Grau-RH; Robertson-SB; Mucho-TP; Garcia-F; Smith-AC | 2002 SME Annual Meeting (Phoenix, Arizona; Feb 25-27, 2002). SME preprint 02-187. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc; :1-7	2002	Publication	Mine disasters; Respiratory diseases
NIOSH Ventilation Research Addressing Diesel Emissions and Other Air Quality Issues in Nonmetal Mines Grau-RH III; Robertson-SB; Mucho-T; Garcia-F, Smith-AC | Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., Transactions 2004, Vol. 316; :149-158	2004	Publication	Mine disasters
NIOSH/Industry Collaborative Efforts Show Improved Mining Equipment Cab Dust Protection Organiscak-JA; Cecala-AB; Thimons-ED; Heitbrink-WA; Schmitz-M; Ahrenholtz-E | SME preprint 03-009. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2003; :1-8	2003	Publication	Respiratory diseases
NIOSH/Industry Collaborative Efforts Show Improved Mining Equipment Cab Dust Protection Organiscak-JA; Cecala-AB; Thimons-ED; Heitbrink-WA; Schmitz-M; Ahrenholtz-E | In: Yernberg WR, ed. Transactions of Society for Mining, Metallurgy, and Explorations, Inc., Vol. 314. Littleton, CO: Society for Mining, Metallurgy, and Explorations, Inc., 2003; :145-152	2003	Publication	Respiratory diseases
NIOSH/NHCA Best Practices Workshop on Impulsive Noise Kardous-CA; Franks-JR; David-RR | Noise Control Engineering Journal, 53(2):53-60	2005	Publication	Hearing loss
Noise and Vibration Reduction of a Vibrating Screen Yantek-DS; Jurovcik-P; Bauer-ER | SME Preprint No. 05-71, 2005 SME Conference, Salt Lake City, Utah, 2005; :1-13	2005	Publication	Hearing loss
Noise Controls for Continuous Miners Kovalchik-PG; Duda-FT; Durr-TM | Proceedings of 10th International Meeting on Low Frequency Noise and Vibration and its Control. York, England, September 200; :299-306	2002	Publication	Hearing loss
Noise Exposure and Hearing Loss Among Sand and Gravel Miners Landen-DD; Wilkins-SW; Stephenson-MR; McWilliams-LJ | J Occup Environ Hyg 1(8), 2004; :532-541	2004	Publication	Hearing loss
Noise Exposure and Overhead Power Line (OPL) Safety Hazards at Surface Drilling Sites Reinke-DC; Homce-GT; Cawley-JC; Barrett-EA | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, December, 2005	2005	Publication	Hearing loss
Noise Exposure Assessment and Abatement Strategies at an Indoor Firing Range Kardous-CA; Willson-RD; Hayden-CS; Murphy-SP; Reeves-ER | Applied Occupational and Environmental Hygiene. Vol 18, 2003 Aug; :629-636	2003	Publication	Hearing loss
Noise Exposure in Longwall Mining and Engineering Controls Research Bauer-ER; Podobinsk-DJ; Reever- ER | In: Proceedings of Longwall USA International Exhibition and Conference, June 13-15, Pittsburgh, PA, Intertec Publishing Corp.; :51-69	2001	Publication	Hearing loss

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Noncoal Contractor Mining Facts - 2001 NIOSH | NIOSH Publication No. 2003-135, 2003 Jul; :1-2	2003	Publication	Surveillance and training
Noncoal Contractor Mining Facts - 2002 NIOSH | NIOSH Publication No. 2004-129, 2004 Jan; :1 pp	2004	Publication	Surveillance and training
Noncoal Contractor Mining Facts - 2003 NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-122, 2005 Feb; :1 pp	2005	Publication	Surveillance and training
Non-directional Magnet Field-Based Proximity receiver with Multiple Warning and Machine Shutdown Capability Schiffbauer-WH | U.S. Patent #6,810,353 B2 (granted Oct 26, 2004)	2004	Patent	Traumatic injuries
Nonmetal Mining Facts - 2001 NIOSH | NIOSH Publication No. 2003-132, 2003 Jul; :1-2	2003	Publication	Surveillance and training
Nonmetal Operator Mining Facts - 2002 NIOSH | NIOSH Publication No. 2004-125, 2004 Jan; :1	2004	Publication	Surveillance and training
Nonmetal Operator Mining Facts - 2003 NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-121, 2005 Feb; :1 pp	2005	Publication	Surveillance and training
Noranda Inc. - Brunswick Mine Diesel Particulate Filter (DPF) Field Study McGinn-S; Grenier-M; Gangal-M; Rubeli-B; Bugarski-A; Schnakenberg-G; Johnson-R; Petrie-D; Crowther-G; Penney-J | Final Report of Investigation to the Diesel Emissions Evaluation Program (DEEP), 2004 Oct :8-88	2004	Publication	Respiratory diseases
Novel Technique Can Reduce Occupational Hearing Loss NIOSH | Web document, http://www.cdc.gov/niosh/enews/enewsV2N1.html#from	2004	Web document	Hearing loss
Numerical Analysis of the Impact of Longwall Panel Width on Methane Emissions and Performance af Gob Gas Ventholes Karacan-CO; Diamond-WP; Esterhuizen-GS; Schatzel-SJ | In: Proceedings of the International Coalbed Methane Symposium (Tuscaloosa, AL; May 18-19, 2005). University of Alabama, 2005; :28 pp	2005	Publication	Mine disasters
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Title	Year	Output Type	Strategic Goal
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Occupational Noise in Coal Mining - A Continuing Problem Bartholomae-RC | In: Proceedings of the 13th Annual International Pittsburgh Coal Conference. Pittsburgh, PA, 1996; :959-964	1996	Publication	Hearing loss
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Organization Profile: TIEMS Kowalski-KM | Psych Intl 2000 Apr; 11(2), 2004 Apr; :4	2000	Publication	Mine disasters
Origin of Mining-Induced Fractures Through Macroscale Distortion White-BG; Larson-M; Iverson-SR | Gulf Rocks 2004: Proceedings, Rock Mechanics Across Borders & Disciplines, s6th North American Rock Mechanics Conference, June 5-10, 2004, Houston, Texas. Report No. ARMA/NARMS 04-569. Alexandria, VA: American Rock Mechanics Association, 2004 Jun; :1-8	2004	Publication	Ground control
Out-of-the-Box Approach to Mine Safety: Focus on Construction, Maintenance, and Repair Activities Kowalski-Trakofler-KM; Rethi-LL | Professional Safety 48(1), 2003; :21-27	2003	Publication	Surveillance and training
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Overview of Dust Explosibility Characteristics Cashdollar-KL | J Loss Prevention in the Process Industries, 2000 May; 13(3-5); :183-199	2000	Publication	Mine disasters
Overview of Fire Detection Technology for Underground Mines Litton-CD | In: Proceedings of the 28th International Conference of Safety in Mines Research Institutes (Sinaia, Romania). Vol. I, 1999; :299-316	1999	Publication	Mine disasters

Title	Year	Output Type	Strategic Goal
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Overview of Ground Control Research for Underground Coal Mines in the United States Mark-C | Proc 17th Intl Mining Congress and Exhibition of Turkey (IMCET 2001) (Ankara, Turkey), 2001; :3-10	2001	Publication	Ground control
Overview of Hazards and Controls Associated With Common Chemicals Found in Mining Scott-DF; Drake-PL | In Proceedings of the Seventh Mine Health and Safety Seminar (Allentown, PA, Jan. 15-16, 2003). 2003; :87-106	2003	Publication	Surveillance and training
Overview of Mine Fire Detection Edwards-JC | Proc Second International Conference on Fire Research and Engineering (August 3-8, 1997; Bethesda, MD), 1998 Aug :489-499	1998	Publication	Mine disasters
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Pennsylvania Incorporates Innovative Programs into Mine Rescue Training Eppley-D; Reinke-DC | MSHA Holmes Safety Association Bulletin, Feb/March 2002; :15-16	2002	Publication	Mine disasters; Surveillance and training
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Portable Tester for Determining Gas Content Within a Core Sample Garcia-F; Schatzel-S | U.S. Patent #5,741,959 (granted April 21, 1998)	1998	Patent	Mine disasters

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Practical Aspects of Mobile Roof Support Usage Chase-FE; McComas-A; Mark-C; Barczak-TM; Goble-CD | In: Ozdemir L, Hanna K, Haramy KY, Peng S, eds. Proceedings of the 15th International Conference on Ground Control in Mining. Golden, CO: Colorado School of Mines, 1995	1996	Publication	Ground control
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Practical Techniques to Improve the Air Quality in Underground Stone Mines Grau-RH; Mucho-TP; Robertson-SB; Smith-AC; Garcia-SF | In: De Souze E, ed. Mine Ventilation: Proceedings of the North American/Ninth U.S. Mine Ventilation Symposium (Kingston, Ontario, Canada) Lisse, Netherlands: A. A. Balkema, 2002 Oct; :123-129	2002	Publication	Mine disasters; Respiratory diseases
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Principles of Adult Learning: Application for Mine Trainers Kowalski-KM; Vaught-C | In: Peters R, ed. Strategies for Improving Miners' Training. Pittsburgh, PA, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2002-156, Information Circular 9463, 2002 Sep :3-8	2002	Publication	Surveillance and training
Principles of Adult Learning: Tips for Trainers Kowalski-KM PhD; Vaught C PhD | Web document, http://www.cdc.gov/niosh/mining/topics/training/adultlearningtips.htm	2003	Web document	Surveillance and training
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Proceedings: New Technology for Coal Mine Roof Support Mark-C; Dolinar-DR; Tuchman-RJ; Barczak-TM; Signer-SP; Wopat-PF, eds. | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2000-151, IC 9453; :1-280	2000	Publication	Ground control
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Programmable Electronic and Hard-Wired Emergency Shutdown Systems: A Quantified Safety Analysis Sammarco-JJ | In: Proceedings of the IEEE Industry Applications Society 40th Annual Meeting. Hong Kong. October 2005	2005	Publication	Traumatic injuries
Programmable Electronic Mining Systems: Best Practice Recommendations (In Nine Parts): Part 6: 5.1 System Safety Guidance Sammarco-JJ | NIOSH Publication No. 2005-150, Information Circular 9480, 2005 Aug; :1-87	2005	Publication	Traumatic injuries
Programmable Electronic Mining Systems: Best Practice Recommendations (In Nine Parts): Part 2: 2.1 System Safety Sammarco-JJ; Fisher-TJ | NIOSH Publication No. 2001-137, Information Circular 9458, 2001 Apr; :1-47	2001	Publication (guidelines)	Traumatic injuries
Programmable Electronic Mining Systems: Best Practice Recommendations (In Nine Parts): Part 3: 2.2 Software Safety Fries-EF; Fisher-TJ; Jobes-CC | NIOSH Publication No. 2001-164, Information Circular 9460, 2001 Sep :1-45	2001	Publication (guidelines)	Traumatic injuries
Programmable Electronic Mining Systems: Best Practice Recommendations (In Nine Parts): Part 4: 3.0 Safety File Mowrey-GL; Fisher-TJ; Sammarco-JJ; Fries-EF | NIOSH Publication No. 2002-134, Information Circular 9461, 2002 May :1-57	2002	Publication (guidelines)	Traumatic injuries

Title	Year	Output Type	Strategic Goal
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Programmable Electronic Mining Systems: Best Practice Recommendations (In Nine Parts): Part 1: 1.0 Introduction Sammarco-JJ; Fisher-TJ; Welsh-JH; Pazuchanics-MJ | NIOSH Publication No. 2001-132, Information Circular 9456, 2001 Apr; :1-10	2001	Publication (guidelines)	Traumatic injuries
Progress in Developing Software Safety Guidelines for the Mining Industry Sammarco-JJ | In: Gurgenci H, Hood M, eds. Proceedings of the Fourth International Symposium on Mine Mechanisation and Automation. Vol. 2 (Brisbane, Queensland, Australia), 1997; :B9-9 to B9-15	1997	Publication (guidelines)	Traumatic injuries
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Progress Toward a Reduced Exposure Mining System Schnakenberg-GH Jr | Min Eng,49(2),1997 Feb; :73-77	1997	Publication	Traumatic injuries
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Protecting Workers From Toxic Fumes Generated by Explosives Mainiero-RJ | Tunnel Business Magazine, 1999 Dec; :15	1999	Publication	Traumatic injuries
Pumpable Roof Supports: Developing Design Criteria by Measurement of the Ground Reaction Curve Barczak-TM; Chen-J; Bower-J | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 22nd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2003 Aug; :283-294	2003	Publication	Ground control
Pursuit of Accurate Navigation and Control of Continuous Mining Machines for Coal Mining Schiffbauer-WH | In: Gurgenci H, Hood M, eds. Proceedings of the Fourth International Symposium on Mine Mechanisation and Automation. Vol. 2, Brisbane, Queensland, Australia, 1997; :B6-33 to B6 46	1997	Publication	Traumatic injuries
P-Wave Signal IDs Stressed Rock in Deep Mines Williams-TJ; Scott-DF | Sensors, The Journal of Applied Sensor Technology, vol. 15, no. 2, 1998 Feb; :12-13	1998	Publication	Ground control
Raising the Bar of Ventilation for Large-Opening Stone Mines Grau-RH; Robertson-SB; Krog-RB; Chekan-GJ; Mucho-TP | In: Ganguli R, Bandopadhyay S, eds. Mine Ventilation: Proc 10th U.S./North American Mine Ventilation Symposium (Anchorage, Alaska, May 16-19 2004). Leiden, Netherlands: A. A. Balkema, 2004 May; :349-355	2004	Publication	Mine disasters; Respiratory diseases

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Rare-Earth Element Sources and Modification in the Lower Kittanning Coalbed: Pennsylvania: Implications for the Origin of Coal Mineral Matter and Rare-Earth Element Exposure in Underground Mines Schatzel-SJ; Stewart-BW | Int J Coal Geol 54, 2003 ; :223-251	2003	Publication	Respiratory diseases
Rating Coal Mine Roof Strength from Exploratory Drill Core Mark-C; Molinda-GM | In: Ozdemir L, Hanna K, Haramy KY, Peng S, eds Proceedings of the 15th International Conference on Ground Control in Mining. Golden, CO: Colorado School of Mines, 1995; :415-428	1996	Publication	Ground control
Rating the Strength of Coal Mine Roof Rocks Molinda-GM; Mark-C | In: Aubertin M, Hassani F, Mitri H, eds. Proceedings of the Second North American Rock Mechanics Symposium: NARMS '96. Montreal, Quebec, Canada, 1996; :413-422	1996	Publication	Ground control
Rating the Strength of Coal Mine Roof Rocks Molinda-GM; Mark-C | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Information Circular 9444. NTIS stock number: PB96-155072, 1996	1996	Publication	Ground control
Reach Enhancement Of A Submerged Waterjet Using Air Shrouding Miller A, Daly D, Connors S | In: Hashish M, ed. Proceedings of the 9th American Waterjet Conference, Vol. 1, 1997; :347-363	1997	Publication	Traumatic injuries
Real-Time Monitoring of Field Measurements for Mine Design: Greens Creek Mine, Admiralty Island, Alaska Orr-TJ; Beus-MJ | Spokane, WA: U.S. Department of the Interior, Bureau of Mines, Report of Investigations 9613. NTIS stock number: PB96-144183, 1996	1996	Publication	Ground control
Real-time Neural Network Application to Mine Fire - Nuisance Emissions Discrimination Edwards-JC; Franks-RA; Friel-GF; Lazzara-CP; Opferman-JJ | In: Ganguli-R and Bandopadhyay-S, eds. Mine Ventilation: Proc 10th U.S./North American Mine Ventilation Symposium (May 16-19, 2004, Anchorage, AK). A. A. Balkema Publishers, Lisse, Netherlands; :425-431	2004	Publication	Mine disasters
Recent Advances in Proximity Warning Technology for Surface Mining Equipment Ruff-TM; Steele-J | Mining Engineering, 56(12); :68-72	2004	Publication	Traumatic injuries
Recent Advances in Proximity Warning Technology for Surface Mining Equipment Ruff-TM; Steele-J | Annual Meeting of Soc. For Mining, Metallurgy, and Exploration (Feb 23-25, 2004; Denver, CO), Preprint 04-03; :5pp	2004	Publication	Traumatic injuries
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Recent Mine Seal Research Conducted by NIOSH Sapko-MJ; Weiss-ES; Greninger-NB | In: Sealbarr '99 - Proceedings of the Polish-American Seminar on Seals and Barriers as a Means of Protection Against Fires and Explosions in Mines (Katowice, Poland, May 27-28, 1999),1999 May; :39-53	1999	Publication	Mine disasters
Recent National Institute for Occupational Safety and Health Research Using Ground Penetrating Radar for Detection of Mine Voids Monaghan-WD; Trevits-MA; Mucho-TP; Wood-J | In: Proceedings - Geophysical Technologies for Detecting Underground Coal Mine Voids: An Interactive Forum (Lexington, KY, July 29-30, 2003), 2003 Jul	2003	Publication	Ground control

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Recommendations for Testing Radar-Based Collision Warning Systems on Heavy Equipment Ruff-TM | NIOSH Report of Investigations 9657, 2002 May; :1-17	2002	Publication (guidelines)	Traumatic injuries
Reduced Explosive-Mass and Damaged Detonator Performance Tests Wieland-MS | In: Proceedings of the 13th Annual Symposium on Explosives and Blasting Research. International Society of Explosives Engineers, 1997; :211-221	1997	Publication	Traumatic injuries
Reducing Enclosed Cab Drill Operator's Respirable Dust Exposure at a Surface Coal Operation Using a Retrofitted Filtration and Pressurization System Cecala-AB; Organiscak-JA; Heitbrink-WA; Zimmer-JA; Fisher-T; Gresh-RE, et al. | In: Yernberg WR, ed. Transactions of Society for Mining, Metallurgy, and Explorations, Inc. Vol. 314. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc; :31-36	2003	Publication	Respiratory diseases
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Reducing Longwall Noise with Acoustical Material on the Shields - A Preliminary Analysis Rider-JP; Thimons-ED; Prokop-AD | In: Proceedings of Longwall USA. Pittsburgh, PA, 1996; :159-171	1996	Publication	Hearing loss
Reducing Roof Bolter Operator Cumulative Trauma Exposure Cornelius-KM; Turin-FC | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin 1997 Jan; :1-8	1997	Publication	Cumulative injuries
Reducing Silica Exposure in Aggregate Operations Cecala-AB; Organiscak-JA; Page-SJ; Thimons-ED | Aggregates Manger 2005 Jan; :24-28	2002	Publication (guidelines)	Respiratory diseases
Reducing the Risk of Ground Falls During Pillar Recovery Mark-C; Chase-FE; Pappas-DM | In: Yernberg WR, ed. Transactions of Society for Mining, Metallurgy, and Explorations, Inc., Vol. 314. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2003; :153-160	2003	Publication	Ground control
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Title	Year	Output Type	Strategic Goal
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Relationship of Roof Movement and Strata-induced Microseismic Emissions to Roof Falls Iannacchione-AT; Coyle-PR; Prosser-LJ Jr; Marshall-TE, Litsenberger-J | Min Eng 56(12):53-60	2004	Publication	Ground control
Relationships Between Electrostatic Charging Characteristics, Moisture Content, and Airborne Dust Generation for Subbituminous and Bituminous Coals Page-SJ | Aerosol Sci Tech 2000 Apr; 32(4):249-267	2000	Publication	Respiratory diseases
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Releasing the Energy of Workers to Create a Safer Workplace: The Value of Using Mentors to Enhance Safety Training Camm-TW; Cullen-ET; | In: Peters R, ed. Strategies for Improving Miners' Training. Pittsburgh, PA, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Information Circular 9463, 2002 Sep :35-38	2002	Publication	Surveillance and training
Remote Control of an Agricultural Tractor in SAE Field Upset Tests Lutz-TJ; Homce-GT | Int J Vehicle Des 34(3), 2004; :286-296	2004	Publication	Traumatic injuries
Remote Controls on an Agricultural Tractor for Performing ASAE/SAE Field Upset Tests Lutz-TJ; Homce-GT | Proceedings of the 93rd Annual International Meeting of the American Society of Agricultural Engineers, Paper No. 007004, Milwaukee, WI, July 9-12, 2000. St. Joseph, MI: American Society of Agricultural Engineers, 2000 Jul; :1-6	2000	Publication	Traumatic injuries
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Remote Monitoring of Mine Seismicity and Earthquakes Using Radio Telemetry, Computers, and the Internet Denton-D; Stickney-M; Williams-T; Langston-R | In: R.K. Singhal, K. Fytas, and C. Chiwetelu, eds., Computer Applications in the Minerals Industries, Proceedings of the Fourth International Conference on Computer Applications in the Minerals Industries (CAMI 2003) (Sept. 8-10, 2003; Calgary, AB), 2003 Sep	2003	Publication	Ground control
Remote Roof Stability Monitoring for Underground Nonmetal Mines Grau-RH III; Iannacchione-AT; Prosser-LJ Jr | In: Proceedings of the 1999 Structures Congress. Reston, VA: American Society of Civil Engineers,1999; :727-730	1999	Publication	Ground control
Removing Booster Influences From Toxic Fumes Wieland-MS | Proc Twenty-Fifth Ann Conf Explos Blasting Tech. Cleveland, OH: Intl Society of Explosives Engineers, 1999; :11-28	1999	Publication	Traumatic injuries
Research by NIOSH for Controlling Respirable Dust and Methane Gas on Continuous Miner Faces Goodman-GVR; Taylor-CD; Colinet-JF; Thimons-ED | Proc Seventh International Mine Ventilation Congress, 2001, Krakow, Poland, 2001 Jan; :237-241	2001	Publication	Mine disasters; Respiratory diseases

Title	Year	Output Type	Strategic Goal
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Respirable Dust Evaluation of Two Portland Cement Operations: Part 1 of 2 Cecala-AB; Timko-RJ; Zimmer-JA; Thimons-ED | Cement Americas 2000 Jan/Feb; :20-23	2000	Publication	Respiratory diseases
Respirable Dust Evaluation of Two Portland Cement Operations: Part 2 of 2 Cecala-AB; Timko-RJ; Zimmer-JA; Thimons-ED | Cement Americas 2000 Mar/Apr; :28-30	2000	Publication	Respiratory diseases
Responders To Underground Mine Fires Conti-RS | Proceedings of the 32nd Annual Conference of the Institute on Mining Health, Safety and Research (Aug 5-7, 2001; Salt Lake City, UT), University of Utah; :111-121	2001	Publication	Mine disasters
Retreat Mining Pillar Stability Mark-C | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin, 1998 Nov; :15	1998	Publication	Ground control
Retrofit Options for Better Dust Control Chekan-GJ; Colinet-JF | Aggregates Manag 8(9); :9-12	2003	Publication (guidelines)	Respiratory diseases
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Review of Technology Available to the Underground Mining Industry for Control of Diesel Emissions Schnakenberg-GH Jr; Bugarski-AD | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2002-154, Information Circular 9462, 2002 Aug :1-51	2002	Publication	Respiratory diseases
Rock Bursting and Seismicity During Ramp Development, Lucky Friday Mine, Mullan, Idaho Whyatt-JK; White-BG | In: Peng SS, ed. Proceedings of the 17th International Conference on Ground Control in Mining, 1998 Aug :317-325	1998	Publication	Ground control
Rock Damage Characterisation from Microseismic Monitoring Gale-WJ; Heasley-KA; Iannacchione-AT; Swanson-PLS; Hatherly-P; King-A | Rock Mechanics in the National Interest. Vol. II, Lisse, Netherlands: A. A. Balkema, 2001 Jul; 2:1313-1320	2001	Publication	Ground control
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Rock Mechanics Study of Shaft Stability and Pillar Mining, Homestake Mine, Lead, SD (In Three Parts): 3. Geomechanical Monitoring and Modeling Using UTAH3 Pariseau-WG; Johnson-JC; McDonald-MM; Poad-ME | US Bureau of Mines, Report of Investigations 9618, NTIS number: PB96-144217, 1996; :1-29	1996	Publication	Ground control
Role of Fault Slip on Mechanisms of Rock Burst Damage, Lucky Friday Mine, Idaho, USA White-BG; Whyatt-JK | In: Hogan TO, ed. SARES 99 - Second Southern African Rock Engineering Symposium. Implementing Rock Engineering Knowledge September 13-15, Johannesburg, S. Africa. Lisboa, Portgual: International Society of Rock Mechanics 1999 Jan; :169-178	1999	Publication	Ground control
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Roof Monitoring Helps Prevent Injuries in Stone Mines Iannacchione-AT; Prosser-LJ Jr; Grau-RH III; Oyler-DC; Dolinar-DR; Marshall-TE; Compton-C | Min Eng 2000 Nov; 52(11):32-37	2000	Publication	Ground control
Roof Monitoring in Limestone - Experience with the Roof Monitoring Safety System (RMSS) Marshall-TE; Prosser-LJ Jr.; Iannacchione-AT; Dunn-M | In: Proceedings of the 19th International Conference on Ground Control in Mining, Peng SS, Mark C, eds., Morgantown, WV: West Virginia University, 2000 Jan; :185-191	2000	Publication	Ground control
Roof Monitoring Safety System for Underground Stone Mines NIOSH | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin, 1998 Nov; :18-19	1998	Publication	Ground control
Roof Screening: Best Practices and Roof Bolting Machines Robertson-SB; Hinshaw-GE | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 21st International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2002; :189-194	2002	Publication	Ground control
Root Causes of Groundfall Related Incidents in U.S. Mining Industry Biswas-K; Zipf-RK Jr | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 22nd Intl Conf on Ground Control in Mining. Morgantown, WV: West Virginia University, 2003 Aug; :335-343	2003	Publication	Ground control
Safer Mine Hoisting With Conveyance Position and Load Monitoring Beus-MJ; Iverson-S | Am J Ind Med, 1999 Sep 36(S1):119-121	1999	Publication	Traumatic injuries
Safer Mine Layouts for Underground Stone Mines Subjected to Excessive Levels of Horizontal Stress Iannacchione-AT; Marshall-TE; Burke-L; Melville-R; Litsenberger-J | Mining Engineering, 55(4), 2003 Apr; :25-31	2003	Publication	Ground control
Safer Mine Layouts for Underground Stone Mines Subjected to Excessive Levels of Horizontal Stress Iannacchione-AT; Marshall-TE; Burke-L; Melville-R; Litsenberger-J | SME Preprint 01-88. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc	2001	Publication	Ground control
Safety Analysis of Surface Haulage Accidents Randolph-RF; Boldt-CMK | Proc 27th Annual Institute on Mining Health, Safety and Research. Blacksburg, VA: Virginia Polytechnic Institute and State University, 1996 Jan; :29-38	1996	Publication	Surveillance and training; Traumatic injuries
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Safety and Health Training for an Evolving Workforce: An Overview From the Mining Industry Kowalski-Trakofler-KM; Vaught-C; Mallett-LG; Brnich-MJ; Reinke-DC; Steiner-LJ; Wiehagen-WJ; Rethi-LL | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2004-155, Information Circular 9474, 2004 Jul :1-15	2004	Publication	Surveillance and training
Safety Challenges at Thin Seam Mines Fotta-B; Peters-RH; Mallett-LG | Holmes Safety Association Bulletin, 1999 Jul/Aug; :5-11	1999	Publication	Surveillance and training
Safety Concerns Associated With the Use of Electrically Powered Haulage to Remove Workers from Mines During Main Fan Stoppages Taylor-CD; Timko-RJ; Thimons-ED; Zimmer-JA | In: De Souze E, ed. Proc North American/Ninth U.S. Mine Ventilation Symposium (Jun 8-12, 2002; Kingston, Ontario, Canada). Lisse, The Netherlands: A. A. Balkema; 2002 Oct; :649-653	2002	Publication	Mine disasters
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Safety Issues and the Use of Software-Controlled Equipment in the Mining Industry Sammarco-JJ; Kohler-JL; Novak-T; Morley-LA | IEEE Industry Applications Society 32nd Annual Meeting (Oct. 5-9, 1997; New Orleans, LA), 1997 Oct; :1-7	1997	Publication	Traumatic injuries
Safety Solution: Conveyor Spillage Prevention Stewart-W | Web document, http://www.cdc.gov/niosh/mining/topics/machinesafety/equipmentdsgn/conveyorspillage.htm	2004	Web document	Cumulative injuries; Traumatic injuries
Safety Solution: Preventing Slide-Backs On Slope Conveyors Stewert-W | Web document, http://www.cdc.gov/niosh/mining/topics/machinesafety/equipmentdsgn/slidebacks.htm	2004	Web document	Cumulative injuries; Traumatic injuries
Sampling Results of the Improved SKC® Diesel Particulate Matter Cassette Noll-JD; Timko-RJ; McWilliams-LJ; Hall-P; Haney-R | Journal of Occupational and Environmental Hygiene, 2(1), 2005 Jan; :29-37	2005	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
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Sand and Gravel Mining Facts - 2001 NIOSH | NIOSH Publication No. 2003-134, 2003 Jul; :1-2	2003	Publication	Surveillance and training
Scaled Cloud Model for Released Toxic Fumes Wieland-MS | Proc 10th Annual High-Tech Blasting Seminar. Allentown, PA: Blasting Analysis International, Inc., 2001 Jan; :P1-P18	2001	Publication	Traumatic injuries
Scaling Accidents in Underground Stone Mines Grau-RH III; Prosser-LJ Jr | Rock Products 100(1), 1997 Jan; 39-41	1997	Publication	Ground control
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Self-Contained Self-Rescuer Field Evaluation: Sixth-Phase Results Kyriazi-N; Shubilla-JP | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Publication No. 98-1998, Information Circular 9451, 2000 Jul; :1-13	2000	Publication	Mine disasters
Self-Contained Self-Rescuer Field Evaluation: Sixth-Phase Results Kyriazi-N; Shubilla-JP | Journal of the International Society for Respiratory Protection 18(1), 2000; :6-21	2000	Publication	Mine disasters

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Semiempirical Model for Predicting Surface Coal Mine Drill Respirable Dust Emissions Page-SJ; Organiscak-JA | Int J Surface Min Reclam Environ 18(1), 2004; :42-59	2004	Publication	Respiratory diseases
Sensor-Enhanced Test Platform Will Refine Safety Measures in Underground Mines Beus-MJ | Sensors, The Journal of Applied Sensor Technology, 14(8), 1997; :14	1997	Publication	Traumatic injuries
Serious Injuries to Dozer Operators: A Discussion of their Characteristics and Ways to Reduce Injury Risk Wiehagen-WJ; Mayton-AG; Friend-TL; Jaspal-JS; Turin-FC | Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., Transactions 2002, Vol. 312, 2002; :57-64	2002	Publication	Traumatic injuries
Setting Priorities for Mine Safety and Health Research Grayson-RL | SME preprint 98-107. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 1998	1998	Publication	All
Shear Behavior Of Cable Bolt Supports In Horizontal Bedded Deposits Goris-JM; Martin-LA; Curtin-RP | In: Ozdemir L, Hanna K, Haramy KY, Peng S, eds. Proceedings of the 15th International Conference on Ground Control in Mining. Golden, CO: Colorado School of Mines, 1996; :511-521	1996	Publication	Ground control
Shear Mechanism for Mining-Induced Fractures Applied to Rock Mechanics of Coal Mines White-B | In: Peng SS, Mark C, Wahab A, and Heasley KA, eds. Proceedings of the 21st International Conference on Ground Control in Mining (Morgantown, WV, Aug. 6-8, 2002), West Virginia University, Morgantown, WV, 2002 Aug; :328-334	2002	Publication	Ground control
Shear Origin of Tension in Excavation-Induced Fractures White-BG; Iverson-S; Larson-M | In: Culligan PJ, Einstein HH, Whittle AJ, eds. Soil and Rock America 2003. 12th Panamerican Conference on Soil Mechanics and Geotechnical Engineering and the 39th U.S. Rock Mechanics Symposium, Vol. 1. Cambridge, MA: Massachusetts Institute of Technology, 2003 Jun; 1:909-916	2003	Publication	Ground control
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Sheathed Explosives Charge Mainiero-RJ | Web document, http://www.cdc.gov/niosh/mining/topics/explosives/sheath.htm	1997	Web document	Traumatic injuries
Shield Design, Construction, and Operation Barczak-TM; Chekan-GJ; Babich-DR | In: Proceedings of Longwall USA International Exhibition & Conference, 1998; :5-47	1998	Publication	Ground control
Shield Evaluation and Performance Testing at the USBM's Strategic Structures Testing Laboratory Barczak-TM; Gearhart-DF | In: Proceedings of Longwall USA. Pittsburgh, PA, 1995; :189-205	1996	Publication	Ground control

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Short-Encapsulation Pull Tests for Roof Bolt Evaluation at an Operating Coal Mine Pile-J; Bessinger-S; Mark-C; Tadolini-SC | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 22nd Intl Conf on Ground Control in Mining. Morgantown, WV: West Virginia University, 2003 Aug; :226-232	2003	Publication	Ground control
Significant Dust Dispersion Models for Mining Operations Reed-WR | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-138, Information Circular 9478, 2005 Sep; :1-29	2005	Publication	Respiratory diseases
Silica Collection Concerns when Using Flooded-Bed Scrubbers Colinet -JF; Jankowski-RA | Society for Mining, Metallurgy, and Exploration, Inc., SME preprint 98-131. Littleton, CO, 1998	1998	Publication	Respiratory diseases
Silica Collection Concerns When Using Flooded-Bed Scrubbers Colinet-JF; Jankowski-RA | Mining Engineering 52(4) 2000; :49-54	2000	Publication	Respiratory diseases
Silica Dust Control in Hard Rock Tunnels Kissell-FN; Jurani-R; Dresel-R; Parker-C | In: Proceedings of the 1999 Rapid Excavation and Tunneling Conference, 1999; :241-247	1999	Publication	Respiratory diseases
Silica Dust Sources in Underground Limestone Mines Chekan-GJ; Colinet-JF | In: Bockosh GR, Kohler JL, Langton JF, Novak T, McCarter MK, Biviano A, eds., Proceedings of the 33nd Annual Institute on Mining Health, Safety and Research. Blacksburg, VA: Virginia Polytechnic Institute and State University, Department of Mining and Minerals Engineering, 2002; :55-70	2002	Publication	Respiratory diseases
Silica Dust Sources in Underground Metal/Nonmetal Mines - Two Case Studies Chekan-GJ; Colinet-JF; Grau-RH, III | 2002 SME Annual Meeting, Feb 25-27, Phoenix, Arizona, preprint 02-037. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2002 Feb; :1-8	2002	Publication	Respiratory diseases
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Simplified Hyperspectral Imaging for Improved Geologic Mapping of Mine Slopes McHugh-EL; Girard-JM; and Denes-LJ | In: Meech JA, Veiga SM, Viega MM, LeClair SR, Maguire JF, eds. Proc Third International Conference on Intelligent Processing and Manufacturing of Materials, 2001, (Vancouver, BC, July 29-Aug 2, 2001); CD-ROM (available from author)	2001	Publication	Ground control
Simplified Pre- and Post-Processing Technique for Performing Finite-Element Analyses of Deep Underground Mines Filgenzi-MT | Proceedings of the 16th International Conference on Ground Control in Mining, Peng SS, ed., Morgantown, WV: West Virginia University, 1997 Jan; :320-328	1997	Publication	Ground control
Size Distribution and Deposition in Human Respiratory Tract: Particle Mass and Number Bugarski-A; Gautam-M | Proc 4th International ETH-Conference on Nanoparticle Measurement, 2001, Bern, Switzerland, August 7-9, 2000. A. Mayer: Niederrohrdorf, Switzerland, 2001 Jan; :1-12	2001	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
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Technology News 482 - Ground Support Safety Training Video NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 482, 2000 Jul :1-2	2000	Publication	Ground control; Surveillance and training
Technology News 483 - Safety Training Tools for Rock Scaling Personnel NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 483, 2001 Jan :1-2	2001	Publication	Ground control; Surveillance and training
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Technology News 487 - Sweeping Compound Application Reduces Dust From Soiled Floors Within Enclosed Operator Cabs NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 487, 2001 Mar :1-2	2001	Publication	Respiratory diseases
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Technology News 489 - Reducing the Danger of Explosions in Sealed Areas (Gobs) in Mines NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 489, 2001 Jun :1-2	2001	Publication	Mine disasters
Technology News 490 - An Inexpensive Device for Monitoring Explosions in Sealed Areas of Underground Mines NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 490, 2001 Jun :1-2	2001	Publication	Mine disasters
Technology News 491 - NIOSH Releases Two New Safety Training Videos NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 491, 2001 Jun :1-2	2001	Publication	Surveillance and training
Technology News 492 - Proceedings of the Second International Workshop on Coal Pillar Mechanics and Design NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 492, 2001 Aug; :1-2	2001	Publication	Ground control
Technology News 493 - Proceedings: New Technology for Coal Mine Roof Support NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 493, 2001 Aug :1-2	2001	Publication	Ground control
Technology News 494 - Expert Miner Training Video Released by NIOSH NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 494, 2002 Mar :1-2	2002	Publication	Surveillance and training
Technology News 495 - NIOSH Releases New Educational Video: Recovery of Farmington No. 9 - An Interview with Danny Kuhn NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 495, 2002 Mar; :1-2	2002	Publication	Mine disasters; Surveillance and training
Technology News 496 - NIOSH Releases New Computer-Based Training Exercise Called MERITS Reinke-D; Mallett-L | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 496, 2002 June; :1-2	2002	Publication	Mine disasters; Surveillance and training
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Technology News 498 - Multiple Fire Sensors for Mine Fire Detection and Nuisance Discrimination NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 498, 2002 Sep :1-2	2002	Publication	Mine disasters

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Technology News 500 - Using In-Place Stone Stoppings to Direct Air in Underground Stone Mines NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 500, 2002 Dec :1-2	2002	Publication	Mine disasters; Respiratory diseases
Technology News 501 - Measuring Very Low Air Velocities in Underground Metal/Nonmetal Mines NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 501, 2003	2003	Publication	Mine disasters
Technology News 502 - New Training Video for Aggregate Operators: Aggregate Training for the Safety Impaired Cullen-E | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 502, January 2003	2003	Publication	Surveillance and training; Traumatic injuries
Technology News 503 - HAZCOM Helper: Compliance Tool for MSHA Rule 30 CFR Part 47 Scott-D; Drake-P | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 503, 2003 Mar; :1-2	2003	Publication	Surveillance and training
Technology News 504 - NIOSH Releases New AHSEM and ARBS Software Programs to Improve Ground Control NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 504, 2003 Apr; :1-2	2003	Publication	Ground control
Technology News 505 - NIOSH Releases New Coal Mine Roof Rating Software NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 505, April 2003; :1-2	2003	Publication	Ground control
Technology News 506 - The Sky is Falling!: NIOSH Releases Safety Video for Surface Mining Operations NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 506, 2004 Aug; :1-2	2004	Publication	Ground control; Surveillance and training
Technology News 507 - NIOSH Safety Talk: The Emergency Communication Triangle NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 507, 2004 Sep; :1-2	2004	Publication	Mine disasters; Surveillance and training
Technology News 508 - NIOSH Releases New Safety Video: Make It Safer With Roof Screen NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 508, 2005 Mar; :1-2	2005	Publication	Ground control

Title	Year	Output Type	Strategic Goal
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Technology News 510 - HazCom Helper - OSHA Version: Compliance Tool For OSHA Rule 29 CFR 1910.1200 NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 510, 2005 Oct; :1-2	2005	Publication	Surveillance and training
Technology News 512 - Improve Drill Dust Collector Capture Through Better Shroud and Inlet Configurations NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 512, 2005 Oct; :1-2	2005	Publication	Respiratory diseases
Technology To Reduce Mine Hoisting Accidents Ruff-T; Beus-M | Engineering and Mining Journal, vol. 200, no. 12, Dec. 1999; :30, 32	1999	Publication	Traumatic injuries
Tell Me a Story: Why Stories are Essential to Effective Safety Training Cullen-ET | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Pub. No. 2005-152, Report of Investigations 9664	2005	Publication	Surveillance and training
Tell Me a Story: Using Narrative to Teach Safety to Skilled Blue-Collar Workers Cullen-E | In: Proceedings, Risk and Safety Management in Industry, Logistics, Transport, and Military Service: New Solutions for the 21st Century. London: U.S. Navy, Office Of Naval Research, International Field Office, 2003 Mar; :1-4	2003	Publication	Surveillance and training
Temperature Corrections to Earth Pressure Cells Embedded in Backfill Tesarik-DR; Seymour-JB; Williams-TJ; Martin-LA; Jones-FM | NIOSH Report of Investigations # 9665, Spokane, WA, December, 2005. 32pp.	2005	Publication	Ground control
Temporal Imaging Of Mine-Induced Stress Change Using Seismic Tomography Friedel-MJ; Scott-DF; Williams-TJ | Eng Geol, 46(2), 1997 Jan; :131-141	1997	Publication	Ground control
Test Report on the Machine-Mounted Continuous Respirable Dust Monitor Kissell-FN; Thimons-ED | Proc Seventh International Mine Ventilation Congress, 2001, (Krakow, Poland); :253-260	2001	Publication	Respiratory diseases
Test Results of Collision Warning Systems for Surface Mining Dump Trucks Ruff-TM | NIOSH Report of Investigations 9652, 2000 May; :44 pp	2000	Publication	Traumatic injuries
Test Results of Collision Warning Systems on Off-Highway Dump Trucks: Phase 2 Ruff-TM | NIOSH Report of Investigations 9654, 2001 Feb; :1-21	2001	Publication	Traumatic injuries
Testing and Evaluation of an Engineering Noise Control on a Longwall Stageloader Bauer-ER; Reeves-ER; Durr-TM; Zuchelli-DR; Armour-D | SME preprint 05-58. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2005; ;1-12	2005	Publication	Hearing loss
Testing Diesel Emission Control Techniques Schnakenberg-GH Jr; Bugarski-AD | In: Proceedings of the Diesel Particulate in Mining Conference (Yeppoon, Queensland, Australia)	2004	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
Testing of Diesel Emissions Control Technologies in Isolated Zone Bugarski-AD; Schnakenberg-GH Jr | In: Proceedings of the Mining Diesel Emissions Conference (Markham, Ontario, Canada)	2003	Publication	Respiratory diseases
Tests of Fibre-Reinforced Shotcrete at the Chief Joseph Mine, Butte, Montana Martin-L; Dunford-J; MacLaughlin-M; Cronoble-R | Presentation at annual meeting of SME, Salt Lake City, UT, Feb. 28-Mar. 2, 2005. Preprint 05-20, 2005; :6 pp	2005	Publication	Ground control
The Advance-and-Relieve Mining Method: a Horizontal Stress Control Technique Chase-FE; Mark-C; Mucho-TP; Campbell-PL | In: Proceedings of the 18th International Conference on Ground Control in Mining, Peng SS, Mark C, eds., SMorgantown, WV: West Virginia University, 1999; :300-308	1999	Publication	Ground control
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The Calculated Risk of Experiencing a Lightning Caused Unplanned Detonation Santis-LD | Proc Fourteenth Annual Symposium on Explosives and Blasting Research, International Society of Explosives Engineers, 1998 Feb :107-119	1998	Publication	Traumatic injuries
The Challenge of Enforcing Safety Rules in Remote Hazardous Work Areas Peters-RH | Presented at Work, Stress, and Health '99: Organization of Work in a Global Economy Conference, Baltimore, MD, March 13, 1999, :13 pp.	1999	Publication	Surveillance and training
The Changing Organization of Work and the Safety and Health of Working People NIOSH | Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disase Control and Prevention, NIOSH, DHHS (NIOSH) Pub No. 2002-116, 2002	2002	Publication	Surveillance and training
The Coal Mine Roof Rating in Mining Engineering Practice Mark-C; Molinda-GM | In: Aziz N, Kininmonth B, eds. Proceedings of the Fourth Underground Coal Operators' Conference. Carlton, Australia: Australian Institute of Mining and Metallurgy	2003	Publication	Ground control
The Concept of Degraded Images Applied to Hazard Recognition Training in Mining for Reduction of Lost-Time Injuries Kowalski-Trakofler-KM; Barrett-EA | J Saf Res 2003; 34(5):515-525	2003	Publication	Surveillance and training
The Consequences of 'Leaky' Enclosures Byrne-DC | SV. Sound and Vibration, 2002 Jan :36-38	2002	Publication	Hearing loss
The Cost of Respirable Coal Mine Dust: An Analysis Based on New Black Lung Claims Page-SJ; Organiscak-JA; Lichtman-K | Appl Occup Environ Hyg 12(12), 1997; :832-839	1997	Publication	Respiratory diseases
The Cost Relationship Between Performance Engineering and Human Behavior Lineberry-GT; Wiehagen-WJ | Trans Soc Min Eng, 298, 1996; :319-326	1996	Publication	Surveillance and training
The Critical Ventilation Velocity in Tunnel Fires - A Computer Simulation Hwang-CC; Edwards-JC | Fire Safety Journal, 2005 Apr; 40(3):213-244	2005	Publication	Mine disasters
The Effect of Standing Support Stiffness on Primary and Secondary Bolting Systems Tadolini-SC; Barczak-TM; Zhang-Y | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 22nd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2003 Aug; pp. 300-307	2003	Publication	Ground control

Title	Year	Output Type	Strategic Goal
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The Effectiveness of Selected Technologies in Controlling Diesel Emissions in an Underground Mine: Isolated Zone Study at Stillwater Mining Company's Nye Mine Bugarski-AD; Schnakenberg-GH; Noll-JD; Mischler-SE; Patts-LD; Hummer-J; Vanderslice-SE; Crum-M; Anderson-R | Proceedings of Diesel Particulate in Mining Conference, Sponsored by Australian Journal of Mining, Yeppoon, Queensland, Australia, June 8-9, 2004	2004	Publication	Respiratory diseases
The Effects of Cable Capacitance on Longwall Power Systems Novak-T; Basar-J; Sottile-J; Kohler-JL | In: Proceedings of the 38th Annual IEEE - IAS Meetings (October 13-17, 2003), Salt Lake City, UT, 2003 Oct; :1615-1621	2003	Publication	Traumatic injuries
The Effects of Cable Capacitance on Longwall Power Systems Novak-T; Basar-J; Sottile-J; Kohler-JL | IEEE Trans Ind Appl 40(5), 2004; :1406-1412	2004	Publication	Traumatic injuries
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The Effects of Lifting Posture on Trunk Muscle Activity Hamrick-CA; Gallagher-S | In: Karwowski W, Wogalter MS, Dempsey PG, eds. Ergonomics and musculoskeletal disorders: research on manual materials handling, 1983-1996, Human Factors and Ergonomics Society, 1997; :28-132	1997	Publication	Cumulative injuries
The Effects of Low Quartz Mass Loading and Spatial Variability on the Quartz Analysis of Surface Coal Mine Dust Samples Page-S; Organiscak-J; Mal-T | Appl Occup Environ Hyg 16(9), 2001 Sept; :910-923	2001	Publication	Respiratory diseases
The Effects of Restricted Workspace on Lumbar Spine Loading Gallagher-S; Hamrick-CA; Cornelius-KM; Redfern-MS | Occupational Ergonomics 2(4), 2001; :201-213	2001	Publication	Cumulative injuries
The Effects of Ventilation and Preburn Time on Water Mist Extinguishing of Diesel Fuel Pool Fires Yuan-L; Lazzara-CP | J Fire Sci 22(5), 2004 Sep; :379-404	2004	Publication	Mine disasters
The Emergency Communication Triangle Mallett-L; Vaught-C; Brnich-MJ | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 99-157, 1999 Oct; :1-16	1999	Publication	Mine disasters; Surveillance and training
The Evolving Mining Workforce: Training Issues Kowalski-KM; Vaught-C; Brnich-MJ; Mallett-L; Reinke-D; Rethi-L; Steiner-L; Wiehagen-W | Proc 32nd Ann Inst Min Health Saf Res 2001 Aug :75-90	2001	Publication	Surveillance and training
The Forgotten Denominator: Pillar Loading Heasley-KA | Pacific Rocks 2000 - Proc Fourth North American Rock Mechanics Symposium, 2000, J. Girard, M. Liebman, C. Breeds, T. Doe, eds., Rotterdam, Netherlands: Balkema, 2000; :457-464	2000	Publication	Ground control
The Future of Mine Health and Safety Research Grayson-RL | In: Proceedings of the Workshop on the Future of Mining Research. Blacksburg, VA: Virginia Polytechnic Institute and State University	1998	Publication	All
The Impact of Extended Depth-of-Cut Mining on Coal Mine Ground Control and Worker Safety [Dissertation] Bauer-ER | University Park, PA: The Pennsylvania State University, Department of Mining Engineering	1998	Publication	Ground control

Title	Year	Output Type	Strategic Goal
The Influence of Seam Height on Lost-Time Injury and Fatality Rates at Small Underground Bituminous Coal Mines Peters-R; Fotta-B; Mallett-L | Appl Occup Env Hyg 16(11), 2001 Nov; :1028-1034	2001	Publication	Surveillance and training
The Influence of Torso Flexion on Fatigue Failure of Lumbosacral Motion Segments Marras-WS; Gallagher-S; Litsky-AS; Burr-D | In: Transactions of the 50th Annual Meeting of the Orthopaedic Research Society. Vol 29. Rosemont, IL: Orthopaedic Research Society, poster No. 1119, 2004	2004	Publication	Cumulative injuries
The Introduction of Roof Bolting to U.S. Underground Coal Mines (1948-1960): A Cautionary Tale Mark-C | 21st International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2002 Aug; :150-160	2002	Publication	Ground control
The Lewis and Clark Line and Coeur d'Alene Mining District White-B; Winston-W; Lange-I | In: Roberts S, Winston D, eds. Geologic Field Trips, Western Montana and Adjacent Areas. University of Montana, Missoula, and Western Montana College of the University of Montana, Dillon, pp. 103-122	2000	Publication	Ground control
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The Role of Total Mining Experience on Mining Injuries and Illnesses in the United States Coleman-PJ | In: Proceedings of the China International Forum on Work Safety (Beijing, China, October 10-12, 2002). Beijing: State Administration of Work Safety (SAWS); :331-336	2002	Publication	Surveillance and training
The Safety and Health of Emergency Workers Kowalski-KM; Vaught-C | J Contingencies Crisis Manag 2001 Sep; 9(3):138-143	2001	Publication	Mine disasters

Title	Year	Output Type	Strategic Goal
The Settlement and Degradation of Nondurable Shales Associated with Coal Mine Waste Embankments Pappas-DM; Vallejo-LE | In: Hudson JA, ed. Proceedings of the 36th U.S. Rock Mechanics Symposium, New York, NY: Columbia University, Paper No. 241, 1997	1997	Publication	Ground control
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The State-Of-The-Art in Coal Pillar Design Mark-C | SME Preprint 99-86. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 1999 Mar; :1-8	1999	Publication	Ground control
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Toolbox Training For Construction Aggregate Miners Boldt-CKM | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication Number 2004-162; 2004 Aug: 1-108	2004	Publication	Surveillance and training; Traumatic injuries

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Toward a Typology of Dynamic and Hazardous Work Environments Scharf-T; Vaught-C; Kidd-P; Steiner-LJ; Kowalski-KM; Wiehagen-WJ; Cole-HP | Hum Ecol Risk Assess 2001 Dec; 7(7):1827-1841	2001	Publication	Surveillance and training
Toxic Fume Comparison of a Few Explosives Used in Trench Blasting Harris-ML; Sapko-MJ; Mainiero-RJ | In: Proceedings of the 29th Annual Conference on Explosives and Blasting Technique (Nashville, TN, Feb. 2-5, 2003). Vol. 2. Cleveland, OH: International Society of Explosives Engineers; :319-336	2003	Publication	Traumatic injuries
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Trunk Extension Strength and Muscle Activity in Standing and Kneeling Postures Gallagher-S | Spine 22(16), 1997 Aug; :1864-1872	1997	Publication	Cumulative injuries
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Two Case Studies of the Performance of Rib Supports Larson-MK; Dunford-JP | In: Ozdemir L, Hanna K, Haramy KY, Peng S, eds. Proceedings of the 15th International Conference on Ground Control in Mining. Golden, CO: Colorado School of Mines, 1996; :527-542	1996	Publication	Ground control

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U.S. Longwall Practices for Controlling Respirable Dust Sources Outby the Shearing Machine Organiscak -JA; Jankowski-RA | In: Proceedings of the International Scientific and Technical Conference on Respirable Dust Hazard Control in the World Mining Industry. Szczyrk, Poland, 1996; :19-25	1996	Publication	Respiratory diseases
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Underground Hazard Recognition Training Barrett-EA; Rethi-LL | Aggregates Manager, 2(11), 1998 Nov; :30-33	1998	Publication	Surveillance and training
Underground Mine Fire Preparedness - Part 1: Part 1 of 4 - Study Overview and Perspective of Underground Mine Fires Wiehagen-WJ; Fowkes-RS; Vaught-C; Conti-RS; Fotta-BA | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Saf Assn Bull, 1997 May; :14-19	1997	Publication	Mine disasters
Underground Mine Fire Preparedness - Part 2: Part 2 of 4 - Preparedness to Evacuate and Miners' Experiences with Incipient Fires Vaught-C; Mallett-LG; Fowkes-RS; Conti-RS; Wiehagen-WJ | Holmes Safety Association Bulletin, 1997 Jul; :1-4	1997	Publication	Mine disasters
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Underground Mine Fire Preparedness - Part 4: Part 4 of 4: Suggested Improvements and Implications for Training Miners in Fire-Fighting Preparedness Conti-RS; Wiehagen-WJ; Fowkes-RS; Vaught-C; Brnich-MJ Jr. | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Saf Assn Bull, 1997 Sep; :3-10	1997	Publication	Mine disasters
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Understanding the Hazard Potentials of Toxic Fumes Weiland-MS | In: Proceedings of the Eighth High-Tech Seminar: Blasting Technology, Instrumentation and Explosives Applications. Allentown, PA: Blasting Analysis International, Inc., 1998; :363-382	1998	Publication	Traumatic injuries

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Update on Mining Health and Safety Research Murphy-JN | Proc 27th Annual Institute on Mining Health, Safety and Research, Blacksburg, VA: Virginia Polytechnic Institute and State University, 1996 Jan; :3-8	1996	Publication	All
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Updating the NIOSH Support Technology Optimization Program (STOP) With New Support Technologies and Additional Design Features Barczak-TM | In: Peng SS, Mark C, Khair AW, eds. Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2001 Aug; :337-346	2001	Publication	Ground control
USBM Health and Safety Legacy Continues Under NIOSH Tuchman-RJ | Itasca, IL: National Safety Council, Safety Focus May-June, 1998; :20	1998	Publication	All
Use of a Directional Spray System Design to Control Respirable Dust and Face Gas Concentrations Around a Continuous Mining Machine Goodman-GVR; Pollock-DE | J Occup Environ Hyg 2004 Dec; 1(12), 2004 Dec; :806-815	2004	Publication	Respiratory diseases
Use of a Test Box to Measure Response Times for Machine-Mounted Monitors Taylor-CD; Chilton-JE; Zimmer-JA | In: Ganguli R, Bandopadhyay S, eds. Mine ventilation: Proc 10th U.S./North American Mine Ventilation Symposium, Anchorage, Alaska, May 16-19, 2004. Leiden, Netherlands: Balkema, 2004 May; :177-182	2004	Publication	Mine disasters
Use of Ground Penetrating Radar and Schmidt Hammer Tests to Determine the Structural Integrity of a Mine Seal Trevits-MA; Monaghan-WD; Mowrey-GL; Sapko-MJ; Thomas-RA | Symposium on the Application of Geophysics to Environmental and Engineering Problems (SAGEEP), Las Vegas, NV, February 10-14, 2002. Denver, CO: Environmental and Engineering Geophysical Society, 2002 Feb; :1-14	2002	Publication	Mine disasters
Use of Ground Penetrating Radar Technology for Mining Applications Trevits-MA; Monaghan-WD; Mucho-TP | SME preprint 05-129. Littleton, CO: Society for Mining, Metallurgy, and Exporation, Inc., 2005; :1-13.	2005	Publication	Mine disasters
Use of Methane Monitors for Estimating Face Gas Conditions Taylor-CD; Goodman-GVR | Appl Occupational and Environmental Hyg 12(12), 1997 Dec; :947-951	1997	Publication	Mine disasters

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Use of Seismic Tomography To Identify Geologic Hazards in Underground Mines Scott-DF; Williams-TJ; Denton-DK | The Professional Geologist, vol. 35, no. 7, 1998 Jun; :3-5	1998	Publication	Ground control
Use of Simulation Exercises for Safety Training in the U.S. Mining Industry Cole-HP; Wiehagen-WJ; Vaught-C; Mills-BS | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2001-141, Information Circular 9459, 2001 Sep; :1-20	2001	Publication	Cumulative injuries; Surveillance and training
Use of Strain-Gauged Rock Bolts to Measure Rock Mass Strain During Drift Development Johnson-JC; Brady-T; Larson-M; Langston-R; Kirsten-H | Rock Mechanics for Industry, Anadeum Kranz, Scott & Smeallie (eds), 1999 Balkema, Rotterdam, ISBN 90 5809 052 3; 497-502	1999	Publication	Ground control
Using Coal Miners' Experience To Identify Effective Operating Cues Cornelius-KM; Steiner-LJ; Turin-FC | Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting, 1998 Oct; :1098-1102	1998	Publication	Cumulative injuries; Traumatic injuries
Using Ergonomics to Enhance Safe Production at a Surface Coal Mine: A Case Study With Powder Crews Wiehagen-W; Torma-Krajewski-J; Peterson-A; Turin-F; Unger-R | In: Proceedings of 2004 Joint Conference on Mine Safety and Health (May 23-28, 2004; Salt Lake City, UT)	2004	Publication	Cumulative injuries
Using Ergonomics to Enhance Safety and Health in the U.S. Mining Industry Steiner-L; Torma-Krajewski-J; Schwerha-D | 31st International Conference of Safety in Mines Research Institutes, 2-5 October 2005, Brisbane, Queensland, Australia. Redbank, Queensland, Australia: Safety in Mines Testing and Research Station (Simtars), 2005 Oct; :106-111	2005	Publication	Cumulative injuries
Using Ground Penetrating Radar for Roof Hazard Detection in Underground Mines Molinda-GM; Monaghan-WD; Mowrey-GL; Persetic-GF | Pittsburgh, PA: U.S. Department of Energy, Report of Investigations 9625. NTIS stock number: PB96-188123, 1996 Jan; :1-14	1996	Publication	Ground control
Using Ground Penetrating Radar for Roof Hazard Detection in Underground Mines Molinda-GM; Monaghan-WD; Mowrey-GL; Persetic-GF | In: Thompson SD, Grayson RL, Wang YJ, eds. Proceedings of the Fifth Conference on the Use of Computers in the Coal Industry. Morgantown, WV: West Virginia University, 1996; :193-203	1996	Publication	Ground control
Using Ground Penetrating Radar for Roof Hazard Detection in Underground Mines Molinda-GM; Monaghan-WD; Mowrey-GL; Persetic-GF | In: Ozdemir L, Hanna K, Haramy KY, Peng S, eds. Proceedings of the 15th International Conference on Ground Control in Mining. Golden, CO: Colorado School of Mines, 1996; :385-402	1996	Publication	Ground control
Using Persuasive Messages to Encourage Voluntary Hearing Protection Among Coal Miners Stephenson-MT; Witte-K; Vaught-C. Zuick-BL; Booth-Butterfield-S; Patel-D; Zuckerman-C | J Safe Res 36(1), 2005; :9-17	2005	Publication	Hearing loss
Using Proximate Analysis to Characterize Airborne Dust Generation from Bituminous Coals Page-SJ; Organiscak-JA | Aerosol Sci Tech 2002 Jun; 36(6):721-733	2002	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
Using Site Case Histories of Multiple Seam Coal Mining to Advance Mine Design Ellenberger-JL; Chase-FE; Mark-C; Heasley-KA; Marshall-JK | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 22nd Intl Conf on Ground Control in Mining. Morgantown, WV: West Virginia University, 2003 Aug; :59-64	2003	Publication	Ground control
Using the Coal Mine Roof Rating (CMRR) to Assess Roof Stability in U.S. Coal Mines Molinda-GM; Mark-C; Debasis-D | Journal of Mines, Metals, and Fuels (India) Aug-Sep 2001; :314-321	2001	Publication	Ground control
Using the Extended Parallel Process Model to Prevent Noise-Induced Hearing Loss Among Coal Miners in Appalachia Murray-Johnson-L; Witte-K; Patel-D; Orrego-V; Zuckerman-C; Maxfield-AM; Thimons-ED | Heath Educ Behav 31(6), 2004; :741-755	2004	Publication	Hearing loss
Using the Internet to Train Emergency Command Center Personnel Glowack-AF; Unger-RL; Fries-EF; Kwitowsk-AJ | Contingencies, emergency, crisis, and disaster management: emergency management in the third millennium--Proceedings of the Seventh Annual Conference of The International Emergency Management Society, Orlando, FL, May 16-19, 2000. Alachua County, FL: The International Emergency Management Society (TIEMS), 2000 May; :247-254	2000	Publication	Mine disasters; Surveillance and training
Using the Point Load Test to Determine the Uniaxial Compressive Strength of Coal Measure Rock Rusnak J; Mark C | In: Peng SS, Mark C, eds. Proceedings of the 19th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, pp. 362-371	2000	Publication	Ground control
Using Ultrasonic Anemometers to Evaluate Factors Affecting Face Ventilation Effectiveness Taylor-CD; Timko-RJ; Thimons-ED; Mal-T | 2005 SME Annual Meeting, February 28 - March 2, Salt Lake City, Utah, preprint 05-80. Littleton, CO, Society for Mining, Metallurgy, and Exploration, Inc., 2005 Feb; :1-7	2005	Publication	Mine disasters
Using Ventilation Control Technology to Reduce Respirable Dust Exposures at US Metal/Nonmetal Mining Operations Cecala-AB; Zimmer-JA; Colinet-JF; Timko-RJ; Chekan-GJ; Pollock-DE | In: Gillies ADS, ed. Proceedings of Eighth International Mine Ventilation Congress (Brisbane, Australia), AusIMM, Victoria, Australia, 2005; :157-165	2005	Publication	Respiratory diseases
Using Water Sprays to Improve Performance of a Flooded-Bed Dust Scrubber Goodman-GV | Applied Occupational and Environmental Hygiene; 15(7), 2000 Jul; 550-560	2000	Publication	Respiratory diseases
Utilizing the 'Advance and Relieve' Method to Reduce Horizontal Stress Affects on the Mine Roof, A Case Study Dolinar-DR; Mucho-TP; Oyler-DC; Pablic-J | In: Proceedings of the 19th International Conference on Ground Control in Mining, Peng SS, Mark C, eds., Morgantown, WV: West Virginia University, 2000 Jan; :137-148	2000	Publication	Ground control
Validation of a Dust Dispersion Model for Haul Trucks Reed-WR | Trans Soc Min Metal Explor. Vol. 316. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc; :163-170	2004	Publication	Respiratory diseases
Validity and Reliability of Sincerity Test for Dynamic Trunk Motions Ferguson-SA; Gallagher-S; Marras-WS | Disability and Rehabilitation 25(4), 2003	2003	Publication	Cumulative injuries
Variation in Dust Levels with Continuous Miner Position Goodman-GVR; Listak-JM | Mining Engineer 51(2),1999; :53-58	1999	Publication	Respiratory diseases
Variation in Dust Levels with Continuous Miner Position Goodman-GVR; Listak-JM | SME preprint 98-130. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc	1998	Publication	Respiratory diseases

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Variation of Horizontal Stresses and Strains in Mines in Bedded Deposits in the Eastern and Midwestern United States Dolinar-DR | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 22nd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University; :178-185	2003	Publication	Ground control
Ventilating the Box Cut of a Two-Pass 40-ft Extended Cut Thimons-ED; Taylor-CD; Zimmer-JA | J Mine Vent Soc S Afr, 52(3), 1999 Jul; :108-115	1999	Publication	Mine disasters
Ventilating the Box Cut of a Two-Pass 40-ft Extended Cut Thimons-ED; Taylor-CD; Zimmer-JA | In: Tien JC, ed. Proceedings of the Eighth U.S. Mine Ventilation Symposium, Rolla, MO: University of Missouri-Rolla Press, 1999; :157-165	1999	Publication	Mine disasters
Ventilation Impacts on Respirable Dust Control Colinet-JF; Chekan-GJ; Listak-JM; Rider-JP | In: De Souze E, ed. Proceedings of the North American/Ninth U.S. Mine Ventilation Symposium (Kingtson, Ontario, Canada). Lisse, Netherlands: Balkema, 2002; :565-572	2002	Publication	Respiratory diseases
Ventilation of a 40-Foot, Two-Pass, Extended Cut Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin, 1998 Dec; :5-6	1998	Publication	Mine disasters
Ventilation Planning Layouts for Large Opening Mines Krog-RB; Grau-RH; Mucho-TP; Robertson-SB | 2004 SME Annual Meeting, Feb 23-25, Denver, Colorado, preprint 04-187. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2004 Feb; :1-9	2004	Publication	Mine disasters; Respiratory diseases
Ventilation Practices on Longwall Faces in the United States Colinet-JF; Jankowski-RA | In: Proceedings of the Fifth International Symposium on Ventilation for Contaminant Control. Ottawa, Ontario, Canada: Session 12-3, 1997	1997	Publication	Mine disasters
Verification and Validation of Roof Bolter Simulation Models for Studying Events Between a Machine and its Operator Bartels-JR; Ambrose-DH; Wang-RC | Society of Automotive Engineers, Inc., technical paper 2001-01-2088, 2001 Jan; :1-14	2001	Publication	Traumatic injuries
Verification of a Roof Bolter Simulation Model Bartels-JR; Kwitowski-AJ; Ambrose-DH | Warrendale, PA: Society of Automotive Engineers, Inc., Technical Paper 2003-01-2217, 203; :1-7	2003	Publication	Traumatic injuries
Video Motion Detection for Real-Time Hazard Warnings in Surface Mines McHugh-E | 2004 SME Annual Meeting, Feb 23-25, Denver, Colorado, preprint 04-74. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2004 Feb; :1-9	2004	Publication	Ground control
Video Motion Detection for Real-Time Hazard Warnings in Surface Mines McHugh-E | SME Transactions 2005 Volume	2005	Publication	Ground control
Virtual Reality for Mine Safety Training Filigenzi-MT; Orr-TJ; Ruff-TM | Applied Occupational and Environmental Hygiene, vol. 15, no. 6, 2000; :465-469	2000	Publication	Surveillance and training
Visibility Unger-RL | Web document, http://www.cdc.gov/niosh/mining/topics/machinesafety/equipmentdsgn/visibility/visibility.htm	1997	Web document	Traumatic injuries
Water Mist Extinguishment of Pool Fires: A Parametric Approach Chaiken-RF; Smith-AC | Presented at the Western States Section of the Combustion Institute, 1998 Spring Meeting, Univ. Of California, Berkeley, CA, Mar. 23-24, 1998; :1-15	1998	Publication	Mine disasters

Title	Year	Output Type	Strategic Goal
Water Well Safety Bits: Health And Safety Information For The Water Well Industry Reinke-DC | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-160, Information Circular 9483	2005	Publication	Hearing loss
Waterjet Cleaning of Truck-Mounted Concrete Mixing Tanks Miller-AL; King-GW; Savanik-GA | In: Hashish M, ed. Proceedings of the 2001 WJTA American Waterjet Conference (Aug. 18-21, 2001, Minneapolis, MN). Vol. 2, Paper 40, Waterjet Technology Assoc.; :551-565	2001	Publication	Traumatic injuries
Wearing Hearing Protection Properly: A 3-D Training Aid for Drillers Barrett-EA; Calhoun-RA | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-107, Information Circular 9472, 2004 Nov :1-15	2004	Publication	Hearing loss; Surveillance and training
Wet Drilling - Technologically Achievable, Administratively Achievable, and Promising Noise Controls (30 CFR Part 62) NIOSH | Information Bulletin P04-18, 2005 (http://www.msha.gov/regs/complian/PIB/2004/pib04-18.pdf)	2005	Publication (guidelines)	Hearing loss
What Causes Equipment Accidents? Unger-RL | Web document, http://www.cdc.gov/niosh/mining/topics/machinesafety/equipmentdsgn/equipmentaccidents.htm	1997	Web document	Traumatic injuries
What Difference Does Age Make? Part 1. Mining in All Commodities Schwerha-DJ; Mallett-LG | Joseph A. Holmes Saf Assoc Bull May/June, 2005; :9-16	2005	Publication	Traumatic injuries
What Does a Hearing Loss Sound Like? NIOSH | Web document, www.cdc.gov/niosh/mining/topics/hearingloss/hlsoundslike.htm	2005	Web document	Hearing loss
What Goes Around Comes Around: An Unexpected Benefit from Community Outreach Cullen-E | Far West Bulletin, Summer 1997	1997	Publication	Surveillance and training
What is Human Factors Research? Randolph-RF | Holmes Saf Assn Bull, 1996 Dec; :18	1996	Publication	Cumulative injuries
What Works (and What Doesn't) in Mining Ergonomics Gallagher-S | Falls Church, VA: U.S. Department of Labor, Mine Safety and Health Administration, Holmes Safety Association Bulletin Nov, 1999 Nov; :9-13	1999	Publication	Cumulative injuries
Whole-Body Vibration and Postural Stress among Operators of Construction Equipment: A Literature Review Kittusamy-NK; Buchholz-B | Journal of Safety Research 2004, vol. 35, no. 3, 2004; :255-261	2004	Publication	Cumulative injuries
Wire Rope Retirement Criteria McKewan-WM | Organisation Internationale pour l'Etude de l'Endurance des Cables (OIPEEC) (International Organization for the Study of the Endurance of Wire Ropes) Bulletin 73, 1997; :21-36	1997	Publication	Traumatic injuries
Work Design: Barriers Facing the Integration of Ergonomics Into System Design Steiner-LJ; Vaught-C | In: Karwowski W, ed. International Encyclopedia of Ergonomics and Human Factors. Vol. II. London, U.K.: Taylor & Francis, Inc., 2001; :1437-1440	2001	Publication	Cumulative injuries
Work Principle for Predicting Explosive Toxic Fumes Wieland-MS | Proceedings of the Fourteenth Annual Symp on Explosives and Blasting Research, Intl Soc of Explosives Engineers, 1998 Feb; :121-135	1998	Publication	Traumatic injuries
Work Sampling Applied to a Human Factors Analysis of Mine Worker Positioning Steiner-LJ; Cornelius-KM; Turin-FC; Stock-DM | Proc Human Factors and Ergonomics Society 42nd Annual Meeting, vol 2, 1998 Oct; :1103-1107	1998	Publication	Cumulative injuries

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Worker Exposure and Equipment Noise in Large Surface Coal Mines Bauer-ER; Babich-DR | SME preprint 03-051. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2003; :1-6	2003	Publication	Hearing loss
Worker Exposure and Equipment Noise in Large Surface Coal Mines Bauer-ER; Babich-DR | Min Eng 56(4), 2004; :49-54	2004	Publication	Hearing loss
Worker Responses To Realistic Evacuation Training Vaught-C; Mallett-LG; Kowalski-KM; Brnich-MJ Jr | Proceedings of the International Emergency Management Society (TIEMS) Conference 1997, Copenhagen, Denmark: 1997 Jan; :55-62	1997	Publication	Mine disasters
Worker Strength Evaluation: Job Design and Worker Selection Gallagher-S; Moore-JS | In: Karwowski W, Marras WS, eds. The Occupational Ergonomics Handbook, Boca Raton, FL: CRC Press LLC, 1999; :371-386	1999	Publication	Cumulative injuries
Workplace Solutions: Ground Fall Injuries in Underground Stone Mines NIOSH | Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2004-106, 2003 Nov; :1-4	2003	Publication	Ground control
Work-Principle Model for Predicting Toxic Fumes of Nonideal Explosives Wieland-MS | Propellants Explosives Pyrotechnics 29(4), 2004; :236-243	2004	Publication	Traumatic injuries
3+3 SCSR Donning Screen Saver	2001	Software	Mine disasters; Surveillance and training
Aggregate Training for the Safety Impaired Cullen-ET | NIOSH 2003 Dec; :Video (VHS format, 35 minutes)	2003	Video	Surveillance and training; Traumatic injuries
Aggregate Training for the Safety Impaired, Spanish version Cullen-ET | NIOSH 2003; :Video (VHS format, 35 minutes)	2003	Video	Surveillance and training; Traumatic injuries
Air Quantity Estimator (AQE) Grau-RH III; Robertson-SB; Dolgos-JG | NIOSH 2004 Jan; :software	2004	Software	Mine disasters; Respiratory diseases
Analysis of Horizontal Stress Effects in Mining (AHSM) NIOSH | NIOSH, 2004 Sep, :software	2004	Software	Ground control
Analysis of Longwall Pillar Stability (ALPS) Mark-C | NIOSH, 2003 Aug, :software	2003	Software	Ground control
Analysis of Retreat Mining Pillar Stability - Highwall Mining (ARMPS-HWM) NIOSH | NIOSH, 2005 Nov, :software	2005	Software	Ground control
Analysis of Retreat Mining Pillar Stability (ARMPS) NIOSH | NIOSH, 2003 Aug, :software	2003	Software	Ground control
Analysis of Roof Bolt Systems (ARBS) NIOSH | NIOSH, 2003 Aug, :software	2003	Software	Ground control

Title	Year	Output Type	Strategic Goal
Belt Fire Injury USBM | USBM, 1996 May	1996	Training	Mine disasters; Surveillance and training
Care and Maintenance of the SR-100 Self-Contained Self-Rescuer NIOSH | NIOSH, 2002	2002	Training	Mine disasters; Surveillance and training
Clothes Cleaning Process NIOSH | NIOSH 2004 Jan; :Video (VHS format)	2005	Video	Respiratory diseases
Coal Mine Roof Rating (CMRR) NIOSH | NIOSH 2004 Dec; :Software	2004	Software	Ground control
Coal Miner's Chest X-ray Program University of Kentucky; USBM; West Virginia University | USBM 1997 Jul	1997	Training	Respiratory diseases; Surveillance and training
Control Design Principles Unger-RL | NIOSH 1996; web page, http://www.cdc.gov/niosh/mining/topics/ergonomics/workstation/controldesign/controldesign.htm	1996	Web document	Traumatic injuries
Crewstation Analysis Programs (CAP) Unger-RL | NIOSH 1996; :Software	1996	Software	Traumatic injuries
Degraded Image Hazard Recognition NIOSH; Illinois Office of Mines and Minerals; Illinois Eastern Community Colleges | NIOSH 1997 Jan; :21 minutes	1997	Training	Surveillance and training; Traumatic injuries
Draft ASTM International Standard - WK2307, Standard Specification for Selection of Fiber-Optic Cable and System Components for Use in Natural Gas Pipelines ASTM | Technical report ANSI/ISA-TR12.21.01-2004	2004	Standards	Traumatic injuries
Drill Rig Incident Barrett-EA; Calhoun-RA | NIOSH Information Circular IC 9473; 2005 Feb; :1-19	2005	Training	Hearing loss; Surveillance and training
Electric Motor-Driven Mine Equipment and Accessories and High-Voltage Longwall Equipment Standards for Underground Coal Mines Federal Register, Vol. 67, No. 47, March 11, 2002, Rules and Regulations, pp. 10972-11005	2002	Standards	Traumatic injuries
Final Draft International Standard IEC 60079-28 Ed. 1.0: Protection of Equipment and Transmission Systems Using Optical Radiation IEC	2005	Standards	Traumatic injuries
Focus on Prevention: Conducting a Fire Risk Assessment Mallett-L; Brnich-MJ Jr | NIOSH, 1999 Oct :1-6	1999	Training	Mine disasters; Surveillance and training
Ground Control Software Toolbar	2005	Software	Ground control

Title	Year	Output Type	Strategic Goal
Handling Explosives in Underground Mines Cullen-ET | NIOSH 1998 Jan; :Video (VHS format, 15 minutes)	1998	Video	Surveillance and training; Traumatic injuries
HASARD Proximity Warning System Urban-C | NIOSH; :Video (Realmedia format)	2001	Video	Traumatic injuries
Hazard Recognition Training Program for Underground Limestone NIOSH | NIOSH, 1998	1998	Training	Ground control; Surveillance and training; Traumatic injuries
Hazards In Motion Cullen-ET | NIOSH 2001; :Video (VHS format, 30 minutes)	2001	Video	Surveillance and training; Traumatic injuries
HazCom Helper - MSHA Version Scott-DF; Drake-PL; Brady-TM | NIOSH Pub. No. 2003-18. 2003; CD-ROM	2004	Software	Surveillance and training
HazCom Helper - OSHA Version Scott-DF; Drake-PL; Brady-TM | NIOSH Pub. No. 2003-18. 2003; CD-ROM	2005	Software	Surveillance and training
Hearing Loss Simulator (HLSim) NIOSH | Version 2.2.0.26; Windows software; CD-ROM and downloadable (http://www.cdc.gov/niosh/mining/products/educationalsoftware.htm)	2004	Software	Hearing loss
Hidden Scars Cullen-ET | NIOSH 2001 Jan; :Video (VHS format, 25 minutes)	2001	Video	Ground control; Traumatic injuries
High-Voltage Continuous Mining Machines RIN 1219-AB34, Federal Register, July 16, 2004, Vol. 69, No. 136, proposed rules, pp. 42811-42840	2004	Standards	Traumatic injuries
How to Wear Soft Foam Earplugs (Roll-Pull-Hold) Randolph-RF | NIOSH 2003 Mar; :Video (RealMedia format, 30 seconds)	2003	Video	Hearing loss; Surveillance and training
I Can't Get Enough Air! - Proper Self-contained Self-rescuer Usage Brnich-MJ Jr; Vaught-C; Cahoun-RA | NIOSH 1999 Oct; :1-43	1999	Training	Mine disasters; Surveillance and training
LAMODEL and MULSIM/NL Pre-Processor (LAMPRE)	2000	Software	Ground control
LAMODEL post-processor (LAMPLT)	2000	Software	Ground control
Main Haulage Scaling Exercise USBM | USBM 1996	1996	Training	Surveillance and training; Traumatic injuries

Title	Year	Output Type	Strategic Goal
Make it Safer With Roof Screen NIOSH | NIOSH 2004 Jan; :Video (VHS format)	2004	Video	Ground control; Surveillance and training; Traumatic injuries
Mine Emergency Response Interactive Training Simulation (MERITS) NIOSH	2002	Training	Mine disasters; Surveillance and training
Miner Mike Saves the Day! or Ground Support... It's Important! Cullen-ET | NIOSH 2000 Jan; :Video (VHS format, 33 minutes)	2000	Video	Ground control; Surveillance and training
NFPA 120 - Standard for Fire Prevention and Control in Coal Mines National Fire Protection Association | Quincy, MA: National Fire Protection Association	2004	Standards	Mine disasters
NFPA 122 - Standard for Fire Prevention and Control in Metal/Nonmetal Mining and Metal Mineral Processing Facilities National Fire Protection Association | Quincy, MA: National Fire Protection Association	2004	Standards	Mine disasters
Preshift Safety Inspection for Scoops NIOSH | NIOSH, 2001	2001	Training	Surveillance and training; Traumatic injuries
Raggs and Curly Machine Guarding Computer Based Training NIOSH | NIOSH, 2001	2001	Training	Surveillance and training; Traumatic injuries
Ready-Adjust-Operate, NIOSH Dragline Workstation Lewis-P; Rossi-EW | 2005 Video	2005	Video	Cumulative injuries
Recovery of Farmington #9: An Interview with Danny Kuhn NIOSH | U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health; :Video (VHS format, 60 minutes)	2000	Video	Mine disasters
Reducing Dust Inside Enclosed Cabs NIOSH | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. Videocassette	2002	Video	Respiratory diseases
Reducing Dust Inside Enclosed Cabs NIOSH | NIOSH 2001 Jan; :Video (RealMedia format, 7 minutes)	2002	Video	Respiratory diseases
Rock Falls - Preventing Rock Fall Injuries in Underground Mines Miller-A | NIOSH 1999 Jan; :Video (VHS format, 20 minutes)	1999	Video	Ground control
Roof Bolting Simulation Ambrose-DH | NIOSH; :Video (MPV format, 37 seconds)	2003	Video	Cumulative injuries; Traumatic injuries

Title	Year	Output Type	Strategic Goal
Safety with Walk-through Bolters NIOSH | NIOSH, 2001	2001	Training	Surveillance and training; Traumatic injuries
Seating Design Principles Unger-RL | NIOSH 1996; web page, http://www.cdc.gov/niosh/mining/topics/ergonomics/workstation/seating.htm	1996	Web document	Cumulative injuries; Traumatic injuries
Stress and Displacement Calculations (LAMODEL) NIOSH	2000	Software	Ground control
Support Technology Optimization Program (STOP) NIOSH	2004	Software	Ground control
The Sky Is Falling Cullen-ET | NIOSH 2004 Aug; :Video (VHS format, 38 minutes)	2004	Video	Ground control; Surveillance and training; Traumatic injuries
The Spokane Resource Cullen-ET | NIOSH 2004; :Video (VHS format, 11 minutes)	2004	Video	Surveillance and training
Toolbox Training for Construction Aggregate Miners NIOSH | NIOSH 2004 Aug: 1-108	2004	Training	Surveillance and training; Traumatic injuries
Trench Safety Awareness Coleman-PJ | NIOSH 2005 Apr	2005	Training	Surveillance and training; Traumatic injuries
Underground Workstation Design Principles Unger-RL | Web page, http://www.cdc.gov/niosh/mining/topics/ergonomics/workstation/workstationlayout.htm	1996	Web document	Traumatic injuries
Vibrational Acceleration Statistical Analysis (VASA) NIOSH	2002	Software	Cumulative injuries; Traumatic injuries
Video Training Modules for Fire Prevention and Preparedness (8 total) NIOSH | NIOSH, 1999	1999	Training	Mine disasters; Surveillance and training
Wearing Hearing Protection Properly: A 3-D Training Aid for Drillers Barrett-EA; Calhoun-RA | NIOSH 2004 Nov; :1-15	2004	Training	Hearing loss; Surveillance and training
You Are My Sunshine Cullen-ET | NIOSH 2002 :Video (VHS format, 69 minutes)	2002	Video	Mine disasters

Title	Year	Output Type	Strategic Goal
Zen and the Art of Rockbolting Cullen-ET | NIOSH 2002 Jan; :Video (VHS format, 33 minutes)	2002	Video	Ground control
2003 Western TRAM Conference NIOSH | Held jointly with the Joseph A. Holmes Safety Association meeting (Reno, NV; June 2003)	2003	Workshop, Seminar, or OIB	Surveillance and training
2004 Train-the-Trainer (T3) Conference NIOSH | Held jointly with the Institute on Mining Health, Safety and Research meeting and ISMSP's Critical Issues Conference (Salt Lake City, UT; May 2004)	2004	Workshop, Seminar, or OIB	Surveillance and training
2005 Train-the-Trainer (T3) Conference NIOSH | Held jointly with the ISMSP's Critical Issues Conference (Reno, NV; May 2005)	2005	Workshop, Seminar, or OIB	Surveillance and training
90-minute workshop at the National Safety Council / World Safety Congress NIOSH | Orlando, FL, Sept. 2005	2005	Workshop, Seminar, or OIB	All
A Look to the Future: the Next 10 Years in NIOSH Mining Health and Safety Research NIOSH | Northwest Mining Association Convention, Dec. 6, 2005	2005	Workshop, Seminar, or OIB	All
A Review of Health & Safety Research at Spokane Research Laboratory NIOSH | NIOSH Open Industry Briefing, held in conjunction with the 105th annual meeting of Northwest Mining Association, Nov. 30, 1999	1999	Workshop, Seminar, or OIB	Surveillance and training
Alternative Methodologies for Evaluating Strength of Mine Seals Workshop NIOSH | Workshop presented to the coal industry, seal manufacturers, MSHA, PA Bureau of Deep Mine Safety, and the United Mine Workers of America (Sept 8, 2004, Pittsburgh, PA; 77 participants)	2004	Workshop, Seminar, or OIB	Mine disasters
Annual Underground Stone Safety Seminar NIOSH | Held in Evansville, IN; Erlanger, KY; Cincinnati, OH and Louisville, KY.	1997	Workshop, Seminar, or OIB	Ground control
Annual Underground Stone Safety Seminar NIOSH | Held in Evansville, IN; Erlanger, KY; Cincinnati, OH and Louisville, KY.	1998	Workshop, Seminar, or OIB	Ground control
Annual Underground Stone Safety Seminar NIOSH | Held in Evansville, IN; Erlanger, KY; Cincinnati, OH and Louisville, KY.	1999	Workshop, Seminar, or OIB	Ground control
Annual Underground Stone Safety Seminar NIOSH | Held in Evansville, IN; Erlanger, KY; Cincinnati, OH and Louisville, KY.	2000	Workshop, Seminar, or OIB	Ground control
Annual Underground Stone Safety Seminar NIOSH | Held in Evansville, IN; Erlanger, KY; Cincinnati, OH and Louisville, KY.	2001	Workshop, Seminar, or OIB	Ground control
Annual Underground Stone Safety Seminar NIOSH | Held in Evansville, IN; Erlanger, KY; Cincinnati, OH and Louisville, KY.	2002	Workshop, Seminar, or OIB	Ground control
Annual Underground Stone Safety Seminar NIOSH | Held in Evansville, IN; Erlanger, KY; Cincinnati, OH and Louisville, KY.	2003	Workshop, Seminar, or OIB	Ground control
Annual Underground Stone Safety Seminar NIOSH | Held in Evansville, IN; Erlanger, KY; Cincinnati, OH and Louisville, KY.	2004	Workshop, Seminar, or OIB	Ground control

Title	Year	Output Type	Strategic Goal
Best Mining Practices, Surface And Underground Co-sponsored with the Bureau of Land Management Phoenix Training Center, a 1-week seminar, Sept. 1999	1999	Workshop, Seminar, or OIB	Surveillance and training
Coal Noise Partnership Meeting/Workshop NIOSH | Held at NIOSH/PRL, 2005	2005	Workshop, Seminar, or OIB	Hearing loss
Collision Warning Systems for Surface Mining Equipment Ruff-TM | Seminar at the Joint Industry Training Seminar, Western Mining Resource Center, Colorado School of Mines, Golden, CO, Jan. 23, 2001	2001	Workshop, Seminar, or OIB	Traumatic injuries
Demonstration of technologies for mine emergency responders NIOSH | National Metal/Nonmetal Mine Rescue Competition (Las Vegas, NV; July 2000)	2000	Workshop, Seminar, or OIB	Mine disasters
Demonstration of technologies for mine emergency responders NIOSH | National Coal Mine Rescue Competition (Louisville KY; Sept 2001)	2001	Workshop, Seminar, or OIB	Mine disasters
Demonstration of technologies for mine emergency responders NIOSH | National Metal/Nonmetal Mine Rescue Competition (Reno NV; Aug 2002)	2002	Workshop, Seminar, or OIB	Mine disasters
Demonstration of technologies for mine emergency responders NIOSH | National Coal Mine Rescue Competition (Louisville, KY; Sept 2003)	2003	Workshop, Seminar, or OIB	Mine disasters
Demonstration of technologies for mine emergency responders NIOSH | National Metal/Nonmetal Mine Rescue Competition (Reno, NV; July 2004)	2004	Workshop, Seminar, or OIB	Mine disasters
Demonstration of technologies for mine emergency responders NIOSH | National Coal Mine Rescue Competition (Louisville, KY; September 2005)	2005	Workshop, Seminar, or OIB	Mine disasters
Design of Mine Ore Passes Beus-M | Seminar lecture at the University of Utah's Spring Semester 2000 Seminar Series, Jan. 20, 2000	2000	Workshop, Seminar, or OIB	Ground control
Developing Toolbox Training for Aggregate Miners Boldt-CMK | Workshop at the Western TRAM Conference, Reno, NV, June 16-20, 2003	2003	Workshop, Seminar, or OIB	Surveillance and training; Traumatic injuries
Dust Control for Continuous Miner and Longwall Sections NIOSH | Joint MSHA/NIOSH workshops in MSHA District 8, Mount Vernon, Illinois, and Vincennes, Indiana, Oct. 4-5, 2005	2005	Workshop, Seminar, or OIB	Respiratory diseases
Edgar Mine Research Scott-D | Seminar at the Colorado School of Mines, Golden, CO, Nov. 18, 1999	1999	Workshop, Seminar, or OIB	Ground control
Electrical Safety for Water Well Drillers An invited, 90-minute workshop held at the National Ground Water Association annual meeting in Las Vegas, NV, December 12, 2004	2004	Workshop, Seminar, or OIB	Traumatic injuries
Electrical Safety for Water Well Drillers NIOSH | An invited, 90-minute workshop held twice at the South Atlantic Water Well Driller's Jubilee, Myrtle Beach, SC, July 30-31, 2005	2005	Workshop, Seminar, or OIB	Traumatic injuries

Title	Year	Output Type	Strategic Goal
Ergonomic Evaluation of Mobile Equipment Kittusamy-NK | IUOE Safety and Health Training Conference, NIOSH Workshop for OEs, San Diego, CA, Apr. 2004	2004	Workshop, Seminar, or OIB	Cumulative injuries
Evaluating Toolbox Training for Construction and Mining Boldt-CMK | NIOSH OIB, 107th annual meeting of Northwest Mining Association meeting, Dec. 2, 2001	2001	Workshop, Seminar, or OIB	Surveillance and training; Traumatic injuries
Evaluating Toolbox Training for Construction and Mining: Sand and Gravel Boldt-CMK | Workshop at the National Holmes Safety Association Conference, San Antonio, TX, Jun. 6-7, 2001	2001	Workshop, Seminar, or OIB	Surveillance and training; Traumatic injuries
Fire Detection Technology Workshop Workshop conducted for 43 participants from coal companies, sensor manufacturers, MSHA, the UMWA, a university, and NIOSH (Pittsburgh Research Laboratory, Sept 4, 2003)	2003	Workshop, Seminar, or OIB	Mine disasters
Fire Safety in Metal and Nonmetal Mines Workshop Smith-AC | Presented at the 10th Annual Safety Seminar for Underground Stone Mines, Dec. 6-7, 2005, Louisville, KY - 58 attendees.	2005	Workshop, Seminar, or OIB	Mine disasters
Frictional Ignition Open Industry Briefing NIOSH | One-day seminar including presentations by NIOSH and industry equipment manufactuers (Pittsburgh, PA; 80 attendees)	1997	Workshop, Seminar, or OIB	Mine disasters
Getting to Zero-The Human Side of Mining NIOSH | NIOSH Open Industry Briefing, held in conjunction with the 110th annual meeting of Northwest Mining Association, Spokane, WA, Dec. 7, 2004	2004	Workshop, Seminar, or OIB	Surveillance and training
Ground Control Instrumentation and Modeling Workshop: Results of Mining Case Studies Seymour-B; Tesarik-D | Workshop at the National Mine Health and Safety Academy, Beaver, WV, Jun 2000	2000	Workshop, Seminar, or OIB	Ground control
Ground Control Software Workshop NIOSH | Held in conjunction with the Longwall USA conference in Pittsburgh, PA. The workshop featured the STOP and SHIELD programs and their application to longwall mine safety.	2003	Workshop, Seminar, or OIB	Ground control
Ground Control Software Workshop NIOSH | Presented by NIOSH staff in Morgantown, WV, Norton, VA and Charleston, WV. Two day hands-on computer workshops featured 8 NIOSH mine safety software packages, including STOP, CMRR, ARMPS, TGRSS, and ARBS. Total attendance: 80	2004	Workshop, Seminar, or OIB	Ground control
Ground Control Training Classes for MSHA Coal Mine Inspectors NIOSH | 3-day course given in 8 sessions to all 400 MSHA CMI's at the National Mine Academy, Beckley, WV	1997	Workshop, Seminar, or OIB	Ground control
Ground Control Training Classes for MSHA Coal Mine Inspectors NIOSH | 3-day course given in 8 sessions to all 400 MSHA CMI's at the National Mine Academy, Beckley, WV	1998	Workshop, Seminar, or OIB	Ground control
Guidelines for the Assessment of Microbiological Contamination in Indoor Environments Kittusamy-NK | NIOSH-hosted teleweb seminar sponsored by the American Industrial Hygiene Association (AIHA) and co-hosted by the Pacific Northwest Section of AIHA, Spokane, WA, 2000	2000	Workshop, Seminar, or OIB	Surveillance and training
Hazardous Chemicals Found in Mining Drake-P; Scott-DF | Seminar presented in Allentown, PA, Jan. 15-16, 2002	2002	Workshop, Seminar, or OIB	Surveillance and training

Title	Year	Output Type	Strategic Goal
Hearing Conservation: the Ears Have It Ingram-DK; Matetic-RJ | Workshop presented at request of the National Ground Water Association, National Ground Water Expo (Orlando, FL; December 9-12, 2003)	2003	Workshop, Seminar, or OIB	Hearing loss
Hearing Safety and Machine Operation Ingram-DK; Moisan-P; Hudak-R | Workshop presented at request of the New England Water Well Association, 2003 Annual Meeting (Marlborough, MA; March 21-22, 2003)	2003	Workshop, Seminar, or OIB	Hearing loss
Hearing Safety: Water Well Drilling Industry Ingram-DK | Workshop requested by the State of Ohio Environmental Protection Agency, Ohio's Annual Refresher Safety Training for the Ohio EPA Inspectors (Columbus, OH; October 22, 2003)	2003	Workshop, Seminar, or OIB	Hearing loss
How to Conduct Coaching Skills Workshops Mallett-L; Vaught-C; Wiehagen-W | Four seminars held in June 2005	2005	Workshop, Seminar, or OIB	Surveillance and training
Incorporating the Exposure Assessment Process into a Risk Ranking and Management Framework NIOSH-SRL hosted teleweb seminar sponsored by the American Industrial Hygiene Association (AIHA) and co-hosted by the Pacific Northwest Section of AIHA, Spokane, WA, 2002	2002	Workshop, Seminar, or OIB	Surveillance and training
International Symposium on Hazards, Prevention, and Mitigation of Industrial Explosions NIOSH; ASTM; NFPA; Warsaw University of Technology; Committee for Thermodynamics and Combustion of the Polish Academy of Sciences | Five-day symposium. Two proceedings volumes were published and 36 papers were later published in peer-reviewed journals (Schaumburg, IL; 100 attendees from 13 countries)	1998	Workshop, Seminar, or OIB	Mine disasters
International Workshop on Coal Mine Roof Support NIOSH | Held in Morgantown, WV, in conjunction with the 19th International Conference on Ground Control in Mining.	2000	Workshop, Seminar, or OIB	Ground control
Investigation of Electromagnetic Emissions in an Underground Mine Scott-DF | Seminar at University of Arizona, Tucson, AZ, May 2004	2004	Workshop, Seminar, or OIB	Ground control
Joint NIOSH/MSHA Mine Fire Control Seminar NIOSH; MSHA | MSHA National Health and Safety Academy (Beaver, West Virginia; June 14, 2000)	2002	Workshop, Seminar, or OIB	Mine disasters
Joint UMWA/NIOSH Fire Preparedness Workshop UMWA; NIOSH | Two workshops, MSHA National Mine Health and Safety Academy, (Sept. 18-19 and October 8-9)	2002	Workshop, Seminar, or OIB	Mine disasters
Joint Western Training Needs Assessment Seminar Co-sponsored with the Colorado School of Mines, Golden, CO, Jul. 23-26, 2001	2001	Workshop, Seminar, or OIB	Surveillance and training
LaModel and CMRR Workshop NIOSH | Held in conjunction with the 18th International Conference on Ground Control in Mining. 57 Attendees.	1999	Workshop, Seminar, or OIB	Ground control
Massey Ground Control Short Course NIOSH | Requested by the Chief Operating Officer of Massey. Covered roof characterization, horizontal stress, pillar design, and roof support, as well as hands-on computer training with an array of NIOSH ground control software packages including ALPS, ARBS, STOP, AHSEM, and the CMRR.	2002	Workshop, Seminar, or OIB	Ground control
Mine Fire Detection Technology Workshop NIOSH | Pittsburgh Research Laboratory; Pittsburgh, PA; Sept 4, 2003	2003	Workshop, Seminar, or OIB	Mine disasters
Mine Fire Preparedness Briefing NIOSH | Presented for Pennsylvania mine rescue teams, Lake Lynn Laboratory; July 31, 1996	1996	Workshop, Seminar, or OIB	Mine disasters

Title	Year	Output Type	Strategic Goal
Mine Fire Preparedness Open Industry Briefing NIOSH | Two OIBs presented at Lake Lynn Laboratory (May 14-15, 1996 and Jun 11-12, 1996)	1996	Workshop, Seminar, or OIB	Mine disasters
Mine Fire Preparedness Open Industry Briefing NIOSH | Two OIBs presented at Lake Lynn Laboratory (Jun 9-11, 1998 and Sep 1-3, 1998)	1998	Workshop, Seminar, or OIB	Mine disasters
Mine Fire Preparedness Open Industry Briefing NIOSH | Two OIBs presented at Lake Lynn Laboratory (May 25-27, 1999 and Aug 31-Sept 2, 1999)	1999	Workshop, Seminar, or OIB	Mine disasters
Mining Hearing Loss Prevention Workshop NIOSH | Hosted by NIOSH-PRL, Charleston, WV; June 21-22, 2005	2005	Workshop, Seminar, or OIB	Hearing loss
MSD Risk Factor Awareness Train-the-Trainer NIOSH | Module presented to safety and health representatives of US Silica, Berkeley Springs, WV, October 2005	2005	Training	Cumulative injuries
MSHA/NIOSH Technology Transfer Seminar NIOSH | Six hours of presentations on various ground control related topics. These presentations were given in Pikeville, Kentucky and Norton, Virginia. Approx. 140 attendees.	1999	Workshop, Seminar, or OIB	Ground control
MSHA/NIOSH Workshop on Diesel Engine Emission Control Bugarski-A | NIOSH Stone Seminar, Dec. 6-7, 2005, Louisville, KY	2005	Workshop, Seminar, or OIB	Respiratory diseases
NIOSH Mine Safety and Health Training NIOSH | NIOSH Open Industry Briefing, held in conjunction with the 106th annual meeting of Northwest Mining Association,, Spokane, WA, Dec. 2000	2000	Workshop, Seminar, or OIB	Surveillance and training
NIOSH Open Industry Briefing NIOSH | Held in conjunction with the 107th annual meeting of Northwest Mining Association meeting, Dec. 2, 2001	2001	Workshop, Seminar, or OIB	Surveillance and training
NIOSH Open Industry Briefing NIOSH | Held in conjunction with the 108th annual meeting of Northwest Mining Association meeting, Spokane, WA, Nov. 2002	2002	Workshop, Seminar, or OIB	Surveillance and training
NIOSH Open Industry Briefing NIOSH | Co-sponsored with the Western Mining Research Center (WMRC) of the Colorado School of Mines and held in conjunction with the 109th annual meeting of Northwest Mining Association, Spokane, WA, Dec. 2, 2003	2003	Workshop, Seminar, or OIB	Surveillance and training
Noise and Dust Hazards Associated with Water Well Drilling Ingram-DK; Matetic-RJ | Workshop presented at request of New York's State Water Well Association, New York Water Well 2002 Annual Conference (Albany, NY; April 18-21, 2002)	2002	Workshop, Seminar, or OIB	Hearing loss
Noise Health Hazards and How to Avoid Them Ingram-DK; Matetic-RJ | Workshop presented at request of the Minnesota Water Well Association, Minnesota Water Well Association's 79th Annual Convention (St. Cloud, MN; January 29, 2001)	2001	Workshop, Seminar, or OIB	Hearing loss
Open Forum on Frictional Ignition and Dust Explosions NIOSH | Presented for the Pennsylvania Department of Environmental Protection, Bureau of Deep Mine Safety (Pittsburgh, PA; 25 attendees)	1999	Workshop, Seminar, or OIB	Mine disasters
Open Forum on Frictional Ignition, Methane, and Ventilation NIOSH | Presented for RAG Emerald Mine personnel (Pittsburgh, PA; 10 attendees)	2004	Workshop, Seminar, or OIB	Mine disasters

Title	Year	Output Type	Strategic Goal
Open Industry Briefing NIOSH | For all Bituminous Division staff. Included a 1 hr talk at the Quaterly Bituminuous Information Meeting on "Tailgate Support for Longwall Mining and the STOP Program"; and, a 1 hour talk at the Quaterly Anthracite Informational Meeting on the "Overview of NIOSH Mining Health and Safety Research." Approx. 100 attendees.	2001	Workshop, Seminar, or OIB	Ground control
Open Industry Briefing on New Technology for Ground Control in Retreat Mining NIOSH | Seminars held in Uniontown, PA; Norton, VA; Pikeville, KY; Charleston, WV; and Evansville, IN. Total attendance: 300.	1997	Workshop, Seminar, or OIB	Ground control
Open Industry Briefings on New Technology for Coal Mine Roof Support NIOSH | Seminars held in Washington, PA; Uniontown, PA; Norton, VA; Beckley, WV, Charleston, WV; Tuscaloosa, AL; Evansville, IN; Price, UT; and Glenwood Springs, CO.	2000	Workshop, Seminar, or OIB	Ground control
Open Industry Briefings on New Technology for Coal Mine Roof Support NIOSH | Seminars held in Washington, PA; Uniontown, PA; Norton, VA; Beckley, WV, Charleston, WV; Tuscaloosa, AL; Evansville, IN; Price, UT; and Glenwood Springs, CO.	2001	Workshop, Seminar, or OIB	Ground control
Open Industry Briefings on NIOSH Ground Control Software NIOSH | Series of 2-Day hands-on training seminars held in Morgantown, WV; Norton, VA; Beckley, WV, Charleston, WV; Tuscaloosa, AL; Evansville, IN; Grand Junction, CO.	2002	Workshop, Seminar, or OIB	Ground control
Open Industry Briefings on NIOSH Ground Control Software NIOSH | Series of 2-Day hands-on training seminars held in Morgantown, WV; Norton, VA; Beckley, WV, Charleston, WV; Tuscaloosa, AL; Evansville, IN; Grand Junction, CO.	2003	Workshop, Seminar, or OIB	Ground control
Open Industry Briefings on NIOSH Ground Control Software Series of 2-Day hands-on training seminars held in Morgantown, WV; Norton, VA; Beckley, WV, Charleston, WV; Tuscaloosa, AL; Evansville, IN; Grand Junction, CO.	2004	Workshop, Seminar, or OIB	Ground control
Open Industry Forum on Frictional Ignition NIOSH | One-day forum including presentations by NIOSH staff, equipment manufacturers, mining companies, and university researchers (Pittsburgh, PA; 60 attendees, including participants from mining companies, equipment manufacturers, MSHA, and universities)	1997	Workshop, Seminar, or OIB	Mine disasters
Ore Pass Analysis and Design Workshop Co-sponsored by the Western Mining Research Center (WNRC), Golden, CO, Spokane, WA, Dec. 2, 2003	2003	Workshop, Seminar, or OIB	Ground control
Programmable Electronic Mining Systems (PEMS): Best Practice Recommendations Sammarco-JJ; Jobes-C | Joint NIOSH/MSHA Workshop (Sept. 26, 2002; Triadelphia, WV)	2002	Workshop, Seminar, or OIB	Traumatic injuries
Programmable Electronic Mining Systems: An Introduction to Safety Sammarco-JJ; Mowrey-G; Jobes-C; Welsh-J | Joint NIOSH/MSHA Workshop (Aug 17, 1999; Triadelphia, WV)	1999	Workshop, Seminar, or OIB	Traumatic injuries
PROP Workshops for MSHA NIOSH | Co-developed 1-day seminars sponsored by different MSHA Districts and given in 9 coalfield locations.	2000	Workshop, Seminar, or OIB	Ground control
PROP Workshops for MSHA NIOSH | Co-developed 1-day seminars sponsored by different MSHA Districts and given in 9 coalfield locations.	2001	Workshop, Seminar, or OIB	Ground control
Proximity Warning Systems for Underground and Surface Mining NIOSH | Open Industry Briefing (Aug 9, 2005; Pittsburgh, PA). Approximately 125 attendees from government (MSHA), industry, labor, and academia	2005	Workshop, Seminar, or OIB	Traumatic injuries
Recognizing Noise and Dust Health Hazards for the Water Well Driller Ingram-DK; Matetic-RJ | Workshop at the 46th Annual South Atlantic Well Drillers Jubilee (Myrtle Beach, SC; July 28-31, 2001)	2001	Workshop, Seminar, or OIB	Hearing loss

Title	Year	Output Type	Strategic Goal
Recognizing Noise and Dust Health Hazards for the Water Well Drilling Industry Ingram-DK; Matetic-RJ | Workshop presented at request of the National Ground Water Association, National Convention and Exposition (Las Vegas, NV; December 13-15, 2000)	2000	Workshop, Seminar, or OIB	Hearing loss
Roof Control Seminar MSHA; NIOSH | This 2 day seminar was designed to update mining personnel on new roof control products, methods and ground control design. Held at the Beckley Academy in Beckley, WV	2005	Workshop, Seminar, or OIB	Ground control
Safety Recommendations for Programmable Electronics in Mining Sammarco-JJ | NMA Workshop (St. Louis, MO)	1998	Workshop, Seminar, or OIB	Traumatic injuries
Safety Recommendations for Programmable Electronics in Mining Sammarco-JJ | NMA Workshops (Denver, CO and St. Louis, MO)	1999	Workshop, Seminar, or OIB	Traumatic injuries
SEALBARR '99 Central Mining Institute (Katowice, Poland) and NIOSH | Two-day seminar with published proceedings held to promote international technology transfer of mine seals and barriers for controlling mine explosions (Katowice, Poland; 57 attendees from 7 countries)	1999	Workshop, Seminar, or OIB	Mine disasters
Second International Workshop on Coal Pillar Mechanics and Design NIOSH | Held in Golden, CO, as part of the 37th U.S. Symposium on Rock Mechanics. Chairman, developed international list of authors, and co-edited Proceedings.	1999	Workshop, Seminar, or OIB	Ground control
Seismic Tomography and Work at the Edgar Mine Scott-D | Seminar at the Colorado School of Mines, Golden, CO, Nov. 12, 1998	1998	Workshop, Seminar, or OIB	Ground control
Seminar on Trenching Fatalities Coleman-P | Presented at the 12th Annual Construction Safety and Health Conference and Exposition in Chicago, IL, May 21-23, 2002	2002	Workshop, Seminar, or OIB	Surveillance and training
Short Courses on the Coal Mine Roof Rating NIOSH | Open Industry Briefings in Beckley, WV and Morgantown, WV; and industry short courses for Consol Research (Library, PA), and Cape Breton Development Co. (Nova Scotia, Canada).	1997	Workshop, Seminar, or OIB	Ground control
Short Courses on the Coal Mine Roof Rating NIOSH | Open Industry Briefings in Beckley, WV and Morgantown, WV; and industry short courses for Consol Research (Library, PA), and Cape Breton Development Co. (Nova Scotia, Canada).	1998	Workshop, Seminar, or OIB	Ground control
Slope Stability Bench Design Miller-S; Whyatt-J; Girard-J | 4-hour workshop during the Mining Expo in Elko, NV, Jun. 15, 2001	2001	Workshop, Seminar, or OIB	Ground control
Summary of Noise Hazards and Engineering Applications to Reduce Noise Hazards Ingram-DK; Yantek-DS | Workshop presented at request of the National Ground Water Association, National Ground Water Expo (Las Vegas, NV; December 8-12, 2002)	2002	Workshop, Seminar, or OIB	Hearing loss
The Use of Rock Mechanics Instrumentation and Numeric Modeling on SRL Backfill Research Studies Seymour-B; Tesarik-D | Seminar lecture at the University of Arizona, May, 2000	2000	Workshop, Seminar, or OIB	Ground control
The Winds of Change NIOSH | NIOSH Open Industry Briefing, held in conjunction with the 104th annual meeting of Northwest Mining Association, Spokane, WA, Dec. 1, 1998	1998	Workshop, Seminar, or OIB	Surveillance and training
Underground Coal Mine Fire Prevention Workshop NIOSH | Seven workshops conducted in Big Stone Gap, VA (Mar 7), Richlands, VA (Mar 9), Carlinville, IL (May 9), Evansville, IN (May 11), Beaver, WV (June 8), Grand Junction, CO (Oct 31), and Price, UT (Nov 2)	2000	Workshop, Seminar, or OIB	Mine disasters

Title	Year	Output Type	Strategic Goal
Underground Coal Mine Fire Prevention Workshops NIOSH | Holiday Inn, Meadowlands, PA; Oct 7, 1999	1999	Workshop, Seminar, or OIB	Mine disasters
Underground Smoke Evacuation Workshop Conducted at the MSHA Academy as part of TRAM 20004 (October 2004)	2004	Workshop, Seminar, or OIB	Mine disasters
Use of Seismic Tomography in Mining Scott-D | Seminar at the Colorado School of Mines, Golden, CO, on Nov. 13, 1997	1997	Workshop, Seminar, or OIB	Ground control
Workshop at Martin-Marietta Minerals Supervisors annual retreat Cullen-ET | Charleston, SC, Mar. 8-9, 2005	2005	Workshop, Seminar, or OIB	Surveillance and training
Workshop on Diesel Emissions Control Technologies in Coal Mines NIOSH | NIOSH-sponsored workshop, Louisville, KY (July 30, 2003)	2003	Workshop, Seminar, or OIB	Respiratory diseases
Workshop on Diesel Emissions Control Technologies in Metal/Nonmetal Mines NIOSH | NIOSH-sponsored workshop, Cincinnati, OH (February 27, 2003), Salt Lake City, UT (March 4, 2003)	2003	Workshop, Seminar, or OIB	Respiratory diseases
Workshop on Extreme Exposure Safety Hintz-P | Held at the Mine Safety Trainers Workshop, National Mine Health and Safety Academy, Beaver, WV, Oct. 2003	2003	Workshop, Seminar, or OIB	Surveillance and training
Wyoming Mining Association seminar Mainiero-RJ | Assisted Wyoming Mining Association in preparing seminar for industry experts and federal regulators, including the US EPA, on blasting techniques and nitrous oxide gases (Jan 2000)	2000	Workshop, Seminar, or OIB	Traumatic injuries

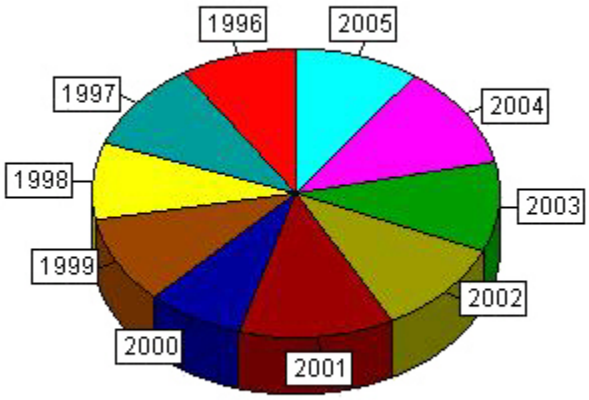
Outputs Summary

Total Outputs: 1428

Note - Strategic Goal percentage totals may not equal 100% due to Outputs being associated with multiple Strategic Goals. Also, other percentage totals may not equal 100% due to rounding errors.

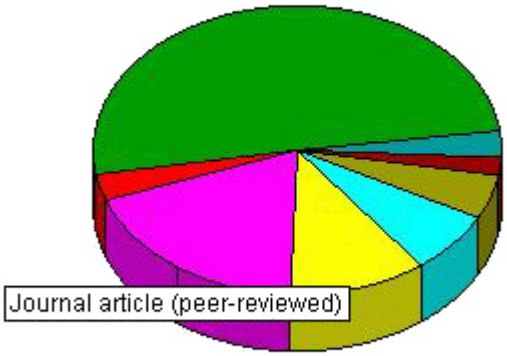
Strategic Goals	N	%
Multiple Goals	35	2.5
Cumulative injuries	85	6
Ground control	422	29.6
Hearing loss	67	4.7
Mine disasters	236	16.5
Respiratory diseases	205	14.4
Surveillance and training	228	16
Traumatic injuries	284	19.9

Year	N	%
1996	132	9.2
1997	144	10.1
1998	123	8.6
1999	140	9.8
2000	110	7.7
2001	176	12.3
2002	152	10.6
2003	143	10
2004	166	11.6
2005	142	9.9



Output Types	N	%
Patent	15	1.1
Publication	1175	82.3
Publication (guidelines)	25	1.8
Software	18	1.3
Standards	6	0.4
Training	18	1.3
Video	20	1.4
Web document	40	2.8
Workshop, Seminar, or OIB	111	7.8

Publication Type	N	%
Book/book chapter/dissertation	20	1.7
Brochure-flyer	31	2.6
Conference proceedings	615	51.3
Hazard Controls/IDs	6	0.5
Journal article (not peer-reviewed)	33	2.8
Journal article (peer-reviewed)	228	19
NIOSH/USBM numbered	129	10.8
Other	80	6.7
Technology News	58	4.8



How Outputs are Categorized

Outputs are externally-distributed publications and products developed by the NIOSH Mining program from 1996 to present. These include outputs developed by the U.S. Bureau of Mines (USBM) and Department of Energy (DOE) prior to the transfer of the Mining Health and Safety Research Program to NIOSH in 1997. The following taxonomies are used to categorize these outputs:

Strategic Goal

Outputs are categorized according to the Strategic Goal (see Section 1.5) addressed by the research:

- **Respiratory diseases** - Reduce respiratory diseases in miners by reducing health hazards in the workplace associated with coal worker pneumoconiosis, silicosis, and diesel emissions.
- **Hearing loss** - Reduce noise-induced hearing loss (NIHL) in the mining industry.
- **Cumulative injuries** - Reduce repetitive/cumulative musculoskeletal injuries in mine workers.
- **Traumatic injuries** - Reduce traumatic injuries in the mining workplace.
- **Mine disasters** - Reduce the risk of mine disasters (fires, explosions, and inundations); and minimize the risk to, and enhance the safety and effectiveness of, emergency responders.
- **Ground control** - Reduce ground failure fatalities and injuries in the mining industry.
- **Surveillance and training** - Determine the impact of changing mining conditions, new and emerging technologies, and the changing patterns of work on worker health and safety.
- **All** - Outputs related to all strategic goals of the Mining Research Plan. This includes technology transfer / health communications efforts and mining research program planning and tracking.

Output Type

Outputs are also categorized by Output Type:

- **Patent** - A U.S. or foreign patent granted for a NIOSH invention.
- **Publication** - An officially-published document (excludes Web documents).
- **Publication (guidelines)** - A publication that recommends a policy or procedure.
- **Web document** - A document developed solely for Web distribution that has not been officially published and is currently available on the NIOSH Mining Safety and Health Research web site (obsolete web documents are not listed.)
- **Software** - A computer program.
- **Standards** - Recommended rules or guidelines for conducting an activity or task, utilizing a product, etc. that are approved by a recognized standards organization or accepted as a de facto standard by the industry.
- **Training** - An educational material comprising an instructor's guide with tested educational materials and supporting documents designed to meet stated educational objectives (Note - if published as a government numbered document, a training material is instead classified as a Publication.)

- **Video** - A videocassette, videotape, or electronic video.
- **Workshop/Seminar/OIB** - An event organized by the NIOSH Mining program, usually to educate the mining industry on particular safety and health issues or research developments.

Publication Type

All publications (outputs with an Output Type of Publication or Publication (guidelines)) are further classified by the specific type of publication.

Published by NIOSH/USBM/DOE:

- **Hazard Controls/IDs** - Hazard Controls describe control techniques to reduce hazardous exposures to workers in a particular application/industry process. Hazard IDs summarize results of NIOSH studies at a specific worksite, identify new or current health and safety hazards, and offer the best recommendations for control or prevention. Both are brief, 1-2 page documents.
- **Technology News** - One-page flyers used to announce a milestone in mining health and safety research, technology ready for transfer to industry, or an opportunity for cooperative research and development.
- **NIOSH/USBM numbered** - Documents published by DHHS (NIOSH), DOE, or the USBM, including Information Circulars (ICs), Reports of Investigation (RIs), Special Publications, and other numbered publications.

Published by external sources:

- **Book/book chapter/dissertation** - Includes PhD dissertations; however, masters theses are classified as Other.
- **Conference proceedings** - Papers published in conference proceedings in either print or electronic format (e.g., CD-ROM).
- **Journal article (peer-reviewed)** - Papers published in journals that have undergone a blind peer-review.
- **Journal article (not peer-reviewed)** - Papers published in journals that have not undergone a blind peer-review.

Published by both NIOSH/DOE/USBM and external sources:

- **Brochure/flyer** - Includes pamphlets, brochures, and flyers. Also includes NIOSH Fact Sheets with surveillance data on fatalities, injuries, and illnesses for various mining commodities.
- **Other** - Other publications not elsewhere classified. Includes contract and MOA reports, MSHA reports, masters theses, bulletins, newsletters, newsletter articles, etc.

3.4 Awards

41 Awards

Title	Date	Recipients	Reference	Sponsor	Strategic Goals
Federal Engineer of the Year Award - Civil Service Category	2005	Whatt-J Ph.D.	For work on structural design of deep mine openings	National Society of Professional Engineers	Ground control
American Industrial Hygiene Association (AIHA) Engineering Committee Award Best Paper Award	2005	Goodman-G; Pollock-D	For the paper "Use of a Directional Spray System Design to Control Respirable Dust and Face Gas Concentrations Around a Continuous Mining Machine", published in JOEH (Dec.'04). Award presented May, 2005	American Industrial Hygiene Association	Respiratory diseases
Roadway Work Zone Safety Awareness Award - Innovations in Technology category	2005	Schiffbauer-WH	For the Work Zone Analysis System for on-site surveillance (video, GPS) of highway construction workers. Presented at the Intertraffic North America Trade Show and Convention on September 29 in Baltimore, MD. The award recognizes outstanding efforts to help reduce roadway work zone construction accidents, injuries, and fatalities.	American Road and Transportation Builders Association (ARTBA)	Traumatic injuries
Bullard-Sherwood Research-to-Practice (r2p) Award	2005	Mowrey-GL PhD; Schiffbauer-WH	Technology Category: Lockout/Tagout, Jammed, and Moving Machinery Controls. HASARD - Proximity Warning System	NIOSH Alice Hamilton	Traumatic injuries
Bullard-Sherwood Research-to-Practice award, honorable mention	2005	Lutz-TJ; Hudson-AJ; Homce-GT	Presented to the technology transfer team for the Roll Over Protection System	NIOSH Alice Hamilton	Traumatic injuries

Title	Date	Recipients	Reference	Sponsor	Strategic Goals
Outstanding Contribution to Science (non-medical), Silver Award	2004	Homce-GT	Analysis of electrical accidents and development of an overhead power line contact alarm for mobile equipment	Pittsburgh Federal Executive Board	Traumatic injuries
SAE Digital Human Modeling Award	2004	Ambrose-D	For the paper: Estimating Low Back Loads of Underground Coal Mine Roof Bolter Operators Using Digital Human Simulations	SAE	Traumatic injuries
Alice Hamilton Award for Excellence in Occupational Safety and Health, Honorable Mention, Educational Materials Category	2004	Robertson-SB; Mark-C; Urban-C	For "Make It Safer with Roof Screen" - NIOSH Video/DVD and Instructional Materials	CDC	Ground control
Applied Rock Mechanics Research Award	2004	Tesarik-DR; Seymour-B; Yanske-T	For the paper Post-Failure of Two Mine Pillars Confined with Backfill published in the Int. J. of Rock Mechanics and Mining Sciences	American Rock Mechanics Association	Ground control
SME Rock Mechanics Award	2004	Mark-C Ph.D.	In recognition of contributions to protect miners from the hazards of ground falls, the development of technology considered industry standards (including the ALPS and ARMPS methods for sizing pillars to prevent mine collapses), and the Coal Mine Roof Rating to evaluate geologic conditions before mining takes place.	SME	Ground control
Stefanko Best Paper Award	2004	Mark-C Ph.D.; Chase-FE; Pappas-DM	For the paper: Reducing the Risk of Ground Falls During Pillar Recovery	SME	Ground control

Title	Date	Recipients	Reference	Sponsor	Strategic Goals
J. W. Woomer Young Engineer Award	2004	Robertson-SB	In recognition of her engineering professionalism in the coal industry	SME Coal and Energy Division	Ground control
John T. Boyd Memorial Young Engineer Award	2004	Krog-RB	In recognition of engineering professionalism	SME Pittsburgh Section	Miscellaneous
R&D 100 Award - TEOM Personal Dust Monitor (PDM)	2004	Volkwein-J; Kohler-J; Thimons-E	Research and Development award for one of the 100 most important research innovations of the year	R&D Magazine	Respiratory diseases
CDC and ATSDR	2004	Vaught-C	In recognition of outstanding research accomplishments leading to major advances in methods of training miners and mine emergency responders	CDC	Surveillance and training
Telly Award, bronze	2003	Cullen-ET	For the video You Are My Sunshine, Best entry, Broadcast Media category	Creative Group	Surveillance and training
SAE Digital Human Modeling Award	2003	Ambrose-D	For the paper: Machine Injury Prediction by Simulation using Human Models	SAE	Traumatic injuries
SAE Digital Human Modeling Award	2003	Bartels-J	For the paper: Verification of a Roof Bolter Simulation Model	SAE	Traumatic injuries
Outstanding Professional Employee	2003	Sammarco-J	In recognition of contributions to research establishing a formal safety framework for computerized mining systems. Bronze Award	Federal Executive Board	Traumatic injuries
Outstanding Professional Employee	2002	Ambrose-D	In recognition of contributions to the field of ergonomics and machine safety. Bronze Award	Federal Executive Board	Traumatic injuries

Title	Date	Recipients	Reference	Sponsor	Strategic Goals
H.L. Boling Award	2002	Spokane Research Laboratory	Consistently going above and beyond the call of duty. This annual award honors those nominated by safety people from all over the country for the highest commitment to the safety and health of miners.	International Society of Mine Safety Professionals	Miscellaneous
Stefanko Best Paper Award	2002	Schiffbauer-WH	For the paper: An Active Proximity Warning System for Surface and Underground Mining Applications	SME	Traumatic injuries
Alice Hamilton Award	2002	Mallett-L; Brnich-M; Vaught-C; Reinke-D; Urban-C; Lenart-P	For their leadership through science by publishing "Care and Maintenance of the SR-100 Self-Contained Self-Rescuer" NIOSH Video Program	NIOSH	Surveillance and training
Honor Award - Information Services	2001	MERITS project team	For significant efforts to develop an Internet-based computer simulation program that is a practical and economical method for delivering quality emergency management training	CDC and ATSDR	Surveillance and training
Bronze Award	2001	MERITS Team (Brnich-M; Mallett-L; Cole-G; Fries-E; Glowacki-A; Jobes-C; Kwitowski-A; Rethi-L; Unger-R; Vaught-C; Reinke-D)	Outstanding Team award	Federal Executive Board Pittsburgh	Surveillance and training

Title	Date	Recipients	Reference	Sponsor	Strategic Goals
Best publication in AIHA/AOEH journal - 2000	2001	Cecal- AB; Timko-RJ; Thimons-ED	For the paper "Methods to Lower the Dust Exposure of Bag Machine Operators and Bag Stackers". Award presented at the AIHA Conference in New Orleans, June 2001	Michigan Industrial Hygiene Society	Respiratory diseases
SAE Digital Human Modeling Award	2001	Bartels-J	For the paper: Verification and validation of roof bolter simulation models for studying events between a machine and its operator	SAE	Traumatic injuries
Honor Award	2001	Ambrose-D	For significant contributions in prevention of roof bolter accidents through research on the Human Factors Design for Machine Safety Project	CDC/ATSDR	Traumatic injuries
CDC Engineer of the Year Award - Civil Service Category	2001	Dubaniewicz-T	For research on laser safety in potentially flammable environments	National Society of Professional Engineers and US Public Health Service	Mine disasters
Outstanding Contribution to Science (nonmedical)	2001	Dubaniewicz-T	For research on laser safety in potentially flammable environments	Pittsburgh Federal Executive Board	Mine disasters
Engineering Literary Award - Engineering Publications category	2000	Dubaniewicz-T	Journal article on ignition of methane-air mixtures by laser heated small targets	US Public Health Service	Mine disasters
SAE Digital Human Modeling Award	2000	Ambrose-D	For the paper: A Simulation Approach Analyzing Random Motion Events Between a machine and its Operator	SAE	Traumatic injuries

Title	Date	Recipients	Reference	Sponsor	Strategic Goals
Highest Degree of Safety Award	2000	Cullen-ET	Outstanding contributions to the reduction in injuries and Illnesses in the mining industry	Int. Soc. of Mine Safety Professionals	Surveillance and training
Stefanko Best Paper Award	1999	Goodman-GVR; Listak-JM	For the paper "Variations in Dust Levels with Continuous Miner Position"	Coal Division, Society for Mining, Metallurgy, and Exploration (SME)	Respiratory diseases
Government Civil Engineer of the Year	1999	Iannacchione-AT Ph.D.	For significant contributions to the practice of Civil Engineering in the public sector	American Society of Civil Engineers	Ground control
Engineer of the Year	1998	Iannacchione-AT Ph.D.	For outstanding contributions and displayed professionalism in the Engineering discipline	Centers for Disease Control and Prevention and Public Health Service	Ground control
Alice Hamilton Award for Excellence in Occupational Safety and Health, Best paper, Engineering and Physical Science Category	1998	Mark-C; Mucho-TP; Dolinar-D	For the paper "Horizontal Stress and Longwall Headgate Ground Control", Mining Engineering, pp. 61-68	CDC	Ground control
Colliery Manager's Award for Best Peer-Reviewed Paper in S.A. Mine Ventilation Journal	1998	Rider-J; Taylor-C; Thimons-E	For the paper "Measuring Low Level Methane Concentrations with an Air Bag Sampling System"	Mine Ventilation Society of South Africa	Mine disasters
FEB Award	1997	Sammarco-J	Chairman's Award for improving government operations. Silver Award	Federal Executive Board	Traumatic injuries
R&D 100 Award - Portable Modified Direct Method Apparatus	1997	Garcia-F; Schatzel-SJ	Research and Development award for one of the 100 most important research innovations of the year	R&D Magazine	Mine disasters

Title	Date	Recipients	Reference	Sponsor	Strategic Goals
Publication of the Year	1997	Vaught-C; Fotta-B; Wiehagen-WJ; Conti-R; Fowkes-R	For paper: A Profile Of Workers Preparedness And Experience In Responding To Underground Mine Fires (RI 9594)	NIOSH	Surveillance and training

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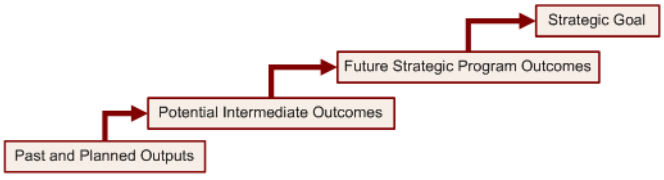
Chapter 4
What will the Mining Program Accomplish?

4.1 Overview of Chapter 4

Chapter 4 addresses the improvements to mineworker safety and health that are predicted to occur over the next five years, as a direct result of the research and prevention activities of the NIOSH Mining Program. The organization of this chapter is similar to the format used in Chapter 3, and many of the same issues discussed in the Overview to that chapter apply here as well. In Chapter 4, the forecasted accomplishments are based on:

- the critical assumption that resources and processes similar to the ones used over the past five years will be continued over the next five years;
- the outputs that have occurred in recent years and appear to be on their way to an intermediate impact; and
- ongoing project outputs, which are expected to lead to intermediate outcomes.

Section 4.2 describes the safety and health accomplishments anticipated over the next five years for each strategic goal of the Mining Research Plan (for more information about this plan, refer to Section 1.5.) This section begins with a list of the seven strategic goals and the **future strategic program outcomes** expected to be produced as the research results for each goal are implemented. Within each goal are 4 to 16 **potential intermediate outcomes** that support the future strategic program outcomes. These potential intermediate outcomes are expected if currently active research projects are concluded successfully, and the results are implemented by the intended customers. For each potential intermediate outcome, there is a brief description of the problem, research approach, intermediate outcome expected from the research, and a list of past and planned **outputs**, which will contribute to the potential outcome. Both past and planned outputs are included since these research projects are in progress. In summary, the hierarchical structure of this section is as follows:



Section 4.3 is a database of outputs which are expected to result from the current research projects or planned follow-up projects over the next five years. The outputs are research products which communicate the results of the research to the public and potential users of the results. Each item in this database includes a title, year produced, type of output, and the strategic goal toward which it is directed. Many of these planned outputs will contribute to the

achievement of the future potential intermediate outcomes and are also listed with those items. The planned outputs are based primarily on current active research projects, and the outputs from these projects are expected in the next 2 or 3 years as most of these project reach their planned conclusion. As a result the number of planned outputs diminishes each year. We expect that the actual number of outputs will be the same or larger, if available resources remain the same. However, it is difficult to be specific in planning outputs from possible future research projects, which have not yet been formally proposed, reviewed or approved.

4.2 Potential Outcomes

This section describes the safety and health accomplishments anticipated over the next five years for each strategic goal of the Mining Research Plan. The section begins with a list of the seven strategic goals and the future strategic program outcomes expected to be produced as the research results for each goal are implemented. Listed within each goal are a number of potential intermediate outcomes that support the future strategic program outcomes. These potential intermediate outcomes are expected if currently active research projects are concluded successfully, and the results are implemented by the intended customers. On the subsequent pages, for each potential intermediate outcome, there is a brief description of the problem, research approach, intermediate outcome expected from the research, and a list of past and planned outputs, which will contribute to the potential outcome. Both past and planned outputs are included since these research projects are in progress.

Strategic Goal 1 - Respiratory diseases: Reduce respiratory diseases in miners by reducing health hazards in the workplace associated with coal worker pneumoconiosis, silicosis, and diesel emissions.

Future Strategic Program Outcomes: Within 10 years, reduce the respirable coal dust overexposures of operators of longwall and continuous mining machines, roofbolters, and surface drills by 50% and the overall silica exposure of crusher operators and stone cutters by 50%. Within 10 years, reduce coal miner exposure to DPM by 80% and metal nonmetal miners DPM overexposure rates by 50%.

Potential Intermediate Outcomes:

1. Canopy Air Curtain
2. Methane Control Handbook
3. Control Technology for Coal Worker Pneumoconiosis (CWP) Hotspots
4. Measuring Diesel Particulate Matter with Diesel Detective Monitoring Technology
5. Guidelines to Reduce Diesel Particulate Matter in Coal, Metal, and Nonmetal Mines
6. Diesel Particulate Filter Selection Guide
7. Cooperative NIOSH/IMA-NA Dust Control Handbook for Mineral Processing Plants
8. Inline Series Spray Scrubber
9. Evaluation of a Continuously Regenerating Diesel Exhaust Trap with Nitrogen Dioxide Control
10. Longwall Dust Surveys
11. Filter Materials for Silica Analysis When Using the Personal Dust Monitor
12. Facilitating the Use of Personal Dust Monitors as a Means of preventing Coal Workers' Pneumoconiosis
13. Assessing the Performance of a Heat Exchanger to Reduce Outby Diesel Exhaust Temperatures
14. Dust Capture and Induced Airflow of Various Spray Nozzle Designs
15. Open Structure Design
16. Hydrogen-Powered Mine Vehicle Reduces Miner Exposure to Diesel Emissions

Strategic Goal 2 - Hearing loss: Reduce noise-induced hearing loss (NIHL) in the mining industry.

Future Strategic Program Outcomes: Reduce the frequency of noise overexposure of miners by 25% in 5 years and 50% in 10 years.

Potential Intermediate Outcomes:

1. Underground Metal Noise Control Guide
2. Improved Hearing Protection
3. A Health Hazard Study of Surface Drilling Operations
4. Model Hearing Loss Prevention Program
5. Engineering Noise Controls for Roof Bolting Machines
6. Engineering Noise Controls for Continuous Mining Machines - Jacketed Tail Roller
7. Engineering Noise Controls for Horizontal Vibrating Screens
8. Administrative Computer Program
9. Engineering Noise Controls for Continuous Mining Machines - Dust Collector Fan

Strategic Goal 3 - Cumulative injuries: Reduce repetitive/cumulative musculoskeletal injuries in mine workers.

Future Strategic Program Outcomes: Reduce repetitive/cumulative musculoskeletal injuries by 35% based on the 2003 repetitive/cumulative musculoskeletal injury rate.

Potential Intermediate Outcomes:

1. Improving Mobile Equipment Operator Ergonomics
2. Age Awareness Training Modules
3. Slips and Falls Research
4. Knee Injury Prevention
5. Improved Risk Assessment for Low Back Disorders in Mining
6. Ergonomic Processes Implementation/Integration and Process Metric
7. Redesign of Dragline Workstations
8. Reducing Injuries during Bagging Tasks
9. Reducing Injuries Due to Railcar Loading and Maintenance Activities
10. MSD Prevention and Intervention Education Modules

Strategic Goal 4 - Traumatic injuries: Reduce traumatic injuries in the mining workplace.

Future Strategic Program Outcomes: By 2014, reduce traumatic injuries by 35% based on the 2003 traumatic injury rate.

Potential Intermediate Outcomes:

1. Guidelines for Improving Ore Pass Safety
2. Forklift Operating Warning System (FLOWS)
3. High-Voltage Continuous Mining Machines
4. Power Line Proximity Warning Alarms
5. Electrical Arc Burns
6. Roof Bolter Health and Safety Guidelines
7. Reducing Blast Area Security and Flyrock - Related Injuries and Fatalities in Mining
8. Remotely-Controlled Bulldozer on Coal Stockpiles

Strategic Goal 5 - Mine disasters: Reduce the risk of mine disasters (fires, explosions, and inundations); and minimize the risk to, and enhance the effectiveness of, emergency responders.

Future Strategic Program Outcomes: Reduce the number of injuries and deaths attributed to mine fires, explosions, inundations, and rescue and response activities by 25% between 2010 and 2014 compared to the average yearly total from 1990-2001 as compiled from MSHA accident statistics.

Potential Intermediate Outcomes:

1. Advanced Methane Control in Underground Coal Mines
2. Reducing Fire Hazards in the Metal-Nonmetal Mining Industry
3. Managing Mine Fires
4. Reducing Fire Hazards in Underground Coal Mines
5. Communications and Decision Making During Mine Emergencies
6. Utilization of Engineered Ventilation Systems in Large Opening Mines
7. Remote Construction of Seals for Fire Control and Abatement
8. Prevention of Catastrophic Coal Dust Explosions in Mines

Strategic Goal 6 - Ground control: Reduce ground failure fatalities and injuries in the mining industry.

Future Strategic Program Outcomes: Reduce mine fatalities by ground failures by 50% within 8 years. Reduce injuries by ground and roof support system failures by 25% within 5 years and by 50% within 8 years. Reduce unplanned roof falls by 20% within 5 years and by 40% within 8 years.

Potential Intermediate Outcomes:

1. Improved Highwall Stability to Reduce Surface Mine Hazards
2. Reducing Injuries by Improving Shotcrete Design Criteria
3. Improved Pillar Design in Metal and Industrial Mineral Mines to Reduce Ground Control Hazards
4. Avoiding Inundations: Developing Guidelines for Mining near Bodies of Water
5. Improved Mine Safety through Optimized Extraction
6. Multiple-Seam Mining Design Guidelines
7. Design of Mine Ventilation Stoppings
8. Roof Span and Pillar Layout Guidelines for Stone Mines
9. Reducing Ground Fall Hazards in Coal Mines with Low Strength Roof
10. Highwall Mining Stability Guidelines
11. Increase Roof Fall Forecast Times with Sensor-Based Monitoring Techniques
12. Reducing Ground Fall Hazards in Metal Mines with Weak Rock

Strategic Goal 7 - Surveillance and training: Determine the impact of changing mining conditions, new and emerging technologies, training, and the changing patterns of work on worker health and safety.

Future Strategic Program Outcomes: Over the next 10 years, identify the impacts of changes and make recommendations for mitigating adverse impacts.

Potential Intermediate Outcomes:

1. Improving Miner Safety by Developing Toolbox Training Sets
2. Improving Miner Safety by Developing Interactive Computer Simulation Training
3. Improving the Accuracy of Determining Worker Exposure to Airborne Silver
4. New Miner Training
5. Improved Technology Transfer Via the Web

Potential Intermediate Outcome for Respiratory Diseases

Canopy Air Curtain

Background

Air curtain being tested on roof bolter

The results of MSHA compliance sampling indicate that roof bolter operators are exposed to some of the highest silica dust levels measured in underground coal mines. From 2000 through 2004, MSHA inspectors collected and analyzed over 4000 samples for silica. Of these, 14% exceeded the permissible exposure limit. Past research by NIOSH has found that significant silica exposure can result when a roof bolter must work downwind of a continuous miner. With the increase of continuous miner supersections, bolter operators are being required to work downwind of con-tinuous miners more frequently. Conse-quently, control technologies are needed that can reduce roof bolter operators´ exposures to dust when working in the return airstream of a continuous miner.

NIOSH researchers developed a system that filters approximately 250 ft^3/m of ventilation air and transports it through flexible tubing to an air curtain mounted on the underside of an operator´s canopy during installation of roof bolts. The air curtain contains baffling material that distributes the clean air evenly down over the operator. Laboratory tests were conducted to evaluate the effectiveness of the air curtain under differing operating conditions. Results showed that the dust levels were reduced under the curtain by approximately 60% for the mean air velocities commonly found in roof bolter entries. An underground evaluation was also completed recently to evaluate air curtain performance in an operating mine. Mine results demonstrated the proof-of-concept and the potential for this control technology.

Potential Outcome

The leading roof bolter manufacturer in the United States has expressed an interest in furthering the development of this technology. After a joint meeting among NIOSH, MSHA, the mine operator, and the bolter manufacturer, it was agreed that NIOSH, the mine operator, and the bolter manufacturer would continue this research to refine and improve the air curtain with the goal of reaching commercialization. Successful imple-mentation of this technology will result in a significant reduction in exposures to respir-able dust and silica among roof bolter operators, particularly when they are forced to work downwind of continuous miners. Field tests of this system should be completed in early 2007, with a bolter manufacturer offering the technology on its equipment by 2008.

Outputs

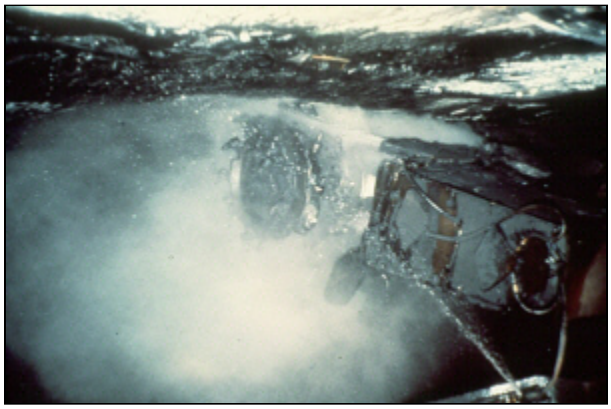
5 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Effective Control of Respirable Dust in Underground Coal Mines in the United States Colinet-JF; Goodman-GVR; Listak-JM; Chekan-GJ; Rider-JP; Pollock-DE; Thimons-ED | In: Gillies ADS, ed. Proceedings of Eighth International Mine Ventilation Congress (Brisbane, Australia), AusIMM, Victoria, Australia, 2005; :129-134	2005	Publication	Respiratory diseases
Evaluation of Methods for Controlling Silica Dust Exposures on Roof Bolters Goodman-GVR; Organiscak-JA | 2002 Transactions, Society for Mining, Metallurgy, and Exploration, Vol. 312; :133-137	2002	Publication	Respiratory diseases
Laboratory Evaluation of a Canopy Air Curtain for Controlling Occupational Exposures of Roof Bolters Goodman-GVR; Organiscak-JA | Proc Seventh International Mine Ventilation Congress, (Krakow, Poland) 2001 Jun; :299-305	2001	Publication	Respiratory diseases
Emerging Technologies Control Respirable Dust Exposures for Continuous Miner and Roof Bolter Personnel - Accepted for presentation and publication at 11th US/North American Mine Ventilation Symposium, Pennsylvania State University, State College, PA, June 5-7, 2006	2006	Publication	Respiratory diseases
Reducing Roof Bolter Operator Dust Exposures with a Canopy Air Curtain - Mining Engineering	2007	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Methane Control Handbook

Background



Methane gas and dust released at the working face

The potential hazards associated with methane gas emissions in underground mines have been well researched and documented. Over the past 20+ years, researchers from the U.S. the Bureau of Mines and NIOSH have developed techniques to identify and control these gas emissions. The problem with all these results is that a single specific source of relevant information has never been compiled for individuals needing to understand how to identify the problem and implement a workable combination of controls. Researchers within NIOSH and the Mine Safety and Health Administration, working with others in the industry, have written various chapters in a handbook that will address methane problems in coal mining, metal and nonmetal mining, and tunneling. All aspects of methane control will be documented, so the reader will be provided with a comprehensive menu of approaches for controlling methane.

Potential Outcome

This work is scheduled to be published sometime late in calendar year 2005 or early in 2006. The potential impact of this publication is that it will provide the first comprehensive source of information that can specifically assist individuals who are tasked with predicting, identifying, and controlling underground methane emissions.

Outputs

1 Planned or completed output

Title	Year	Output Type	Strategic Goal
Handbook for Methane Control in Mining - NIOSH IC	2006	Publication	Mine disasters

Potential Intermediate Outcome for Respiratory Diseases

Control Technology for Coal Worker Pneumoconiosis (CWP) Hotspots

Background

Longwall shearer operating in lower seam

Analyses of data obtained from the National Coal Workers´ X-Ray Surveillance Program along with data obtained from the Miners Choice x-ray program have shown that mine workers from small mines in the southern Appalachian region are showing almost three times the national average of CWP and nearly five times the rate of pulmonary massive fibrosis (PMF). In response, NIOSH is initiating a program to implement improved dust control technologies into these mines to address this problem. NIOSH researchers will utilize MSHA compliance sampling results to identify mines of interest in the southern Appalachian region. Researchers will then visit MSHA offices in the region to gather and analyze data from dust control plans on file for each mine. Information from mine inspector reports on production rates, mine equipment types, mining practices, and other characteristics specific to the mines will also be noted. Dust surveys will be conducted at selected mines to determine problem areas, to assess the state of control technology being employed, and to determine where additional control technology is needed. The small mines involved may require individual dust control technologies because of their limited budgets and specific operating conditions. NIOSH will conduct laboratory and field research to optimize existing technologies and to develop new technologies that will have a higher probability of acceptance and success in these mines.

Potential Outcome

As NIOSH researchers learn what dust control technologies are the most practical for these small operations, regional workshops will be conducted to transfer findings to mine operators and miners to improve knowledge about successful dust controls. By 2007, NIOSH researchers should have an initial understanding of why these mining operations have such a high prevalence of CWP. By 2008, information on how to control the dust in these mines effectively and economically should be available for publication. The potential future impact is that cost-effective dust control technology specific to these small mines will be developed and implemented with a high likelihood of having a positive impact on reducing the rate of both CWP and PMF.

Outputs

3 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Characterizing Dust Exposures and Controls for Mines Operating in the Southern Appalachian Region - Coal Age	2008	Publication	Respiratory diseases
Dust Control for Mines Operating in the Southern Appalachian Region - workshops in KY, VA and WV	2009	Workshop, Seminar, or OIB	Respiratory diseases
Factors Impacting Successful Dust Control in Small Mines - SME Transactions	2008	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Measuring Diesel Particulate Matter with Diesel Detective Monitoring Technology

Background

Triplicate Diesel Detectives in a diesel engine exhaust

The efficacy of diesel particulate matter control depends on the ability to measure engine emissions quickly and effectively. A NIOSH-patented detector tube technology is being used to solve this problem. NIOSH work on this project has been conducted jointly through a Cooperative Research and Development Agreement with SKC, Inc., of Eighty-Four, PA. The device, known as the Diesel Detective, will enable front-line personnel to determine quickly the particulate emission levels of an engine and determine if control technology maintenance may be required. Because of this NIOSH research, the Department of Minerals Resources, New South Wales, Australia, has tested the prototype Diesel Detective in laboratory and field trials and has recommended use of the technology in Australian mines.

Potential Outcome

In response to these U.S. and Australian research results, SKC, Inc., is funding the commercialization of the instrument. In 2005, BHP-Billiton (the largest mining company in the world) published an article entitled "Diesel Emissions Manage-ment." In this report, the authors recommend that the Diesel Detective be used by all diesel fleet managers to examine engines and isolate those in need of particulate emission control. SKC, Inc., now has orders in-hand for this device and is working on commercialization. This development has the potential to provide the entire mining industry with an inexpensive and reliable tool for evaluating the performance of diesel emission controls in a timely manner. In U.S. coal mines where no ambient air testing is done, this device will make it possible to evaluate the performance of DPM control filters to test for failures during routine maintenance quickly. In metal/nonmetal mines, it will provide a valuable tool to engineering and maintenance personnel to find out if a filter is performing as designed. The technology is now available and proven and should be commercially available in 2006.

Outputs

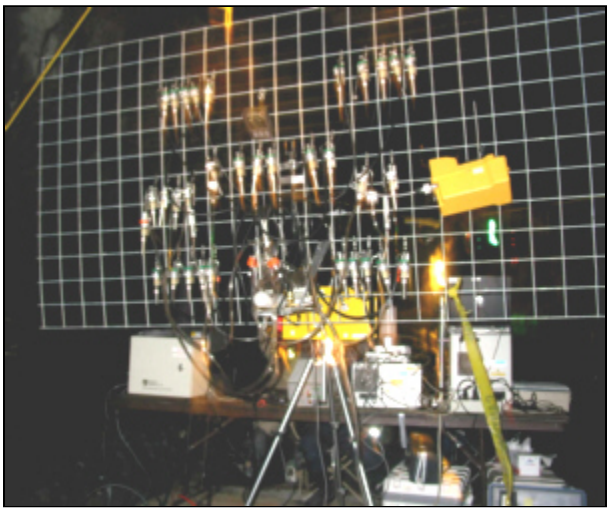
4 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
A Continuous Personal Diesel Emission Exposure Monitor - Engineering & Mining Journal	2009	Publication	Respiratory diseases
A Differential Pressure Method used to Monitor Efficiencies of Diesel Emission Control Technologies - NIOSH RI	2007	Publication	Respiratory diseases
A Direct Method to Measure Relative Levels of Engine Tailpipe Diesel Particulate Matter - Journal of Aerosol Science	2006	Publication	Respiratory diseases
Differential Pressure Method to Measure Elemental Carbon in Undiluted Diesel Exhaust - Environmental Science & Technology	2006	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Guidelines to Reduce Diesel Particulate Matter in Coal, Metal, and Nonmetal Mines

Background



Sampling grid at Stillwater Mine

Continual expansion of the use of diesel engines in the mining industry and the uncertainty associated with the long- and short-term effects of diesel exhaust emissions on miners´ health have focused attention on the control of emissions from diesel engines. The potential exposure to diesel emissions has raised a host of health concerns and garnered interest from various regulatory agencies throughout the world. In 2001, the Mine Safety and Health Administration (MSHA) promulgated two rules, one (30 CFR 57.5060) limiting exposures of underground metal and nonmetal miners to total and elemental carbon and the other (30 CFR 72.500, 72.501, and 72.502) limiting diesel particulate matter (DPM) emissions from diesel-powered coal mining equipment.

To reduce miners´ exposures to DPM and to abide by the measure of current U.S. regulations, NIOSH has formed partnerships with the U.S. underground mining community to work on identifying controls for the curtailment of DPM and gaseous emissions from both existing and new diesel-powered vehicles. To date, the replacement of older diesel engines with cleaner modern engines, improvements in diesel engine maintenance, and the implementation of various diesel emission control technologies, including diesel particulate filter systems and reformulated fuels, are all viewed as effective methods to reduce DPM concentrations in mine air. To assist mine operators with the potentially complicated process of choosing the proper DPM control strategy, NIOSH will develop guidelines to reduce diesel particulate matter in coal, metal, and nonmetal mines.

Potential Outcome

The long-term impact of these guidelines will be that mine operators will have correct guidance as they work to develop a successful DPM control strategy. These guidelines will lay out a multifaceted approach for DPM control, including the use of newer, cleaner engines; alternative fuels; exhaust after-treatment systems; and proper engine maintenance. NIOSH is currently working on several levels to gain the necessary knowledge to complete these guidelines. In the previous 3 years (2002 to 2004), NIOSH completed four field studies at the Deer Creek coal mine and at the Stillwater Mine to evaluate the effectiveness of various filters and alternative fuels as to their ability to reduce DPM concentrations in mine air.

NIOSH is also testing a continuously regenerating trap at the University of Minnesota. If successful, this system will give the mining industry a diesel particulate filter that can be installed and forgotten, at least for 250 hours, or the period between normal engine maintenance. A DPM tailpipe monitor that monitors in real time is also being developed to assist mine mechanics with proper maintenance of mine vehicles and ensure that control technologies are effective.

A filter selection guide that walks mine operators through each step in choosing a proper filter is being designed; currently NIOSH is working with the Queenstake Mining Co., of Elko, NV, to evaluate the effectiveness of the guide. Once these guidelines are finalized, NIOSH will sponsor a series of workshops to explain the guidelines in detail to operators. In addition, the guidelines will be available to all operators through the NIOSH Internet and in NIOSH publications.

Outputs

12 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Diesel Particulate Matter Control Technologies and Measurements in US Mines Mischler-SE; Bugarski-AD; Schnakenberg-GH | In: Gillies ADS, ed. Proceedings of Eighth International Mine Ventilation Congress (Brisbane, Australia), AusIMM, Victoria, Australia, 2005; : 263-274	2005	Publication	Respiratory diseases
Differential Pressure as a Measure of Particulate Matter Emissions from Diesel Engines Mischler-SE; Volkwein-JC | Environ Sci Technol 2005 Apr; 39(7):2255-2261	2005	Publication	Respiratory diseases
Evaluation of Diesel Particulate Filter Systems and Biodiesel Blends in an Underground Mine Bugarski-A; Schnakenberg-GH Jr; Noll-JD; Mischler-S; Crum-MW; Anderson-R | Trans Soc Min Metal Explor. Vol 318. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.; :27-35	2005	Publication	Respiratory diseases
The Effectiveness of Selected Technologies in Controlling Diesel Emissions in an Underground Mine: Isolated Zone Study at Stillwater Mining Company's Nye Mine Bugarski-AD; Schnakenberg-GH; Noll-JD; Mischler-SE; Patts-LD; Hummer-J; Vanderslice-SE; Crum-M; Anderson-R | Proceedings of Diesel Particulate in Mining Conference, Sponsored by Australian Journal of Mining, Yeppoon, Queensland, Australia, June 8-9, 2004	2004	Publication	Respiratory diseases
Guidelines to Reduce Diesel Particulate Matter in Coal, Metal, and Nonmetal Mines - NIOSH RI	2009	Publication	Respiratory diseases
Guidelines to Reduce Diesel Particulate Matter in Coal, Metal, and Nonmetal Mines." - NIOSH internet	2009	Web document	Respiratory diseases
A series of workshops for coal mine operators explaining the "Guidelines to Reduce Diesel Particulate Matter in Coal Mines"	2009	Workshop, Seminar, or OIB	Respiratory diseases
A series of workshops for metal/nonmetal mine operators explaining the "Guidelines to Reduce Diesel Particulate Matter in Metal, and Nonmetal Mines	2009	Workshop, Seminar, or OIB	Respiratory diseases
Reformulated Fuels and After Treatment Technology Effectiveness in Controlling Diesel Emissions. Stillwater Mining Co. Nye Mine Study - NIOSH RI	2006	Publication	Respiratory diseases
Report to the partnerships on the results from the Jerritt Canyon mine study - Partnership Report	2007	Publication	Respiratory diseases
Report to the partnerships on the results of the Johnson-Matthey CRT tests - Partnership Report	2006	Publication	Respiratory diseases
Report to the partnerships on the results of the Rohmac heat exchanger tests - Partnership Report	2006	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Diesel Particulate Filter Selection Guide

Background

Particulate filter designed to reduce diesel engine emissions

Currently, a wide range of applications are available to control diesel particulate matter (DPM) emitted from engines in mine vehicles effectively. One effective control option is the use of a diesel particulate filter. Because of the wide variety of function and applicability of the filters, mine operators have found it difficult to select the proper one to use with specific pieces of underground equipment. Factors that include duty cycle, engine exhaust temperature, and limited available volume constraints must be considered when selecting the proper filter. To assist mine operators with this potentially complicated process, NIOSH researchers have developed a "Filter Selection Guide." This handbook is currently available through Internet links on both the NIOSH mining and Mine Safety and Health Administration Websites. The "Filter Selection Guide" walks operators through each step of the selection process and outlines the information necessary to complete each step. At the completion of the guide, operators are provided the best filter options to control DPM emissions.

Potential Outcome

The long-term impact of the "Filter Selection Guide" is that it will provide mine operators with correct guidance for selecting filter-based diesel emission controls and will avoid the unnecessary and costly expense of installing inappropriate controls. Use of this guide will enhance the potential for miners to be better protected from diesel emissions. To obtain more practical knowledge that would be incorporated into the guide, NIOSH is currently working with the Queenstake Mining Co., of Elko, NV, to evaluate the guide´s effectiveness in assisting mine personnel in choosing the appropriate diesel particulate filter for various diesel-powered vehicles used in their operation. This work will add significant real-world input to the guide. The research should be completed in early 2007, and the guide updated with new information by early 2008.

Outputs

7 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Metal and Nonmetal Diesel Particulate Filter Selection Guide Schnakenberg-GH; Bugarski-AD; Angel-J; Saseen-G | Web document, http://www.msha.gov/nioshmnmfilterselectionguide/dpmfilterguide.htm	2005	Web document	Respiratory diseases
Long-Term Evaluation of Diesel Particulate Filter Systems at Inco's Stobie Mine Stachulak-JS; Conard-BR; Bugarski-AD; Schnakenberg-GH | Proceeding of the Eighth International Mine Ventilation Congress, Brisbane, Queensland, Australia, July 6-8, 2005	2005	Publication	Respiratory diseases
Diesel Particulate Matter Control Technologies and Measurements in US Mines Mischler-SE; Bugarski-AD; Schnakenberg-GH | In: Gillies ADS, ed. Proceedings of Eighth International Mine Ventilation Congress (Brisbane, Australia), AusIMM, Victoria, Australia, 2005; : 263-274	2005	Publication	Respiratory diseases
Evaluation of Diesel Particulate Filter Systems and Biodiesel Blends in an Underground Mine Bugarski-A; Schnakenberg-GH Jr; Noll-JD; Mischler-S; Crum-MW; Anderson-R | Trans Soc Min Metal Explor. Vol 318. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.; :27-35	2005	Publication	Respiratory diseases
Evaluation of Diesel Emission Control Technologies Used in U.S. Underground Coal and Non-Coal Mines Schnakenberg-GH; Bugarski-AD; Mischler-SE; Noll-JD | Proceedings of the 31st Intl Conf of Safety in Mines Res Institutes, Brisbane, Australia, Oct 2-5, 2005; :277-280	2005	Publication	Respiratory diseases
An Update on the Metal and Nonmetal Diesel Particulate Filter Selection Guide - web based publication	2008	Web document	Respiratory diseases
From Theory to Practice: Examining Diesel Exhaust Filter Implementation and Performance in the Jerritt Canyon Mine - NIOSH RI	2007	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Cooperative NIOSH/IMA-NA Dust Control Handbook for Mineral Processing Plants

Background

Bag cleaning unit installed in plant

Workers performing a vast array of different job functions at mineral processing operations are often overexposed to silica and other respirable dusts. Health and safety specialists and engineers are constantly looking for new engineering control techniques to lower respirable dust exposures for workers at these facilities. NIOSH and the Industrial Minerals Association-North America (IMA-NA) recently formed a dust control task group in an effort to improve dust control at processing operations. This task group is mainly composed of health and safety specialists from a number of mineral processing corporations, as well as members from IMA-NA and NIOSH. The initial goal of this dust control task group is to pursue the development of a dust control handbook for mineral processing plants that would provide information on proven and effective control technology to lower workers´ respirable dust exposures at mineral processing plants. This handbook is to be fashioned after the ACGIH´s Industrial Ventilation Manual: A Manual of Recommended Practices. Chapters within the handbook will be written to address the different dust exposure topics of concern and provide engineering control techniques to lower workers´ exposures to respirable dust. It is anticipated that much of the information for this handbook will come from the current NIOSH mineral processing dust control handbook. However, new information will be added. This handbook also will address a wider array of workers with a significant emphasis on maintenance workers, who are often overlooked with respect to dust exposure, but who are often highly exposed.

Potential Outcome

Once completed, this handbook will be an extremely valuable resource to the industry by providing information on proven and effective dust control technology to lower workers´ respirable dust exposures throughout the minerals processing industry. It is anticipated that this joint effort will start in 2006 and continue through 2008, with the handbook coming out in 2009.

Outputs

2 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Control Technologies Being Used to Control Silica Exposures in Mineral Processing Plants - Aggregates Manager	2008	Publication	Respiratory diseases
Dust Control Handbook for Mineral Processing Operations - NIOSH IC	2009	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Inline Series Spray Scrubber

Background

Adjusting airflow through water-powered scrubber

Mining machine operators have some of the highest frequencies of overexposure to both respirable coal and silica dust. From 2000 through 2004, over 8,500 samples collected from operators of continuous miners by MSHA inspectors and mine operators exceeded the 2 mg/m3 respirable dust standard. Although water spray dust suppression systems continue to make significant contributions toward reducing dust exposure among miners, NIOSH has identified diminishing returns, and simple increases in pressure and/or quantity have not adequately provided the dust control needed to reach permissible exposure levels, particularly when dust standards are lowered due to excessive silica in the samples. To improve dust capture by water sprays operated at the pressures typically found in underground mines, NIOSH has developed a portable inline series spray scrubber to improve removal of localized airborne dust emitted at the source. Laboratory results show that the inline spray scrubber can move between 484 to 679 ft3/min of air and achieve 69% to 81% respirable dust capture efficiencies when operated at 250 psi. NIOSH laboratory and field research studies are continuing in order to optimize this dust scrubber technology.

Potential Outcome

Use of these portable scrubbers close to the source of dust generation on a mining machine is expected to reduce the amount of airborne dust resulting in reduced exposures for mining machine operators. This technology will also likely have applications outside of mining. For example, inline spray scrubbers could be used for a number of applications in mineral processing facilities. Laboratory tests of this concept should be completed in 2007, and information published in late 2007 or early 2008.

Outputs

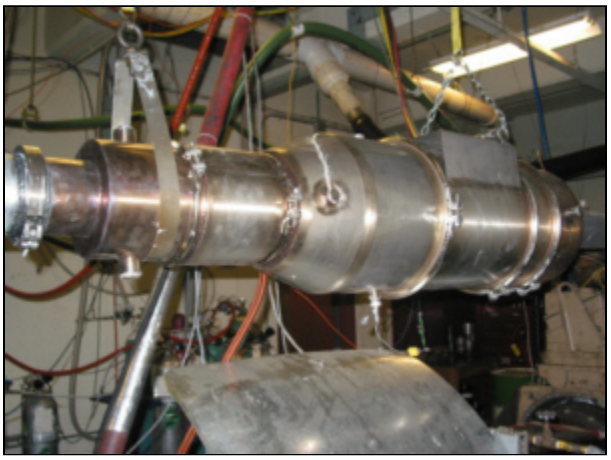
3 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Development of a Lower Pressure, Water-Powered Spot Scrubber for Mining Applications Organiscak-JA; Pollock-DE | SME preprint 05-103. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc, 2005; :1-9	2005	Publication	Respiratory diseases
Controlling Dust Generation in a Dimension Stone Shop with a Low-Pressure Scrubber - Rock Products Magazine	2006	Publication	Respiratory diseases
Utilizing Spot Scrubbers to Reduce Dust Levels on Continuous Mining Machines - SME transactions	2008	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Evaluation of a Continuously Regenerating Diesel Exhaust Trap with Nitrogen Dioxide Control

Background



Johnson Matthey continuously regenerating trap being evaluated at the University of Minnesota

The diesel particulate filter has been shown to reduce the amount of diesel particulate matter (DPM) emitted from diesel-powered vehicles effectively. However, the mining industry has voiced concern regarding the amount of maintenance required to institute a diesel particulate filter program. A major issue is the necessity to clean accumulated DPM from the filter. At high exhaust temperatures, DPM can be removed through combustion often initiated by a catalyst, a process known as regeneration. However, using a catalyst for regeneration often leads to the release of excessive quantities of nitrogen dioxide (NO_2). This is a concern because NO_2 is a very toxic gas that affects the throat and lungs. It is a fast-acting substance having a ceiling value of only five parts per million parts of air. To supply the mining industry with a diesel particulate filter that both effectively reduces DPM emissions and allows for low-temperature natural regeneration, NIOSH is working with Johnson Matthey, Inc., of Taylor, MI, to develop and test a continuously regenerating trap with NO_2 control. This device continuously regenerates the filter medium with NO_2, which is produced by a catalyst positioned directly upstream of the filter. NO_2 is effective in catalyzing low-temperature DPM combustion soot that has accumulated on the DPF. The continuously regenerating trap system is currently used in road vehicles. A problem with NO_2 slip, the process whereby NO_2 is emitted from an exhaust pipe, has prevented this technology from being used in underground mines. To solve NO_2 slip, Johnson-Matthey has developed a NO_2 control that is currently being tested under a NIOSH contract at the University of Minnesota´s Center for Diesel Research in Minneapolis, MN.

Potential Outcome

If successful, this system will give the mining industry a diesel particulate filter that will be simple to install and use for at least 250 hours, or the period between normal engine maintenance. This should solve one of industry´s major problems relative to instituting a filter program. Successful development of this continuously regenerating trap will directly relate to lower DPM exposures for miners. Research at the University of Minnesota should be completed by late 2006, and if successful, followed by in-mine tests of the system in a U.S. metal/nonmetal mine (under the Metal/Nonmetal Diesel Partnership) in 2007. Results should be published and available to the industry in late 2007.

Outputs

2 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Evaluation of a Continuously Regenerating Diesel Emission Trap for use Underground - proceedings of the Mining Diesel Emission Conference	2007	Publication	Respiratory diseases
Bugarski, A.D. and Schnakenberg, G.H. Effects of Control Technologies on Diesel Emissions in Underground Mines. NIOSH Report of Investigation. 2008	2008	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Longwall Dust Surveys

Background

Evaluating directional water sprays on a longwall shearer

Historically, mine workers on longwall faces have had the highest degree of exposure to underground dust relative to the 2 mg/m3 dust standard. As longwall production increases, mine operators struggle with maintaining consistent compliance with the mandated dust standard. In compliance samples collected from 2000 through 2004, 19% of the return side face workers, 11% of the tailgate-side shearer operators, and 10% of the jacksetters exceeded the 2 mg/m3 dust standard. Production levels are projected to increase further, heightening the need for improved longwall control technologies. NIOSH researchers are conducting benchmark surveys in approximately 20% of the U.S. longwalls in an effort to identify the major sources of dust generation, the state of the art of longwall dust control technology, successful control technologies, and issues of additional need. To date, longwall surveys have been completed in six longwalls.

Potential Outcome

At the completion of these sur-veys, information on successful controls will be summarized in a handbook. The surveys will be completed by late 2006, and the information will be summarized and ready for publication by late 2007. This information will be disseminated throughout the longwall mining industry to provide guidance for reducing dust levels on longwalls. Gaps or needs for additional control technologies will also be identified and addressed through future research. The potential impact of this work lies in the fact that all longwall mining operations will have access to the latest proven longwall dust control technologies with guidance for implementing these controls.

Outputs

4 Planned or completed outputs

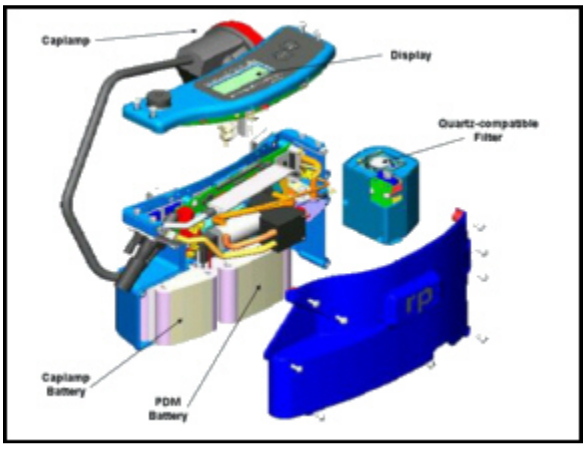
Title	Year	Output Type	Strategic Goal
Benchmarking Effective Longwall Dust Controls - proceedings of Longwall USA	2007	Publication	Respiratory diseases
Dust Controls on Longwalls - Assessment of the State-of-the-Art - proceedings 11th US/North American Mine Vent Symposium	2006	Publication	Respiratory diseases
Factors Impacting Shield Dust Entrainment in High Velocity Airstreams - SME transactions	2008	Publication	Respiratory diseases
Longwall Dust Control Handbook - NIOSH IC	2007	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Filter Materials for Silica Analysis When Using the Personal Dust Monitor

Background

The development and evaluation (both laboratory and field) of the personal dust monitor have been successful. However, the filter material currently being used in the monitor is not effective in analyzing silica, an airborne respirable dust commonly found in underground mines. NIOSH researchers have recently identified a filter material that is both compatible with the analytical method used to quantify airborne silica and stable when measuring total respirable dust mass.



An expanded view of the personal dust monitor showing the location of the quartz-compatible filter

Potential Outcome

NIOSH has applied for a patent for this development. Successful implementation of this research will increase the utility of the personal dust monitor for routine monitoring of coal miners´ exposure to not only coal mine dust, but also to the fraction of silica in that dust. Laboratory tests of this filter material are near completion. Thermo Electron Co., the producer of the personal dust monitor technology, is interested in licensing the technology for the monitor. In 2006, the information on this technology will be shared with Thermo-Electron, which will provide it to industry.

Outputs

3 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Implementing Infrared Determination of Quartz Particulates on Novel Filters for a Prototype Dust Monitor - Journal of Occupational and Environmental Hygiene	2007	Publication	Respiratory diseases
Locating a Filter Medium Suitable for Quartz Analysis with the Personal Dust Monitor - proceedings SME Annual Meeting	2007	Publication	Respiratory diseases
Patent on filter medium suitable for quartz analysis with PDM	2007	Patent	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Facilitating the Use of Personal Dust Monitors as a Means of preventing Coal Workers' Pneumoconiosis

Background

Miner wearing PDM

An important potential impact of PRL training research during the next few years will be the development of effective training materials and health communications for coal miners and mine managers on how the personal dust monitor can be used to reduce workers´ exposure to respirable dust. In recent years, coal workers' pneumoconiosis (CWP) has contributed to the deaths of approximately 1,000 people in the United States each year. Federal black lung program payments totaled more than $1.5 billion distributed to nearly 190,000 beneficiaries in 1999.

NIOSH, in collaboration with Rupprecht & Patashnik Co., Inc., of Albany, NY, recently developed a personal dust monitor. This new device represents a major advance in the tools available for assessing coal miners´ exposures to respirable dust levels. Over the next 2 years, NIOSH human factors researchers will collect data to identify how personal dust monitor use affects miners´ exposures to respirable dust. First, researchers will identify several specific examples of how miners use information about the monitors to discover which parts of their jobs and/or which aspects of their work environment may cause them to be overexposed to respirable dust. Second, they will identify the types of changes that miners and mine managers could implement to reduce their exposure. Researchers will develop material for communicating this important information to miners and mine managers. They will also develop training modules to (1) explain the capabilities and use of personal dust monitors to coal miners and (2) explain how to download data, clean the monitor unit, and program it for the next shift of dust sampling to mine health and safety technicians.

Potential Outcome

Once miners know how to use properly the information that a personal dust monitor is capable of providing, they should start adjusting their workplace and work procedures in ways that should reduce their exposure to respirable coal dust. As miners´ exposure to respirable dust is reduced, the incidence of CWP should significantly decline, and miners´ longevity and quality of life should significantly improve. This work will be completed by the end of 2007.

Outputs

6 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Examples and Strategies for using the PDM to Reduce Miners' Exposures to Respirable Dust - Coal Age	2007	Publication	Respiratory diseases
Miners' opinions about the PDM and how they can be used to reduce respirable dust exposure - Journal of Intl Society for Respiratory Protection	2007	Publication	Respiratory diseases
New Training on the Use and Maintenance of the PDM - proceedings SME conference	2007	Publication	Respiratory diseases
Training Module for Coal Mine Health and Safety Technicians on how to Maintain the PDM - NIOSH IC	2006	Publication	Respiratory diseases
Training Module for Coal Miners on the Purpose and Operation of the PDM - NIOSH IC	2006	Publication	Respiratory diseases
Miners' Opinions about the PDM and how they can be used to Reduce Respirable Dust Exposure - proceedings SME conference	2007	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Assessing the Performance of a Heat Exchanger to Reduce Outby Diesel Exhaust Temperatures

Background

Rohmac system installed on a diesel-powered locomotive

Presently, MSHA requires heavy-duty, diesel-powered outby vehicles used in coal mines to be equipped with a diesel particulate filter. For inby diesel-powered equipment, the exhaust temperature is regulated, and thus disposable paper filters can be used in conjunction with either water scrubbers or aqueous heat exchangers. Both of these systems cool the exhaust and reduce the potential for the paper filter to ignite. However, because of the high expense and maintenance problems associated with water scrubbers or heat exchangers, coal mine operators are reluctant to apply these systems to outby engines where exhaust temperatures are not regulated. Options are limited. One is to use high-temperature disposable filters on outby equipment. However, heavy-duty outby vehicles can have exhaust temperatures as high as 1300°F. Due to these high exhaust temperatures, some coal mines have experienced filter fires. The filter itself does not burn, but the solid emissions trapped by the exhaust and other engine hydrocarbons that build up on the filter can ignite. To find practical alternatives to this problem, NIOSH has collaborated with Rohmac, Inc., of Mount Storm, WV, on a project to design, fabricate, and evaluate an exhaust gas cooling device for diesel engines in conjunction with a high-temperature disposable diesel particulate filter for outby use. This device will reduce the exhaust temperature to less than the 650°>F maximum temperature recommended by manufacturers, thereby reducing the possibility of fire and providing a necessary emission control option for coal mine operators. NIOSH researchers are currently evaluating this heat exchanger on a diesel-powered locomotive in an underground coal mine to determine its effectiveness in reducing exhaust temperatures.

Potential Outcome

If this research is successful, it will provide the coal industry with a practical alternative to using paper filters on outby diesel equipment and reduce miners´ exposures to diesel particulate matter. In-mine tests of this system should be completed in early 2006, and the results made available to the industry by late summer 2006.

Outputs

2 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Effects of Coal Mine Diesel Emission Control Technologies - NIOSH RI	2007	Publication	Respiratory diseases
Performance Evaluation of an Exhaust-gas Cooling Device in an Underground Coal Mine - proceedings SME Annual Meeting	2007	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Dust Capture and Induced Airflow of Various Spray Nozzle Designs

Background

Unconfined spray on longwall shearer

Water sprays have been used throughout the mining industry as a primary means of controlling respirable dust. In addition to wetting, the spray pattern of water sprays can be used to induce air movement. NIOSH researchers have should that air movement induced by unenclosed water sprays mounted on coal-mining machines can be beneficial (longwall shearer-clearer) or detrimental (dust rollback on continuous miners) to controlling machine operators´ exposures to respirable dust. While higher water spray pressures increase dust capture in enclosed spaces, they can also increase spray-induced airflow and, as a result, reduce dust capture in unenclosed spaces. NIOSH has characterized water spray droplet formation, air inducement, and dust capture efficiency for various spray nozzle types. Results indicate that hollow cone and wider spray-cone-angle nozzles generally generate smaller and slower water droplets, which induce more airflow and have lower dust capture efficiencies. A flat spray pattern and sprays with narrower discharge angles tend to generate larger and faster water droplets, which induce less airflow and have higher dust capture efficiencies. This fundamental information about sprays will be verified in the laboratory and the field and applied to improvements in current spray system designs by reducing the detrimental effects of spray nozzles that push dust over machine operators.

Potential Outcome

Completion of these studies can demonstrate the pros and cons of spray nozzle types and their operating parameters to optimize respirable dust controls. This information, when fully understood and verified, will be used to educate the mining industry about optimizing the design of machine-mounted water spray systems to improve dust capture and reduce operators´ exposures to dust. This research should be completed by late 2008, and the findings made available to the industry in early 2009.

Outputs

3 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Spray Characterization for Coal Mine Dust Removal Gemci-T; Chigier-N; Organiscak-JA | In: Proceedings of the Ninth International Conference on Liquid Atomization and Spray Systems (Sorrento, Italy, July 13-18, 2003), 2003	2003	Publication	Respiratory diseases
Airborne Dust Capture and Induced Airflow of Various Spray Nozzle Designs - Journal of Occup & Environmental Hygiene	2007	Publication	Respiratory diseases
Improved Utilization of Water Sprays for Reducing Worker Dust Exposure in Mining - Mining Engineering	2009	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Open Structure Design

Background

Open structure plant sampled for project

Workers at mineral processing facilities are often exposed to high levels of hazardous respirable dust, generally in the form of silica dust. Federal compliance records have shown that workers at these facilities have some of the higher silica exposure rates in the entire metal/nonmetal mining industry, especially in those operations processing silica sand. Many different types of structures and materials have been used to build mineral processing facilities over the past few decades. Although the structure type and building material have not historically been considered factors with respect to silica exposure, recent NIOSH studies have addressed this issue. NIOSH researchers conducted field surveys to evaluate respirable dust levels associated with three different types of processing plants: closed metal structure, closed block structure, and an open structure design. This research determined that an open structure design for mineral processing operations was superior to walled structures in terms of reducing silica exposures. Preliminary findings show that for similar production rates, the open structure is far superior because it eliminates the dust gradients that form throughout a closed structure during the course of a shift. In the open structure design, the natural environment acts as an effective method of diluting and carrying away dust generated and liberated during product processing.

Potential Outcome

It appears that the use of open structure designs shows great promise in reducing silica exposure of workers in mineral processing operations. NIOSH is discussing work with the Industrial Minerals Association-North America to further evaluate the impact of structural design on dust exposures in mineral processing operations. While the preliminary work is completed, future work would likely run through 2007, with final results available in 2008.

Outputs

2 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Impact of Structural Design on Dust Levels in Mineral Processing Plants - NIOSH RI	2006	Publication	Respiratory diseases
Modifying the Structure of Processing Plants to Reduce Dust Levels - Aggregates Manager	2008	Publication	Respiratory diseases

Potential Intermediate Outcome for Respiratory Diseases

Hydrogen-Powered Mine Vehicle Reduces Miner Exposure to Diesel Emissions

Background

Zero Emissions Utility Solution at the Stillwater mine

The use of hydrogen as a fuel to power underground mine vehicles has the potential to reduce significantly worker exposures to the particulates and toxic gasses generated by diesel-powered vehicles. The first step to implementation of new hydrogen technologies is to establish safe practices for handling and use of the hydrogen fuel. A prototype hydrogen-fueled mining vehicle, dubbed the Zero Emission Utility Solution (ZEUS), was outfitted with the safety systems necessary for MSHA-compliant underground deployment. ZEUS is a modified EIMCO 975 articulated utility vehicle designed for underground use. A naturally aspirated water-cooled Caterpillar 3304 diesel engine was re-engineered to burn hydrogen. Fuel storage consisted of a modular metal hydride system mounted within the trailer flatbed. Metal hydride storage of hydrogen is the same technology under widespread development for fuel-cell technology. In addition to common safety features (e.g., ROPS and FOPS protection, back-up alarm, lamps, and seat belts), the vehicle was equipped with five sensors to detect gaseous hydrogen at low levels, yet minimize false readings from other gases and compounds. The hydrogen sensors also address the possibility for failures of the fuel storage and distribution systems. Refueling presents a hazard different than that posed by the liquid fuels miners are traditionally trained to use; therefore, a protocol for safe refueling was developed for the demonstration.

ZEUS, with its unique safety systems, was successfully demonstrated at the Stillwater Mine in Nye, MT, in 2004. This was the first time a hydrogen-fueled vehicle was operated in an underground mine in the United States. The demonstration of this vehicle in a mine provided regulators and industry with the opportunity to evaluate the safety systems and controls necessary for advancing the use of hydrogen as an industrial fuel.

In addition to being highlighted in the Engineering & Mining Journal (September 2004), the demonstration was well publicized in the Montana press by the Billings Gazette (http://www.billingsgazette.com) and Stillwater County News (http://www.stillwatercountynews.com). ZEUS was also driven in three community parades in Montana towns near the mine - Fishtail, Red Lodge, and Columbus.

Potential Outcome

The introduction of hydrogen as an alternative fuel for underground mine vehicles opens new avenues for reducing miner exposure to diesel particulate matter (DPM), an identified health hazard. This research demonstrated that some vehicles in the mining fleet can be retrofitted to burn hydrogen safely. The application of hydrogen technology will likely be a last resort because it is still expensive; however, the cost of modular metal hydride storage for hydrogen will be reduced within the next 10 to 15 years. Where DPM controls are not feasible, hydrogen can be considered an alternative to diesel fuel for mine vehicles.

Potential Intermediate Outcome for Hearing Loss

Underground Metal Noise Control Guide

Background

Measuring sound intensity on a LHD

An important enabling step for the application of existing noise control technology or the development of new technology is the identification of what controls currently exist and their effectiveness. Therefore, engineering noise control technologies used in or applicable to the mining industry are being documented and evaluated by NIOSH. Researchers visited a number of underground metal mines to study the effectiveness of the controls in terms of reducing worker exposure to noise. Another goal is to understand noise-generating mechanisms so new technology can be developed to reduce the sound levels to which workers are currently being exposed.

Potential Outcome

Based on the finding of this study, a Noise Control Guidebook for Underground Metal Mines is being developed and will be completed in 2006. The guidebook will provide information on the basic noise controls currently in use in the industry and emphasize lessons learned over the course of the research. Such lessons include:

1. What controls work and what controls don't work.
2. Engineering noise controls that work on the surface may not work as well as expected underground.
3. Properly installed barriers are effective in providing noise reduction; improperly placed absorptive material has little to no effect on sound levels.
4. A noise problem should be verified before a solution is attempted.

An important benefit of the guidebook will be that the noise control information obtained from throughout the underground metal-mining industry will be distributed to other sectors of the industry. Use of the guidebook should lead to the use of more robust noise controls, which in turn, will reduce worker noise exposure and the risk of noise-induced hearing loss. The guidebook will be initially published as a NIOSH publication, and then the information will be disseminated to industry through partnership efforts, conferences, and workshops. The impacts of this guidebook on the mining industry are expected to begin in 2006 after the research findings are published.

Outputs

8 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Noise Exposure in Longwall Mining and Engineering Controls Research Bauer-ER; Podobinsk-DJ; Reever- ER | In: Proceedings of Longwall USA International Exhibition and Conference, June 13-15, Pittsburgh, PA, Intertec Publishing Corp.; :51-69	2001	Publication	Hearing loss
Assessment of Noise Controls Commonly Used on Jumbo Drills and Bolters in Western Underground Metal Mines Reeves-ER | SME preprint 04-112. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.; :7 pp	2004	Publication	Hearing loss
Assessment of Noise Controls Commonly Used on Jumbo Drills and Bolters in Western United States Underground Metal Mines Reeves-ER | Min Eng 57(1), 2005; :41-47	2005	Publication	Hearing loss
Mining Hearing Loss Prevention Workshop NIOSH | Hosted by NIOSH-PRL, Charleston, WV; June 21-22, 2005	2005	Workshop, Seminar, or OIB	Hearing loss
Testing and Evaluation of an Engineering Noise Control on a Longwall Stageloader Bauer-ER; Reeves-ER; Durr-TM; Zuchelli-DR; Armour-D | SME preprint 05-58. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2005; ;1-12	2005	Publication	Hearing loss
Reeves ER [2006]. Noise control in underground metal mining. Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH IC) Publication No. In review, Dec.	2006	Publication	Hearing loss
NIOSH-PRL HLPB [2006]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2006]. Noise workshop in Salt Lake City UT, Hosted by NIOSH-PRL, Mining Hearing Loss Prevention Workshop, April, 2006	2006	Workshop, Seminar, or OIB	Hearing loss

Potential Intermediate Outcome for Hearing Loss

Improved Hearing Protection

Background

Earmuffs, earplugs, and other hearing protectors can be effective adjuncts to noise controls in preventing noise-induced hearing loss, but they have some significant drawbacks. Reported usage rates are below 50%, and those workers who do wear hearing protection typically receive far less noise protection than they might expect. Because of poor fit, real-world protection levels are reported well below 50% of the rated protection determined in the optimal setting of a laboratory. Hearing protectors can also interfere with communication and localization of alarms and important ambient sounds.

Laboratory evaluation of hearing protection

To overcome these shortcomings, NIOSH is addressing both hearing protector technology and worker behavior. New research-based guidelines are being developed to match hearing protectors to the noise and task environments without impeding communication. A simplified "roll-pull-hold" technique was developed to make the critical earplug-donning steps easier to remember and perform correctly. An interactive training package for surface drill operators was developed using three-dimensional slides and extensively field tested with workers.

The researchers also investigated improvements to hearing protectors that would make them function better. A special lubricant currently marketed for easing the fitting of hearing aids was evaluated for use with earplugs. Subjects who used the lubricant were significantly more likely to obtain a good protective seal with their earplugs. Also, a new hearing protector technology with a built-in electronic dose and exposure feedback system was subjected to laboratory trials. The system uses inexpensive microphones built into the hearing protectors, and these were found to provide a useful approximation of the amount of hazardous noise reaching the user.

Potential Outcome

Research on improved training and hearing protector technologies was completed in 2005, and follow-on studies to evaluate peer feedback training will be complete in 2007. Beginning in 2003 and continuing through 2008, the results of these studies are being disseminated in a series of practical training products in print, video, and Web format. Hearing protector communication guidelines will be distributed as a Web-based decision tool that will help optimize the match between protectors and different work settings. These products will have an impact on the estimated 90% of miners and drill workers who need to wear hearing protection during at least part of their working shifts. By implementing the training and protector modifications and

improving protector usage rates and effectiveness, workers will significantly reduce their exposure to noise. For instance, the roll-pull-hold technique alone achieves 9 dB of improved protection that, if adopted industry-wide, would substantially reduce the incidence of noise-induced hearing loss.

Outputs

16 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
How to Wear Soft Foam Earplugs (Roll-Pull-Hold) Randolph-RF | NIOSH 2003 Mar; :Video (RealMedia format, 30 seconds)	2003	Video	Hearing loss; Surveillance and training
How To Wear Soft Foam Earplugs Randolph-RF | Web document, http://www.cdc.gov/niosh/mining/topics/hearingloss/earplug.htm	2003	Web document	Hearing loss
Wearing Hearing Protection Properly: A 3-D Training Aid for Drillers Barrett-EA; Calhoun-RA | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-107, Information Circular 9472, 2004 Nov :1-15	2004	Publication	Hearing loss; Surveillance and training
Mining Hearing Loss Prevention Workshop NIOSH | Hosted by NIOSH-PRL, Charleston, WV; June 21-22, 2005	2005	Workshop, Seminar, or OIB	Hearing loss
Coal Noise Partnership Meeting/Workshop NIOSH | Held at NIOSH/PRL, 2005	2005	Workshop, Seminar, or OIB	Hearing loss
Hearing Protection Training for Drillers Barrett-EA; Calhoun-RA | National Ground Water Association, Water Well Journal, Volume 59, Number 12, Dec., 2005	2005	Publication	Hearing loss
Reeves ER [2008]. Guidelines for matching hearing protectors to workers and settings - NIOSH numbered publication	2008	Publication (guidelines)	Hearing loss
Barrett EA, Calhoun RA. Noise and hearing protection training for drillers. Professional Safety, In review, Dec, 2005: 18 pages. (refereed)	2006	Publication	Hearing loss
Randolph RF, Byrne DC, Hudak RL [2006]. Effectiveness of a simplified earplug insertion technique on attenuation performance. Journal of the Acoustical Society of America (refereed)	2006	Publication	Hearing loss
Byrne DC, Reeves ER [2006]. Analysis of non-standard noise dosimeter microphone positions. Journal of the Acoustical Society of America. (refereed)	2006	Publication	Hearing loss
Randolph RF, Kissell FN [2006]. The effect of an insertion lubricant on the noise attenuation of foam earplugs. Journal of Occupational and Environmental Hygiene. (refereed)	2006	Publication	Hearing loss
Byrne DC [2006]. Effectiveness of electronic earmuffs for underground miners. Mining Engineering Magazine (refereed).	2006	Publication	Hearing loss
NIOSH-PRL HLPB [2006]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2006]. Noise workshop in Salt Lake City UT, Hosted by NIOSH-PRL, Mining Hearing Loss Prevention Workshop, April, 2006	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2007]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2007	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2008]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL (2 per year)	2008	Workshop, Seminar, or OIB	Hearing loss

Potential Intermediate Outcome for Hearing Loss

A Health Hazard Study of Surface Drilling Operations

Background

Partial cab protection for drill operator

NIOSH researchers are developing engineering noise controls for air rotary surface drill rigs used in the mining and construction industries. Air rotary drills are used to drill vertical holes for such purposes as driving water and environmental monitoring wells, gathering geological information, and drilling blast holes during mining and construction projects. Field investigations of drill rigs and audiogram tests of operators have shown that operators of air rotary drill rigs are overexposed to noise. This research has developed two practical engineering controls and several training tools to help reduce hearing loss among operators of air rotary drills. A secondary aspect of the project is to develop materials to assist the industry with educating and training workers how to prevent hearing loss.

Potential Outcome

The engineering controls developed as a result of this research will help prevent overexposure to noise among drill rig operators operating cab and noncab air rotary drilling equipment. One of the engineering controls, which will reduce sound levels in the operator's cab, can be easily retrofitted onto drill rigs already in production. The other control, which is referred to as "partial-cab," will protect operators on drill rigs having no operator's cab from sound levels over 90 dB(A). It is anticipated that the impact of these engineering controls could reduce an operator's daily noise dosage (time-weighted average for 8 hours) by 112% to 570%.

Six publications are currently being written to target the drilling industry´s safety, educational, and training programs. These publications include formal classroom training materials, informal "tailgate" or "on-the-worksite" noise health and safety information pamphlets, and industry trade journals directed to awareness and prevention of hearing loss. The National Ground Water Association has shown an interest in promoting and distributing research results to its 60,000-person membership. All the knowledge gained from this project will be communicated to the construction and mining industries and research institutions via partnership councils, research journals, industry-centered publications, seminars, and conferences. The affects of this research on the drilling industry began in 2005 with many requests for the published training materials. The effects of the engineering controls are expected to begin in 2006, when test results are finalized and published.

Outputs

22 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Recognizing Noise and Dust Health Hazards for the Water Well Drilling Industry Ingram-DK; Matetic-RJ | Workshop presented at request of the National Ground Water Association, National Convention and Exposition (Las Vegas, NV; December 13-15, 2000)	2000	Workshop, Seminar, or OIB	Hearing loss
Preventing High Insurance Premiums and On-the-Job Injuries: What are Poor Health and Safety Habits Costing You? Matetic-RJ; Ingram-DK | Water Well Journal, 2001 Aug; :10-13	2001	Publication	Surveillance and training
Noise Health Hazards and How to Avoid Them Ingram-DK; Matetic-RJ | Workshop presented at request of the Minnesota Water Well Association, Minnesota Water Well Association's 79th Annual Convention (St. Cloud, MN; January 29, 2001)	2001	Workshop, Seminar, or OIB	Hearing loss
Recognizing Noise and Dust Health Hazards for the Water Well Driller Ingram-DK; Matetic-RJ | Workshop at the 46th Annual South Atlantic Well Drillers Jubilee (Myrtle Beach, SC; July 28-31, 2001)	2001	Workshop, Seminar, or OIB	Hearing loss
Summary of Noise Hazards and Engineering Applications to Reduce Noise Hazards Ingram-DK; Yantek-DS | Workshop presented at request of the National Ground Water Association, National Ground Water Expo (Las Vegas, NV; December 8-12, 2002)	2002	Workshop, Seminar, or OIB	Hearing loss
Noise and Dust Hazards Associated with Water Well Drilling Ingram-DK; Matetic-RJ | Workshop presented at request of New York's State Water Well Association, New York Water Well 2002 Annual Conference (Albany, NY; April 18-21, 2002)	2002	Workshop, Seminar, or OIB	Hearing loss
Are You Operating an Air Rotary Drilling Rig? Is It Loud? Ingram-DK; Matetic-RJ | Water Well Journal, 57(7), 2003; :18-22	2003	Publication	Hearing loss
Hearing Safety: Water Well Drilling Industry Ingram-DK | Workshop requested by the State of Ohio Environmental Protection Agency, Ohio's Annual Refresher Safety Training for the Ohio EPA Inspectors (Columbus, OH; October 22, 2003)	2003	Workshop, Seminar, or OIB	Hearing loss
Hearing Conservation: the Ears Have It Ingram-DK; Matetic-RJ | Workshop presented at request of the National Ground Water Association, National Ground Water Expo (Orlando, FL; December 9-12, 2003)	2003	Workshop, Seminar, or OIB	Hearing loss
Hearing Safety and Machine Operation Ingram-DK; Moisan-P; Hudak-R | Workshop presented at request of the New England Water Well Association, 2003 Annual Meeting (Marlborough, MA; March 21-22, 2003)	2003	Workshop, Seminar, or OIB	Hearing loss
Wearing Hearing Protection Properly: A 3-D Training Aid for Drillers Barrett-EA; Calhoun-RA | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-107, Information Circular 9472, 2004 Nov :1-15	2004	Publication	Hearing loss; Surveillance and training
Mining Hearing Loss Prevention Workshop NIOSH | Hosted by NIOSH-PRL, Charleston, WV; June 21-22, 2005	2005	Workshop, Seminar, or OIB	Hearing loss
Drill Rig Incident Barrett-EA; Calhoun-RA | DHHS (NIOSH) Publication No. 2005-108, IC 9473, 2005 Feb; :1-51	2005	Publication	Hearing loss; Surveillance and training

Title	Year	Output Type	Strategic Goal
Coal Noise Partnership Meeting/Workshop NIOSH | Held at NIOSH/PRL, 2005	2005	Workshop, Seminar, or OIB	Hearing loss
Water Well Safety Bits: Health And Safety Information For The Water Well Industry Reinke-DC | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-160, Information Circular 9483	2005	Publication	Hearing loss
Hearing Protection Training for Drillers Barrett-EA; Calhoun-RA | National Ground Water Association, Water Well Journal, Volume 59, Number 12, Dec., 2005	2005	Publication	Hearing loss
Hearing Protection and Air Rotary Drilling - Part 1 Ingram-DK; Jurovcik-P | National Driller. Vol. 26, No. 11, 2005; :10-15	2005	Publication	Hearing loss
Noise Exposure and Overhead Power Line (OPL) Safety Hazards at Surface Drilling Sites Reinke-DC; Homce-GT; Cawley-JC; Barrett-EA | Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, December, 2005	2005	Publication	Hearing loss
Hearing Protection and Air-Rotary Drilling - Part 2 Ingram-DK; Jurovcik-P | National Driller. Vol. 26, No. 12, Dec. 2005	2005	Publication	Hearing loss
Barrett EA, Calhoun RA. Noise and hearing protection training for drillers. Professional Safety, In review, Dec, 2005: 18 pages. (refereed)	2006	Publication	Hearing loss
NIOSH-PRL HLPB [2006]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2006]. Noise workshop in Salt Lake City UT, Hosted by NIOSH-PRL, Mining Hearing Loss Prevention Workshop, April, 2006	2006	Workshop, Seminar, or OIB	Hearing loss

Potential Intermediate Outcome for Hearing Loss

Model Hearing Loss Prevention Program

Background

Hearing conservation programs are mandated for most U.S. mining operations. The conventional program, as codified in OSHA and MSHA regulations and widely taught to hearing conservationists, consists of noise exposure monitoring, hearing tests, promotion of hearing protection, education, and record-keeping. NIOSH best-practices guidelines recommend that the programs will be enhanced by including procedural audits, support of noise controls, program evaluation, and worker motivation (as an adjunct to education). With these enhancements, NIOSH refers to the ideal approach as a hearing loss prevention program.

Education and motivation are essential for an effective hearing loss prevention program

To provide information about the best way to implement a hearing loss prevention program, NIOSH needed to collect and evaluate best practices in a field setting. A cooperative agreement with the Pennsylvania State University resulted in a study that implemented many of the principles NIOSH put forth in its 1996 publication, "Preventing Occupational Hearing Loss: A Practical Guide."

Potential Outcome

The cooperative project was completed in 2004, and the results began to be disseminated through a series of workshops in 2005. The model hearing loss prevention program forms the basis for a new research study that incorporates worker participation in problem-solving. The new study, to be conducted during 2005-2008, will yield a series of intervention products, culminating in guidelines for implementing "best practices" through worker participation. These impacts will affect the majority of the workforce enrolled in hearing conservation programs. For instance, program enrollment rose from 7% to 82% of all coal miners from 2000 to 2003. If adopted, an effective hearing loss prevention program could substantially reduce the incidence of noise-induced hearing loss to an annual rate of less than 1% standard threshold shifts.

Outputs

14 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
A Model Hearing Conservation Program for Coal Miners Bise-CJ; Frank-T | Cincinnati, OH: Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Final Report.- Cooperative Agreement U60/CCU315855	2004	Publication	Hearing loss
Mining Hearing Loss Prevention Workshop NIOSH | Hosted by NIOSH-PRL, Charleston, WV; June 21-22, 2005	2005	Workshop, Seminar, or OIB	Hearing loss
Coal Noise Partnership Meeting/Workshop NIOSH | Held at NIOSH/PRL, 2005	2005	Workshop, Seminar, or OIB	Hearing loss
Reinke DC, Randolph RF [2008]. Guidelines on reducing barriers to adoption of noise control technologies - NIOSH numbered publication	2008	Publication (guidelines)	Hearing loss
Randolph RF, Reinke DC, Hudak RL [2008]. Guidelines for worker empowerment for "best practices" hearing loss prevention program - NIOSH numbered publication	2008	Publication (guidelines)	Hearing loss
Randolph RF, Reinke DC, Hudak RL [2008]. Team-based hearing loss communication interventions. Journal of Health Communication. (refereed)	2008	Publication	Hearing loss
Randolph RF, Reinke DC, Hudak RL [2008]. Evaluation of hearing loss prevention program. Ear and Hearing. (refereed)	2008	Publication	Hearing loss
Randolph RF, Reinke DC, Hudak RL [2008]. Effectiveness of participative teams for hearing loss prevention. Journal of Occupational Environmental Hygiene. (refereed)	2008	Publication	Hearing loss
NIOSH-PRL HLPB [2006]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2006]. Noise workshop in Salt Lake City UT, Hosted by NIOSH-PRL, Mining Hearing Loss Prevention Workshop, April, 2006	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2007]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2007	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2008]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL (2 per year)	2008	Workshop, Seminar, or OIB	Hearing loss
Reinke DC, Randolph RF [2008]. Guidelines on reducing barriers to adoption of noise control technologies - Web content	2008	Web document	Hearing loss
Randolph RF, Reinke DC, Hudak RL [2008]. Guidelines for worker empowerment for "best practices" hearing loss prevention program - Web content	2008	Web document	Hearing loss

Potential Intermediate Outcome for Hearing Loss

Engineering Noise Controls for Roof Bolting Machines

Background

Sound power testing of a HDDR roof bolter

NIOSH is working with the Noise Partnership Committee to evaluate and develop various controls for reducing noise related to roof bolting machines. MSHA data indicate that this machine is third among equipment that exceeds 100% operator dosage in coal mining and second in underground coal mining. The goal of this research is to determine the major contributors to an operator's noise exposure during the drilling and bolting cycle and then reduce the noise generated during these cycles by 10 dB(A). The investigation will provide methods and solutions for minimizing overexposure to noise among operators of roof bolting machines.

Potential Outcome

Research on engineering noise controls for roof bolting machines will be completed in 2007. To raise industry awareness of these controls, results will be disseminated through publications in journals and trade magazines and presentations at industry briefings related to noise exposure in the mining industry. By reducing roof bolting machine noise by 10 dB(A), it is anticipated that 90% of roof bolting machine operators´ exposure to noise will fall below MSHA's permissible exposure limit.

Outputs

17 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
A Sound Power Level Study of a Roof Bolter Peterson-JS; Kovalchik-PG; Matetic-RJ | SME Preprint No. 05-72, 2005 SME Conference, Salt Lake City, Utah, 2005; :8 pp	2005	Publication	Hearing loss
Mining Hearing Loss Prevention Workshop NIOSH | Hosted by NIOSH-PRL, Charleston, WV; June 21-22, 2005	2005	Workshop, Seminar, or OIB	Hearing loss
Wet Drilling - Technologically Achievable, Administratively Achievable, and Promising Noise Controls (30 CFR Part 62) NIOSH | Information Bulletin P04-18, 2005 (http://www.msha.gov/regs/complian/PIB/2004/pib04-18.pdf)	2005	Publication (guidelines)	Hearing loss
Mist System - Technologically Achievable, Administratively Achievable, and Promising Noise Controls (30 CFR Part 62) NIOSH | Information Bulletin P04-18, 2005 (http://www.msha.gov/regs/complian/PIB/2004/pib04-18.pdf)	2005	Publication (guidelines)	Hearing loss
Coal Noise Partnership Meeting/Workshop NIOSH | Held at NIOSH/PRL, 2005	2005	Workshop, Seminar, or OIB	Hearing loss
Guidelines on effective engineering noise controls for roof bolting machines - NIOSH numbered publication	2006	Publication (guidelines)	Hearing loss
Babich DR, Bauer ER [2006], Underground bituminous coal mine noise surveys, Mining Engineering Magazine, 2006. (refereed)	2006	Publication	Hearing loss
Peterson JS, Kovalchik PG, Matetic RJ [2007]. Noise source identification on a roof bolting machine using a beamforming technique, Society for Mining, Metallurgy, and Exploration, Inc., 2007 SME Conference	2007	Publication	Hearing loss
Peterson JS [2007]. Estimating sound power radiated by surfaces on a roof bolting machine using vibration measurements. In: Proceedings of NOISE-CON 2007	2007	Publication	Hearing loss
Peterson JS [2008]. Evaluation of engineering noise controls for a roof bolting machine. In: Proceedings of NOISE-CON 2008	2008	Publication	Hearing loss
MSHA [2008]. Information Bulletin P04-18, Roof bolting machine engineering controls, "Technologically Achievable, Administratively Achievable, and Promising Noise Controls 30 CFR Part 62	2008	Standards	Hearing loss
Video on implementing and the development of roof bolting machines noise controls, 2008	2008	Video	Hearing loss
NIOSH-PRL HLPB [2006]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2006]. Noise workshop in Salt Lake City UT, Hosted by NIOSH-PRL, Mining Hearing Loss Prevention Workshop, April, 2006	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2007]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2007	Workshop, Seminar, or OIB	Hearing loss

Title	Year	Output Type	Strategic Goal
NIOSH-PRL HLPB [2008]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL (2 per year)	2008	Workshop, Seminar, or OIB	Hearing loss
Guidelines on effective engineering noise controls for roof bolting machines - Web content	2006	Web document	Hearing loss

Potential Intermediate Outcome for Hearing Loss

Engineering Noise Controls for Continuous Mining Machines - Jacketed Tail Roller

Background

Engineering noise controls are being developed to reduce the noise generated by continuous mining machines, which produce some of the highest sound levels in underground mining. The project involves the development of a jacketed tail roller, which is a roller at the tail end of the conveyor of the machine. By encasing this roller in hard, durable plastic, the conveyor chain and coal being transported will be contacting a metal roller (for durability) constrained by polyurethane material, which should reduce the noise generated by the process. It is hoped the development of this product will reduce the sound level at the operator's position by 3 dB(A).

Jacketed tail roller installed on a continuous mining machine

Use of a jacketed tail roller may be applicable to other underground mining equipment such as loaders and shuttle cars and could reduce the amount of noise to which the operators of these types of equipment are exposed. This project complements the work done to introduce coated flight bars on conveying systems.

Potential Outcome

To raise industry awareness of the engineering noise controls developed through this work, research results will be published in a trade magazine article and presented at industry briefings concerning noise exposure in the mining industry. It is anticipated that this research could lead to a noise reduction of up to 10 dB(A) at the operator position on the continuous miner´s conveying systems. By reducing the noise generated by the machines by this amount, 50% of the continuous mining machine operators and 100% of the loader and shuttle car operators could be working in an environment where noise levels are below the MSHA permissible exposure limit.

Outputs

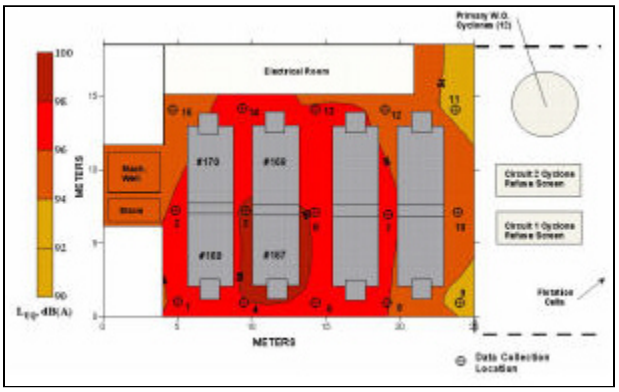
5 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Jurovcik P [2007]. Underground evaluation of a jacketed tail roller as an effective engineering noise control for continuous mining machines, Society for Mining, Metallurgy, and Exploration, Inc., 2007 SME Conference	2007	Publication	Hearing loss
MSHA [2007]. Jacketed tail roller - Program Information Bulletin P04-18 [2007], "Technologically Achievable, Administratively Achievable, and Promising Noise Controls," 30 CFR Part 62	2007	Standards	Hearing loss
NIOSH-PRL HLPB [2006]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2006]. Noise workshop in Salt Lake City UT, Hosted by NIOSH-PRL, Mining Hearing Loss Prevention Workshop, April, 2006	2006	Workshop, Seminar, or OIB	Hearing loss
Jurovcik P [2008]. Evaluation of a jacketed tail roller as an effective engineering noise control for continuous mining machines. In: Proceedings of NOISE-CON 2008: Institute of Noise Control Engineering of the USA	2008	Publication	Hearing loss

Potential Intermediate Outcome for Hearing Loss

Engineering Noise Controls for Horizontal Vibrating Screens

Background



Sound levels around 8 horizontal vibrating screens

Engineering noise controls are being developed and tested to reduce the noise generated by horizontal vibrating screens used in coal preparation plants. These screens are among the equipment used in preparation plants that generate the highest sound levels. A NIOSH cross-sectional survey project indicated that 20 out of 46 surveyed coal preparation plant workers (43.5%) had noise exposures exceeding MSHA´s permissible exposure level (PEL). Based on the cross-sectional survey and MSHA data, it appears that more than 3,400 coal preparation plant workers are overexposed to noise across the country.

NIOSH is working with mining companies and vibrating screen manufacturers to evaluate various controls for reducing noise related to the screens. Measurements taken by NIOSH showed that the sound levels around a group of eight horizontal vibrating screens ranged from 94 to 98 dB(A). The goal of this project is to develop engineering noise controls that will reduce sound levels by 10 dB(A).

Potential Outcome

Research on engineering noise controls for horizontal vibrating screens will be completed in 2008. To raise industry awareness of the engineering noise controls developed, results will be disseminated through publications in journals and trade magazines and also presentations at technical conferences and industry briefings related to noise exposure in the mining industry. In addition, an informational DVD/CD that summarizes the development and safety benefits of the developed engineering noise controls will be produced. This DVD/CD will target vibrating screen manufacturers and industries that use vibrating screens. This work has the potential to eliminate noise overexposures for approximately 3,400 coal preparation plant workers. It is anticipated that 43% of the coal preparation plant workers could be affected by 2009.

Outputs

15 Planned or completed outputs

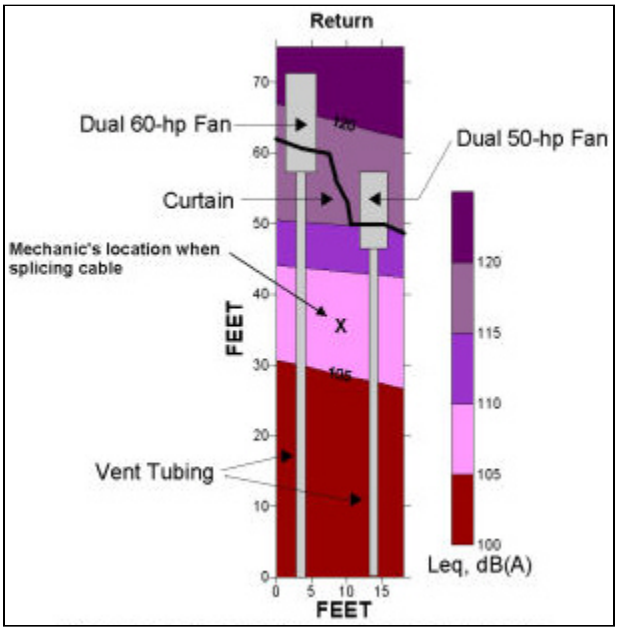
Title	Year	Output Type	Strategic Goal
Estimated Sound Power Radiated by Surfaces on a Continuous Miner Tail Section Using Vibration Measurements Yantek-DS | NOISE-CON 2003. Ames, IA: Institute of Noise Control Engineering of the USA, 2003 Jun; :1-9	2003	Publication	Hearing loss
Noise and Vibration Reduction of a Vibrating Screen Yantek-DS; Jurovcik-P; Bauer-ER | SME Preprint No. 05-71, 2005 SME Conference, Salt Lake City, Utah, 2005; :1-13	2005	Publication	Hearing loss
Mining Hearing Loss Prevention Workshop NIOSH | Hosted by NIOSH-PRL, Charleston, WV; June 21-22, 2005	2005	Workshop, Seminar, or OIB	Hearing loss
Yantek DS [2006]. Noise source identification on horizontal vibrating screens using a beamforming technique, Society for Mining, Metallurgy, and Exploration, Inc., 2006 SME Conference	2006	Publication	Hearing loss
Yantek DS [2008]. Evaluation of engineering noise controls for horizontal vibrating screens. Proceedings of NOISE-CON 2008: Institute of Noise Control Engineering of the USA	2008	Publication	Hearing loss
Yantek DS [2008]. NIOSH-RI, Summarizing the results related to engineering noise controls for horizontal vibrating screens	2008	Publication	Hearing loss
MSHA [2009]. Information Bulletin P04-18 Vibrating screen engineering control, "Technologically Achievable, Administratively Achievable, and Promising Noise Controls 30 CFR Part 62	2009	Standards	Hearing loss
Video on implementing and development of vibrating screen noise controls, 2009	2009	Video	Hearing loss
NIOSH-PRL HLPB [2006]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2006]. Noise workshop in Salt Lake City UT, Hosted by NIOSH-PRL, Mining Hearing Loss Prevention Workshop, April, 2006	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2007]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2007	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2008]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL (2 per year)	2008	Workshop, Seminar, or OIB	Hearing loss
Guidelines on effective engineering noise controls for horizontal vibrating screens - NIOSH numbered publication	2008	Publication (guidelines)	Hearing loss
Yantek DS [2007]. Estimating sound power radiated by horizontal vibrating screens, Proceedings of NOISE-CON 2007, In: Institute of Noise Control Engineering of the USA	2007	Publication	Hearing loss
Guidelines on effective engineering noise controls for horizontal vibrating screens - Web content	2008	Web document	Hearing loss

Potential Intermediate Outcome for Hearing Loss

Administrative Computer Program

Background

Noise exposure data recently collected by NIOSH researchers during project surveys in the mining industry indicate that nearly 50% of the workers were exposed to noise levels above 90 dB(A), and some exposures were nearly six times the permissible exposure level (PEL). Information on the MSHA Web site notes that there are approximately 223,000 employees in the mining industry across the United States. If the rate of overexposure is extrapolated (at the 50% overexposure rate) across all employees in mining, more than 111,000 workers across the country would be overexposed to noise.



Sound profile map of auxilliary ventilation fans

The long-term objective of this study is to obtain multi-shift data on worker noise exposure and equipment noise levels in order to develop an up-to-date comprehensive profile of the amount of noise the mining population is exposed to as a function of equipment and activity-specific operations. Specific aims are to collect cross-sectional noise exposure information by occupation and equipment noise level, and develop the source and/or dose relationship based on this information. From these data, appropriate noise controls can be selected for occupations routinely overexposed to noise.

A computer program is currently being developed that will assist mine operators in analyzing a worker´s noise exposure and then selecting an appropriate administrative control. This program will simplify the record-keeping associated with selecting administrative controls, as well as allowing observational information (task observations/time studies) to be input more easily. The program will indicate what tasks are responsible for most of a worker´s exposure and suggest appropriate controls. The resulting impact will be the reduction of noise exposures because of an improved administrative controls selection process.

Potential Outcome

All workers in the mining industry could be affected by this research. Once completed, the program will be validated through testing in several mines and then communicated to the mining industry via partnership meetings, mining journals, NIOSH publications, seminars, and conferences. It is anticipated that the impacts of this research will begin in 2006 with the initial release of the administrative control computer program.

Outputs

19 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Cross-Sectional Survey of Noise Exposure in the Mining Industry Bauer-ER; Kohler-JL | Proc 31st Annual Institute of Mining Health, Safety and Research, Aug 27-30, 2000, Roanoke, VA, Bockosh-G, Karmis-M, Langton-J, McCarter-MK, Rowe-B, eds. Virginia Tech 2000 Aug; :17-30	2000	Publication	Hearing loss
Noise Exposure in Longwall Mining and Engineering Controls Research Bauer-ER; Podobinsk-DJ; Reever- ER | In: Proceedings of Longwall USA International Exhibition and Conference, June 13-15, Pittsburgh, PA, Intertec Publishing Corp.; :51-69	2001	Publication	Hearing loss
Worker Exposure and Equipment Noise in Large Surface Coal Mines Bauer-ER; Babich-DR | SME preprint 03-051. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2003; :1-6	2003	Publication	Hearing loss
Administrative Controls for Reducing Worker Noise Exposures Bauer-ER; Babich-DR | SME preprint 04-09. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2004; :1-9	2004	Publication	Hearing loss
Worker Exposure and Equipment Noise in Large Surface Coal Mines Bauer-ER; Babich-DR | Min Eng 56(4), 2004; :49-54	2004	Publication	Hearing loss
Mining Hearing Loss Prevention Workshop NIOSH | Hosted by NIOSH-PRL, Charleston, WV; June 21-22, 2005	2005	Workshop, Seminar, or OIB	Hearing loss
Testing and Evaluation of an Engineering Noise Control on a Longwall Stageloader Bauer-ER; Reeves-ER; Durr-TM; Zuchelli-DR; Armour-D | SME preprint 05-58. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2005; ;1-12	2005	Publication	Hearing loss
Noise and Vibration Reduction of a Vibrating Screen Yantek-DS; Jurovcik-P; Bauer-ER | SME Preprint No. 05-71, 2005 SME Conference, Salt Lake City, Utah, 2005; :1-13	2005	Publication	Hearing loss
Wet Drilling - Technologically Achievable, Administratively Achievable, and Promising Noise Controls (30 CFR Part 62) NIOSH | Information Bulletin P04-18, 2005 (http://www.msha.gov/regs/complian/PIB/2004/pib04-18.pdf)	2005	Publication (guidelines)	Hearing loss
Mist System - Technologically Achievable, Administratively Achievable, and Promising Noise Controls (30 CFR Part 62) NIOSH | Information Bulletin P04-18, 2005 (http://www.msha.gov/regs/complian/PIB/2004/pib04-18.pdf)	2005	Publication (guidelines)	Hearing loss
Bauer ER, Babich DR, Vipperman JS [2006]. Equipment noise and worker exposure in the coal mining industry. Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No., IC, In review.	2006	Publication	Hearing loss
Vipperman JS, Bauer ER, Babich DR [2006]. Survey of noise in coal preparation plants. Journal of Acoustical Society of America, Submitted to Journal. (refereed)	2006	Publication	Hearing loss
Bauer ER, Babich DR [2006]. Administrative controls for reducing worker noise exposures. Trans Soc Min Eng, Vol. 318. (refereed)	2006	Publication	Hearing loss

Title	Year	Output Type	Strategic Goal
Mining Engineering Journal article: Noise Surveys at Surface and Underground Stone Mines, 2007. (refereed)	2007	Publication	Hearing loss
Society of Mining Engineering 2008 Annual Meeting and Exhibit: Sand and Gravel Noise Surveys, 2008	2008	Publication	Hearing loss
Journal of Acoustical Society of America: Nonmetal Mine Noise Surveys, 2009. (refereed)	2009	Publication	Hearing loss
Software and users manual for assisting mine operators to select, implement, and evaluate administrative controls, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Pittsburgh, PA: DHHS (NIOSH IC) Publication No., 2007	2007	Software	Hearing loss
NIOSH-PRL HLPB [2006]. Noise workshop in Salt Lake City UT, Hosted by NIOSH-PRL, Mining Hearing Loss Prevention Workshop, April, 2006	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2007]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2007	Workshop, Seminar, or OIB	Hearing loss

Potential Intermediate Outcome for Hearing Loss

Engineering Noise Controls for Continuous Mining Machines - Dust Collector Fan

Background

NIOSH is working with the Pennsylvania State University and Joy Mining Machinery to develop engineering noise controls to reduce noise generated by continuous mining machines. The research involves the development of noise treatments for a dust collector fan, which is a vane axial fan located inside the continuous mining machine. The noise treatments applied to the fan were:

A dust collector fan with noise treatments installed

1. moving the turning vanes downstream,
2. changing the shape of the leading edges of the turning vanes from straight and radial,
3. extending the perforations and outside adsorptive layer to cover the entire fan housing,
4. adding an extension with an absorptive layer on the onside to the fan discharge, and
5. replacing the rotor with unevenly spaced blades with a rotor with evenly spaced blades

The effort resulted in an overall A-weighted sound power level reduction of 5 dB with only a 4 % reduction in the volume flow velocity through the dust collector. This research compliments the work performed on coated flight bars and the jacketed tail roller on continuous mining machine conveying systems.

Potential Outcome

The engineering noise controls developed as a result of this research, along with the prior research on the continuous miner's conveying systems (coated flight bars and jacketed tail roller), could lead to an overall noise reduction of up to 10 to 12 dB(A) at the operator position of the continuous mining machine. With these controls properly installed, it could be anticipated that 90% of the operators of continuous mining machines noise exposure will fall below MSHA´s permissible exposure limit. To raise industry awareness of the engineering noise controls developed through this work, research results will be published in trade magazine articles and presented at industry briefings concerning noise exposure in the mining industry. The effects of the engineering controls are expected to begin in 2006, when underground test results are finalized and published.

Outputs

4 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Reduction of Noise Emissions from the Vane Axial Fan in a Dust Collector in a Continuous Miner Carter-BA; Burroughs-CB | The Pennsylvania State University Applied Research Laboratory, Final Technical Report 04-01 under Contract No. 200-2001-08005, July 30, 2004	2004	Publication	Hearing loss
NIOSH-PRL HLPB [2006]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2006]. Noise workshop in Salt Lake City UT, Hosted by NIOSH-PRL, Mining Hearing Loss Prevention Workshop, April, 2006	2006	Workshop, Seminar, or OIB	Hearing loss
MSHA [2007]. Noise treatments for a dust collector fan - Program Information Bulletin P04-18 [2007], "Technologically Achievable, Administratively Achievable, and Promising Noise Controls," 30 CFR Part 62	2007	Standards	Hearing loss

Potential Intermediate Outcome for Cumulative Injuries

Improving Mobile Equipment Operator Ergonomics

Background

Heavy haulage equipment

There are over half a million operators of heavy equipment (i.e., dozers, loaders, haul trucks, etc.) in mining and construction in the United States, and this number is expected to increase. Factors in the work environment, such as whole body vibration, awkward postural requirements (including static sitting), repetitive motions, poor seat design, poorly designed cabs or controls, and a host of other ergonomics issues, have the potential to cause injury and expose operators to the risk of developing musculoskeletal disorders. In mining, MSHA data show that between 1999 and 2003, 4,079 accidents in the surface mining industry were classified as back injuries and contributed to the nearly 173,000 lost or restricted work days (an average of 42 days lost or restricted per accident). Truck drivers, dozer operators, and front-end loader operators alone accounted for over one-third of these injuries.

Potential Outcome

Potential impacts include the development of engineering interventions to alleviate back injuries among operators of mobile equipment. Another potential impact is increased awareness of the need to address ergonomically functional cab designs before equipment is modified. For example, changes made to a mobile equipment operator´s cab to reduce noise exposure may produce unintended compromises to the operator´s posture or line of sight. Increased awareness would avoid these well-intended, but sometimes counterproductive efforts.

Outputs

10 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Tying Acceleration and GPS Location Information Together To Create a Mine Management Tool Miller-RE; Bowman-P; Walden-J; Rhoades-S; Gibbs-R | SME Annual Meeting, March 1-3, 1999, Denver, Colorado; Preprint 99-118; 4 pp	1999	Publication	Cumulative injuries; Traumatic injuries
Acceleration and GPS Data Monitor Truck-Haulage Jolts Miller-RE; Boman-P; Walden-J; Rhoades-S; Gibbs-R | Min Eng, 52(8):20-22	2000	Publication	Cumulative injuries; Traumatic injuries
An Ergonomic Evaluation of Excavating Operations: A Pilot Study Kittasamy-NK; Buchholz-B | Applied Occupational and Environmental Hygiene, vol. 16, no. 7, 2001; :723-726	2001	Publication	Cumulative injuries
Ergonomic Risk Factors: a Study of Heavy Earthmoving Machinery Operators Kittusamy-NK | Professional Safety: Journal of American Society of Safety Engineers, 2002 Oct	2002	Publication	Cumulative injuries
Self-Reported Musculoskeletal Symptoms Among Operators of Heavy Construction Equipment Kittusamy-NK | In: Ergonomics in the Digital Age: Proceedings of the XVth Triennial Congress of the International Ergonomics Association and 7th Joint Conference of Ergonomics Society of Korea/Japan Ergonomics Society (Seoul, Korea, Aug. 24-29, 2003). Seoul, Korea: Ergonomics Society of Korea, 2003 Aug	2003	Publication	Cumulative injuries
A Checklist for Evaluating Cab Design of Construction Equipment Kittusamy-NK | Applied Occupational and Environmental Hygiene 18, 2003; :721-723	2003	Publication	Cumulative injuries
Assessment of Ergonomic Risk Factors Among Operators of Heavy Earthmoving Machinery Kittusamy-NK | In: Proceedings of the 2003 ASSE Professional Development Conference (Denver, CO, June 22-26, 2003), American Society of Safety Engineers, 2003 Jun; :11 pp	2003	Publication	Cumulative injuries
A Systematic Comparison of Different Seats on Shuttle Cars Used in Underground Coal Mines Kittusamy-NK; Mayton-AG; Jobes-CC; Ambrose-DH | In: Proceedings of Inter-Noise 2003, the 32nd International Congress and Exposition on Noise Control Engineering (Seogwipo, Korea, Aug. 25-28, 2003). 2003 Aug; :2025-2032	2003	Publication	Cumulative injuries; Traumatic injuries
Comparison of Jolting and Jarring in a Newer and Older Dozer at a Highway Construction Site Kittusamy-NK; Miller-RE | In: Ergonomics in the Digital Age: Proceedings of the XVth Triennial Congress of the International Ergonomics Association and the 7th Joint Conference of the Ergonomics Society of Korea/Japan Ergonomics Society. Seoul, Korea: Ergonomics Society of Korea, 2003; :1-3	2003	Publication	Cumulative injuries; Traumatic injuries
Whole-Body Vibration and Postural Stress among Operators of Construction Equipment: A Literature Review Kittusamy-NK; Buchholz-B | Journal of Safety Research 2004, vol. 35, no. 3, 2004; :255-261	2004	Publication	Cumulative injuries

Potential Intermediate Outcome for Cumulative Injuries

Age Awareness Training Modules

Background

Typical underground mining crew

On average, employees working in mining are older than those working in other industries. It is projected that the median age of U.S. mine workers will continue to increase throughout the next decade. Changes in physical and cognitive abilities that accompany the normal aging process may be accelerated in mine workers as compared to other industries and have the potential to increase the risk of injury. For instance, changes in vision may affect a person´s ability to perceive a warning signs and changes in strength may place a person at risk for injury. A need exists for general training about the normal changes that accompany aging and ways that worksites can mediate those changes. In keeping with the Steps to a Healthier U.S. Workforce (STEPS) approach, this training combines occupational injury prevention with health promotion by combining recommendations for both worksite modifications and improvements in individual behaviors.

This program includes management training, a seven-module training program (with a newsletter and safety talk guide for each module), and an instructor´s guide. The training modules included in the Age Awareness Training are designed to be given individually in 10-minute safety talks or combined in a longer training session. The newsletter included in each training module could also be disseminated to an employee through company newsletters or other mailings sent to employees´ homes. The Age Awareness Training has the potential to reach management, employees, and even the families of employees.

Potential Outcome

Potential impacts from this project by 2008 are:

1. Increased awareness of normal age-related changes and ways to mediate them through worksite changes and improvements in individual behaviors can lead to reductions in injuries, and
2. Reductions in injuries and improved lifestyle behaviors that will lead to decreased medical costs. Such decreases could be realized either through costs associated with worker´s compensation or, in the case of self-insured companies, regular medical costs.

These training modules will be piloted at several mines and then presented at both mining and safety conferences. MSHA is interested in giving this training to its inspectors. The training will be available on a CD or downloadable through NIOSH Web pages. In addition, this training might be used as a prototype method and applied to other industries, such as agriculture and construction.

Outputs

2 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Aging and Musculoskeletal Injuries in the US Mining Industry - Journal of Safety Research	2006	Publication	Cumulative injuries
Age Awareness Training for Miners: A Holistic Approach to Injury Reduction - peer-reviewed SME Journal	2007	Publication	Cumulative injuries

Potential Intermediate Outcome for Cumulative Injuries

Slips and Falls Research

Background

Operator egressing from loader

Across the nation, falls account for 12.5% of all fatal occupational injuries and 19.9% of all nonfatal occupational injuries involving days away from work. The annual direct cost of fall-related occupational injuries in the United States has been estimated at $6 billion, and the burden of slip-, trip-, and fall-related occupational injuries has been estimated as ranging from 20% to 40 % of all disabling occupational injuries. Injury surveillance in mining parallels national statistics and indicates that falls account for a large number of incidents in all mine workers, plus an increased risk of injury from slips and falls exists for older miners. To respond to the need for better methods of injury prevention, two projects have begun: (1) a project on tread design that will evaluate the coefficient of friction for different treads and materials on different mining surfaces and (2) a study on methods to evaluate ingress/egress systems and suggest techniques to reduce the risk of injury from getting on and off equipment. Our goal is to provide employees with better protection against a potential slip or fall while they are either walking or getting on or off equipment. This approach involves the use of improved personal protective equipment as well as improved human/machine interfaces and commercialization opportunities. These recommendations will address the abilities of an age-diverse workforce.

Potential Outcome

By 2009, recommendations for tread designs and sole materials for miner boots and safer ingress/egress systems will lead to a reduction in injuries from slips and falls related to walking and getting on and off equipment (this project does not address falls from heights). In the case of ingress/egress, the recommendations may include maximum distances for the first step, for the reach to a handrail, and/or the depth of a platform or step. A reduction in injuries in these areas will lead to decreased financial and personal burdens. In addition, since slips and falls are a universal problem, recommendations for better tread designs and materials for miners in certain environments and better ingress/egress systems may also benefit workers in construction and agriculture. Knowledge gained from these studies will be disseminated in the form of guidelines, design specifications, training modules, and evaluation tools passed on at conferences, workshops, and industry-wide briefings.

Outputs

8 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Guidelines on designing for ingress/egress from equipment - International Journal of Ergonomics	2007	Publication (guidelines)	Cumulative injuries
Development of a Methodology for Tread Study - to be submitted to Human Factors	2007	Publication	Cumulative injuries
Evaluation of Different Boot Tread Designs in Different Environments to Reduce the Risk of Slips and Fall in the Mining Industry - to be submitted to Ergonomics	2007	Publication	Cumulative injuries
Guidelines for the Selection of Tread Design and Materials for Mine Worker Boots - peer-reviewed SME journal	2007	Publication	Cumulative injuries
Investigating Criteria for the Evaluation of Ingress/Egress Systems on Wheel Loaders - Conference proceedings, International Ergonomics Association Meeting (Maastrict, Netherlands).	2006	Publication	Cumulative injuries
Training Materials on Preventing Injuries from Operating Mobile Equipment: Focus on Ingress/Egress and Vibration - Industrial Minerals Association of North America workshop (Pittsburgh, PA)	2006	Training	Cumulative injuries
Development of Criteria for the Evaluation of Ingress/Egress Systems for the Risk of Injuries - Journal of Industrial Ergonomics	2007	Publication	Cumulative injuries
Guidelines for tread design	2007	Video	Cumulative injuries

Potential Intermediate Outcome for Cumulative Injuries

Knee Injury Prevention

Background

Roof bolting in low coal

As higher-seam coal mines are increasing mined out, companies are turning to low-seam options as ways to meet the demand for coal. Seam height in low-seam mines can range from 36 to 44 inches, requiring miners to spend a large percentage of their days either crawling or working in a kneeling position. Because of these nonneutral restricted postures, mine workers experience knee pain and injury earlier and to a greater degree than would be experienced in nonmining environments. Many mine companies consider low-seam coal mining to be a young man´s game! To reduce the risk of knee injury, a multi-faceted research project has been started that includes an epidemiology study, task analyses of different occupations in low-seam mining, the creation of a biomechanical model of the knee, and a healthy knee training module. These tasks all contribute to the goal of recommending improved designs for work methods as well as the development of personal protective equipment. A comprehensive study on ways to reduce knee injuries in coal mining has never before been initiated.

Potential Outcome

By 2009, this study will lead to the reduction of knee injuries in coal miners, so that coal miners can work longer in low-seam operations. In addition, analyses using the biomechanical model of the knee may lead to the reduction of knee injuries in people working in other occupations. The development of new knee pad designs will contribute to the reduction of knee injuries in mining. All these reductions in injuries will decrease the personal and financial burden of these injuries. Knowledge gained as a result of this study will be disseminated in the form of guidelines, training programs, recommendations for better work practices, and recommendations for improved knee pad designs. These results will be disseminated through mining and safety conferences, as well as through MSHA. Success of this multi-faceted, skills-leveraging approach that utilizes the talent of people working in industry, government, and academia may inspire others to use the same approach to answer their research questions.

Outputs

6 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
An Epidemiological Study of Knee Injuries in Low Seam Coal Mining - to be submitted to SME (peer-reviewed)	2007	Publication	Cumulative injuries
The Development of a Healthy Knee Module for Low Seam Coal Miners - Journal of Safety Research	2006	Publication	Cumulative injuries
The Development of a Finite Element Biomechanical Model of the Knee - model completed and will be submitted to Clinical Biomechanics journal	2007	Publication	Cumulative injuries
Evaluating the Risk of Knee Injury Using a Finite Element Model of the Knee - Occupational Biomechanics journal (peer-reviewed)	2007	Publication	Cumulative injuries
The Evaluation of New Knee Pad Designs to Prevent Injuries in Low Seam Coal Miners - to be submitted to peer-reviewed Ergonomics and SME journals	2007	Publication	Cumulative injuries
Guidelines for reducing the risk of injury while working in low seam coal mines - peer-reviewed SME journal	2007	Publication	Cumulative injuries

Potential Intermediate Outcome for Cumulative Injuries

Improved Risk Assessment for Low Back Disorders in Mining

Background

Reducing low back disorders for mine workers

Extensive evidence exists that work-related low back disorders affect mine workers to a greater degree than workers in other industries. Studies have shown that miners experience more disability from back pain, more disk degeneration, and a higher rate of worker´s compensation claims in comparison to other industrial populations. Low back disorders are consistently the single leading cause of lost-time injuries in the U.S. mining industry. The high incidence of low back disorders in mining is certainly a reflection of the physically demanding nature of mining jobs; however, the mining environment often imposes additional biomechanical demands by forcing workers to adopt restricted postures (such as stooping or kneeling) for prolonged periods when working. In terms of low back stress, the stooping posture (which involves flexion of the torso) is of particular concern and has been associated with increased risk for low back disorders in epidemiologic studies.

Many scientists believe that back pain is the result of a cumulative process of damage to spinal tissues caused by repetitive loading. However, few studies have examined the tolerance of spinal tissues to repetitive loading, and none have examined how increased spinal loads when lifting in torso flexion affect how quickly spinal tissues fail when they are loaded repetitively. Accordingly, a cadaver study involving 54 spine motion segments (two vertebrae and the intervening disc) was performed to simulate compressive and shear forces during simulated lifting of a 9-kg load in three torso flexion postures (neutral, partial flexion, full flexion). The number of cycles to specimen failure was used as the primary dependent measure. Results demonstrated that the number of cycles to fatigue failure were dramatically reduced in simulated flexed lifting compared to lifting in more upright postures. The average number of cycles to failure for upright, partial flexion, and full flexion were 8846, 4549, and 1485, respectively. The more rapid development of spinal tissue failure in flexed lifting may help explain the high incidence of low back disorders in coal mining (where flexed lifting is prevalent), but also have great relevance toward development of effective prevention measures. In particular, these results suggest that exposure to flexed lifting may be a key risk in low back disorders and that minimizing such exposure may be quite effective in reducing low back disorders in mining.

Potential Outcome

Results of this study and other important recent research findings related to low back pain are currently being used in the development of an "evidence-based" low back exposure assessment tool for the mining industry. The specific aims of this project are to develop guidelines and a tool for a paper-and-pencil low back exposure assessment that (1) is applicable to the unique physical stresses encountered in the mining environment, (2) takes advantage of recent research findings on potential injury pathways to the low back, and (3) is easy to use and administer. This tool is currently being pilot tested at a cooperating minesite. If this approach proves ultimately successful in developing a model that can predict risks of low back disorder at mining worksites, by 2009 the proposed exposure assessment tool is likely to have a remarkable impact on the design and evaluation of work tasks in the mining industry.

Outputs

17 Planned or completed outputs

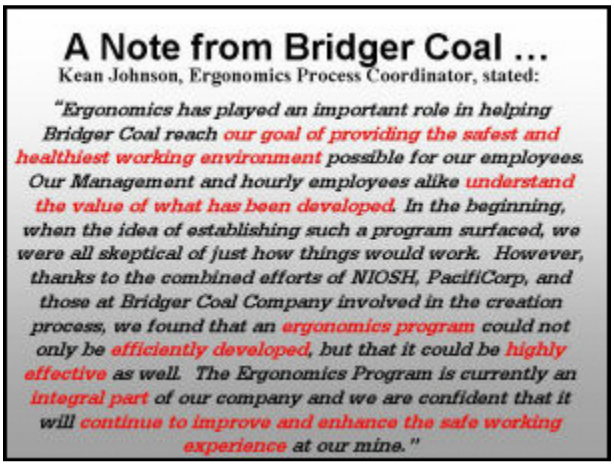
Title	Year	Output Type	Strategic Goal
Physical Limitations and Musculoskeletal Complaints Associated With Work in Unusual or Restricted Postures: A Literature Review Gallagher-S | J Saf Res 2005 Jan; 36(1):51-61	2005	Publication	Cumulative injuries
Torso Flexion Loads and Fatigue Failure Mode of Human Lumbosacral Motion Segments Gallagher-S; Marras-WS; Litsky-AS; Burr-D | Spine 30(20)	2005	Publication	Cumulative injuries
Validity and Reliability of Sincerity Test for Dynamic Trunk Motions Ferguson-SA; Gallagher-S; Marras-WS | Disability and Rehabilitation 25(4), 2003	2003	Publication	Cumulative injuries
Effects of Posture on Dynamic Back Loading During a Cable Lifting Task Gallagher-S; Marras-WS; Davis-KG; Kovacs-K | Ergonomics, 2002 45(5), 2002; :380-398	2002	Publication	Cumulative injuries
The Effects of Restricted Workspace on Lumbar Spine Loading Gallagher-S; Hamrick-CA; Cornelius-KM; Redfern-MS | Occupational Ergonomics 2(4), 2001; :201-213	2001	Publication	Cumulative injuries
Trunk Extension Strength and Muscle Activity in Standing and Kneeling Postures Gallagher-S | Spine 22(16), 1997 Aug; :1864-1872	1997	Publication	Cumulative injuries
Dynamic Biomechanical Modeling of Symmetric and Asymmetric Lifting Tasks in Restricted Postures Gallagher-S; Hamrick-CA; Love-AC; Marras-WS | Ergonomics 37(8): 1289-1310	1994	Publication	Cumulative injuries
Acceptable Workloads for Three Common Mining Materials Gallagher-S; Hamrick-CA | Ergonomics 35(9):1013-1031	1992	Publication	Cumulative injuries
The Kyphotic Lumbar Spine: Issues in the Analysis of Stresses in Stooped Lifting Gallagher-S; Hamrick-CA | International Journal of Industrial Ergonomics 8(1):33-47	1991	Publication	Cumulative injuries
Acceptable Weights and Physiologic Costs of Performing Combined Manual Handling Tasks in Restricted Postures Gallagher-S | Ergonomics 34(7): 935-952	1991	Publication	Cumulative injuries
Lifting Under Four Restrictive Roof Heights: Psychophysical, Physiological, and Biomechanical Effects of Lifting in Stooped and Kneeling Postures Gallagher-S; Unger-RL | Applied Ergonomics, 21(3): 237-245	1990	Publication	Cumulative injuries
Recommendations for Handling Materials in Low-seam Coal Mines Gallagher-S | Applied Industrial Hygiene, 4(6): F8 BF12	1989	Publication	Cumulative injuries
Lifting in Stooped and Kneeling Postures: Effects on Lifting Capacity, Metabolic Cost, and Electromyography of Eight Trunk Muscles Gallagher-S; Marras-WS; Bobick-TG | International Journal of Industrial Ergonomics, 3(1): 65-76	1988	Publication	Cumulative injuries
Gallagher, S., Marras, W.S., Litsky, A.S., and Burr, D., in press. Factors Associated with Specific Failure Modes in Fatigue Testing of Human Lumbosacral Motion Segments, accepted for publication in the journal Clinical Biomechanics	2006	Publication	Cumulative injuries
Gallagher, S., Marras, W.S., Litsky, A.S., and Burr, D., in review. The influence of bone mineral content and specimen morphology on the risk of fatigue failure of lumbar motion segments, European Spine Journal	2006	Publication	Cumulative injuries
Assessment tool for low-back exposure - Journal of Applied Ergonomics	2008	Publication	Cumulative injuries

Title	Year	Output Type	Strategic Goal
Benefits of using the Low Back Assessment tool and its effectiveness in diagnosing problem areas. To be submitted to Occupational Ergonomics and for a NIOSH Informational Circular	2007	Publication	Cumulative injuries

Potential Intermediate Outcome for Cumulative Injuries

Ergonomic Processes Implementation/Integration and Process Metric

Background



A note from Bridger Coal

Musculoskeletal injuries have long been identified as a significant and costly problem for the mining industry. Research has shown that establishment of a process to identify ergonomic risk factors, implement solutions to reduce injury, and determine the effectiveness of these solutions is the best way to reduce injury and illness and their related costs, as well as to improve work performance and quality. The ergonomics literature contains numerous reports of ergonomic programs that successfully reduced work-related injury and illness. However, the documented evidence for dynamic work environments such as mining, construction, and agriculture describes only time-limited or quick-fix actions. Time-limited actions address a specific problem at a certain time and often remain an isolated event with time-limited results. In addition, few scientific evaluations of ergonomics programs and/or processes have been developed. Although guidelines regarding basic process elements exist, no scientific study that documents specific tasks and resources necessary for implementation has been conducted.

Processes will be implemented at two sites, the Badger Mining Co. and Vulcan Materials. Badger has provided training to all its employees at its two mines in Wisconsin, completed a baseline assessment of risk factor exposures, and is in the process of integrating ergonomics with its behavior-based safety system. For the Badger process, a risk factor checklist was written for the baseline assessment, observer training was developed to improve the capabilities of the observers to reduce exposures, and an observation form was created for observers to document their observations and solutions. Vulcan Materials is in the planning stage of how best to integrate ergonomics into its safety program.

In addition to working with Badger and Vulcan, partnerships will be formed with trade associations to promote the application of ergonomics to their memberships. The partnerships will provide a mechanism to reach more companies than what NIOSH researchers alone could do. To date, one partnership has been established with the Industrial Minerals Association-North America. Other partnerships will be initiated in 2006 with the National Stone, Sand and Gravel Association and the National Mining Association. To develop a process metric, a focus group composed of professional ergonomists will be asked to develop a rating scheme that will be used to rate the ergonomics processes of participating companies and

identify a list of tasks relevant to process implementation. The rating scheme and task list will then be used by companies with histories of having implemented successful ergonomics processes. The information gained from these companies will be validated through external evaluations.

Potential Outcome

The primary benefits of this work will be to gain a better understanding of the specific activities that contribute significantly to the development of effective processes and provide evidence to the mining industry that well-developed ergonomics processes are proactive mechanisms that greatly reduce risks for musculoskeletal disorders. Specifically, as more mining companies implement processes, risks for musculoskeletal disorders will be reduced by 2010, and improvements in health and safety for the worker and workplace will be put into place. Knowledge gained will be disseminated to the mining industry through trade association partnerships, industry-oriented publications, professional research journals, NIOSH publications, industry briefings, workshops, and conferences.

Outputs

10 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Using Ergonomics to Enhance Safety and Health in the U.S. Mining Industry Steiner-L; Torma-Krajewski-J; Schwerha-D | 31st International Conference of Safety in Mines Research Institutes, 2-5 October 2005, Brisbane, Queensland, Australia. Redbank, Queensland, Australia: Safety in Mines Testing and Research Station (Simtars), 2005 Oct; :106-111	2005	Publication	Cumulative injuries
Simple solutions ergonomics publication for underground mining - NIOSH IC	2006	Publication	Cumulative injuries
Simple solutions ergonomics publication for surface mining - NIOSH IC	2009	Publication	Cumulative injuries
Torma-Krajewski, J., Steiner, L., Lewis, P., Gust, P., Johnson, K. Ergonomics and Mining: Charting a Path to a Safer Workplace, NIOSH Information Circular	2006	Publication	Cumulative injuries
Torma-Krajewski, J., Steiner, L., Wiehagen, W., Unger, R., Lewis, P., Gust, P., Johnson, K. Ergonomics and Mining: Oil and Water or Cream and Sugar. Submitted to the International Journal of Industrial Ergonomics. In review, peer reviewed	2006	Publication	Cumulative injuries
Designing with a Purpose: Equipment Issues in Mining - SME journal (peer reviewed)	2007	Publication	Cumulative injuries
Implementation of an ergonomics process by the Badger Mining Company - SME journal (peer reviewed)	2007	Publication	Cumulative injuries
Implementation of an ergonomics process by the Vulcan Mining Company - SME journal (peer reviewed)	2007	Publication	Cumulative injuries
Development of a metric that can be used to evaluate the effectiveness of ergonomics processes. To be submitted to Applied Ergonomics	2007	Publication	Cumulative injuries
Developing a metric for defining and evaluating process element activities and the effects of these activities on MSD incident rates and other outcome measures. To be submitted to Applied Ergonomics	2007	Publication	Cumulative injuries

Potential Intermediate Outcome for Cumulative Injuries

Redesign of Dragline Workstations

Background

Dragline operators work 8- to 12-hour shifts removing overburden and parting material to expose coal seams. The operators are continuously exposed throughout the shift to repetitive motions, static postures, and awkward postures as they manipulate the dragline bucket using two joysticks. Average cycle time is 60 seconds; for a typical 12-hour shift, the operator will complete 600 cycles. Dragline operators have reported discomfort in their wrists, shoulders, back, and legs, and have also experienced carpal tunnel syndrome. To address exposures to risk factors resulting in discomfort and musculoskeletal disorders, three activities associated with dragline workstations are being conducted.

Poster of NIOSH designed dragline workstation

Bridger Dragline Workstation: A field study was conducted to determine the effects of modifying a dragline workstation. The workstation in the 103 dragline was modified to include improved armrests (better support and adjustability) and a low-profile footrest. Operators were also given a brief orientation on how to adjust the armrests, operate the joysticks, and use good postures when operating the dragline. Discomfort survey data and videos of operators before and after the intervention were collected. In addition, operators were interviewed to obtain information about the modified workstations and their effects on how they used the joystick controls and their postures while operating the dragline.

Southern Illinois University Dragline Training Center: An adjustable workstation was developed and installed at the Center to collect data about the effectiveness of workstation adjustments in improving worker comfort. Because students attending this Center come from mines located throughout the United States, data will be obtained from a representative population of dragline operators who have a variety of experiences in operating draglines.

Falkirk Mine Dragline Workstations: The Falkirk Mining Co. operates several draglines equipped with adjustable workstations, including adjustable joysticks. Operators were surveyed to obtain user data on the effectiveness of the adjustments in improving comfort. Videos of the operators were obtained to evaluate postures and adjustments made prior to operating the dragline.

Potential Outcome

The objective of this intervention is to develop recommendations on how to improve workstations for draglines and other types of equipment where operators are required to work for long periods of time. By 2010, the improvements will allow workers to perform their jobs with less exposure to risk factors, result in fewer musculoskeletal disorders, and improve comfort and efficiency. Materials, such as videos and posters, will be developed to assist with the transfer of knowledge gained during these tasks. The prototype workstation will also continue to be available to the industry at Southern Illinois University for training purposes. Knowledge gained will be disseminated to the mining industry through trade association partnerships, industry-oriented publications, professional research journals, NIOSH publications, workshops, and conferences.

Outputs

4 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Ready-Adjust-Operate, NIOSH Dragline Workstation Lewis-P; Rossi-EW | 2005 Video	2005	Video	Cumulative injuries
Effectiveness of Adjustability in Dragline Workstations - SME journal or Applied Ergonomics (peer reviewed)	2007	Publication	Cumulative injuries
Design Criteria for Dragline Workstations - NIOSH Information Circular	2007	Publication	Cumulative injuries
Video production on Mobile Equipment Operator Workstations	2007	Video	Cumulative injuries

Potential Intermediate Outcome for Cumulative Injuries

Reducing Injuries during Bagging Tasks

Background

Tying a bulk bag

Packaging products in bags of all sizes is a common way of transporting the product to the end user. Bags used in the mining industry, for the most part, fit in two categories: bulk bags and small bags. Bulk bags, also known as, flexible intermediate bulk containers (FIBC) or super sacks, are used in many industries, including pharmaceuticals, agriculture, construction, and mining. Within the mining industry, there is a concern about injuries and exposures during bagging operations. One of our cooperating minesites recently had two employees sustain shoulder injuries during bagging tasks. The ergonomic risk factors in bulk bagging operations occur primarily when the operator opens and prepares the bag for filling and again when the bag is being closed. Both the opening and closing of the bag may introduce musculoskeletal injuries to the operator´s low back, shoulders, arms, neck, wrists, and hands. This task requires forceful work and awkward postures due to the size of the bag and the current design of the bags. Small bags (usually carrying 100 pounds or less) are also a common means of packaging and transporting mined industrial minerals. Depending on the level of automation and the work practices at a given site, a number of possible risk factors need to be addressed, such as manual lifting of the bags for weighing or manually stacking bags on a pallet. The most common risk factors associated with small bag operations will be identified and investigated to develop ergonomic interventions to reduce and/or eliminate these factors. The objective of this study is to identify the best design features for bagging tasks and thus reduce exposure of operators to ergonomic risk factors.

Potential Outcome

By 2008, the research on bagging will lead to the development of recommendations for purchasing bags and work practices for operators to reduce injury risk during bulk bagging operations. Improving this common work task will provide a safer work environment. Results from this task will be provided to industry in a guidance document and mining journal publications and will include an overview of bagging operations, descriptions of bulk bag design characteristics, work methods used in bagging, exposures to ergonomic risk factors, and appropriate control methods for reducing exposures. Because bulk and small bagging operations are part of several industries in addition to mining, the results of this project will be applicable to these industries as well.

Outputs

2 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Bag design characteristics and the reduction of ergonomic risk factors - Journal of Applied Ergonomics	2007	Publication	Cumulative injuries
Guidelines on purchasing bags with potential for reduction of ergonomic risk factors - NIOSH Information Circular	2007	Publication	Cumulative injuries

Potential Intermediate Outcome for Cumulative Injuries

Reducing Injuries Due to Railcar Loading and Maintenance Activities

Background

A large proportion of mined material is transported via rail. Unfortunately, loading, unloading, maintenance, and other railyard activities can be extremely physically demanding and associated with a high incidence of low back disorders. Workers frequently have to adopt awkward postures when working on the tops of railcars (opening hatches) or when working underneath (opening or cleaning dump points). Many tasks demand the use of a great deal of force, including opening gates with a steel bar, opening steel hatches on covered hopper cars, throwing switches, and setting brakes.

Railworker tending a car dump point

Many challenges are present in trying to improve methods of loading and unloading railcars, particularly since many railcars are leased and not owned (making modifications difficult or impossible) and the railcars tend to be of highly variable design. However, despite these challenges considerable opportunities exist to improve efficiency and reduce musculoskeletal risk through the application of ergonomics principles. As part of a cooperative research effort with the Industrial Minerals Association of North America, NIOSH researchers are currently analyzing tasks associated with railcar loading, unloading, and maintenance activities so that interventions can be developed and implemented to reduce the risk of low back disorders.

Potential Outcome

Expected interventions will include recommendations for improvements in switch design, methods for opening top and bottom hatches, and design and layout of rail facilities. Results of these interventions and recommendations will be presented to the industry through workshops and industry-directed publications. The impact of this research is likely to realized by 2008. Given the large number of mining companies that use rail for shipment of their products, this work in improving the design of and workplace practices for rail loading, unloading, and maintenance activities has the potential for far-reaching impacts in the mining industry.

Outputs

3 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Railcar and rail yard ergonomics issues and the reduction of ergonomic risk factors - NIOSH Information Circular	2007	Publication	Cumulative injuries
Guidelines on railcar ergonomics in the mining industry - NIOSH Information Circular	2007	Publication	Cumulative injuries
Workshop presentation to IMA-NA members on Railcar and Railyard Ergonomics	2006	Workshop, Seminar, or OIB	Cumulative injuries

Potential Intermediate Outcome for Cumulative Injuries

MSD Prevention and Intervention Education Modules

Background

MSD risk factor awareness training session

Although generic ergonomics training materials have been commercially produced, none of these materials discuss specific ergonomic issues related to mining. As part of the ergonomics process implementation by Bridger Coal Co., NIOSH developed an ergonomics awareness course that was presented to all Bridger employees. As information about this course became known, requests from the mining industry have led to the course being offered several times at both national and local mining conferences and at other mine sites. The popularity of this course has demonstrated a need in the mining industry for courses that not only help companies identify risk factor exposures, but also to control and reduce exposures to these risk factors.

Three separate training courses will be developed and placed on the NIOSH mining Web page: "MSD Risk Factor Awareness," "Building Better Jobs", and "Designing for Maintainability." The first course is an introductory course with an emphasis on describing work-related musculoskeletal disorders and identifying risk factors associated with the development of MSD's. The second course provides information on how to improve jobs by reducing exposures to risk factors. The final course promotes the design of equipment and workplaces to permit maintenance activities without exposing workers to risk factors during these activities.

Each course will be developed at two levels, the employee level and the trainer level. The employee-level courses will be formatted as Power Point presentations that include interactive exercises and demonstrations and will be designed to be given as classroom training. The trainer-level course will be formatted so it can be accessible on the Internet and be taken as a stand-alone learning experience. The material covered in the train-the-trainer course will prepare a trainer to present the employee-level course. An instructor's kit will be available for downloading to assist trainers when presenting the employee-level course. Each kit will contain an electronic copy of the Power Point presentation, training evaluations for employees, a narrative manual to accompany the presentation, and background information about ergonomics.

Potential Outcome

The primary benefit of this task will be to reduce MSD incidence rates as the mining industry increases its knowledge about MSD risk factors and ways to improve jobs and so reduce exposures to these risk factors. As alternate methods for delivering the courses become available, more trainers will be qualified to offer the courses to their employees. Information about the courses will be available on the NIOSH mining Website, and courses will continue to given by NIOSH staff at conferences and workshops throughout many mining sectors. Impact of this research is expected to be felt during 2006-2010.

Outputs

7 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
MSD Risk Factor Awareness Train-the-Trainer NIOSH | Module presented to safety and health representatives of US Silica, Berkeley Springs, WV, October 2005	2005	Training	Cumulative injuries
MSD Risk Factor Awareness Training Module at Badger Mining Company (Fairwater and Taylor Mines)	2006	Training	Cumulative injuries
Instructor´s manual for the MSD Risk Factor Awareness Train-the-Trainer course (Wiehagen-W, Torma-Krajewski-J, Steiner-L), NIOSH IC	2006	Publication	Cumulative injuries
MSD Risk Factor Awareness Train-the-Trainer Module to safety and health representatives of Vulcan Materials Company	2006	Training	Cumulative injuries
Train-the-Trainer Materials for Building Better Jobs: (1) Concept and implementation; (2) Tool design; (3) Anthropometrics and biomechanics for design; (4) Maintenance; (5) Equipment purchasing and retrofitting; and (6) Control design	2008	Training	Cumulative injuries
Designing for Maintainability : Guidelines for Designers and Maintenance Personnel - NIOSH Information Circular	2007	Publication	Cumulative injuries
Designing for Maintainability : Guidelines for Designers and Maintenance Personnel - web version	2007	Web document	Cumulative injuries

Potential Intermediate Outcome for Traumatic Injuries

Guidelines for Improving Ore Pass Safety

Background

Ore passes are constructed within the rock mass for the purpose of vertical transfer of ore and waste rock from stopes or development headings. Their function is to deliver material to a lower haulage level or to shaft loading pockets for hoisting to the surface. The figure shows a typical mine ore pass with truck loadout and LHD vehicle dump.

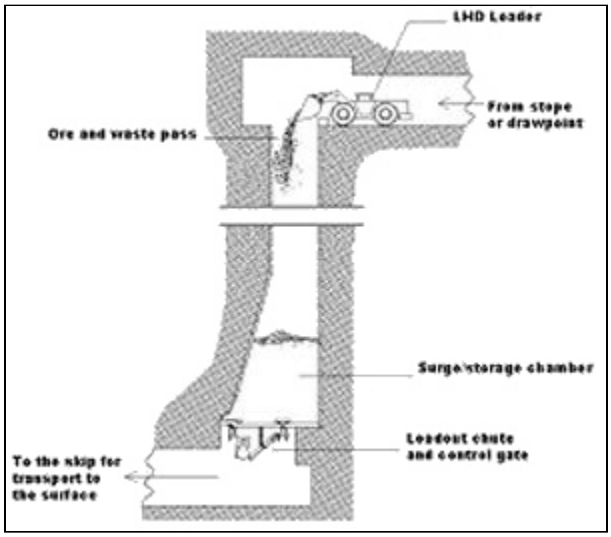


Diagram of a typical ore pass

The ore pass design research was started at the request of MSHA after several fatalities resulted from workers attempting to free clogged ore pass chutes. A review of MSHA injury and fatality data for the 20-year period between 1975 and 1995 shows that nearly 75% of the injuries were directly or indirectly related to pulling or freeing ore pass chutes, the use of hand tools, falls of broken rock, and structural failures of the chute or gate and ore pass walls. During the period 1991-2000, 83 traumatic injuries specifically caused by pulling or freeing hang-ups in chutes were reported in 18 underground metal/nonmetal mines. In addition to ore pass accidents, about one fatality per year resulted from the collapse of coal bridges that formed over feeders on coal surge piles

Particle-flow computer programs have been used in analyzing mine ore and waste passes. Preliminary finite-element analyses determined safety factors of typical ore chute control gates. New algorithms have been developed to characterize ore pass materials and conditions more accurately and specifically, and results of numerical calculations on typical ore pass systems have been validated with experimental observations.

Potential Outcome

Improved ore pass design methods can prevent accidents caused by hang-ups and structural failures. Field tests indicated that particle size and shape and ore pass system stiffness and friction properties must be determined for accurate computer analysis. Highly sophisticated computer modeling routines were adapted as a design tool for mine ore pass designers.

Outputs

11 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Ore Pass Analysis and Design Workshop Co-sponsored by the Western Mining Research Center (WNRC), Golden, CO, Spokane, WA, Dec. 2, 2003	2003	Workshop, Seminar, or OIB	Ground control
Application of Physical Modelling and Particle Flow Analysis to Evaluate Ore-pass Design Beus-MJ; Iverson-S; Stewart-B | Inst Min Metall, Trans, Sect A: Min Ind, 1998 Sep 106():A110-A117	1997	Publication	Ground control; Traumatic injuries
Development of a Mine Hoist and Ore Pass Research Facility Beus-MJ; Ruff-TM | Spokane, WA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, NIOSH, DHHS (NIOSH) Publication No. 97-134, Report of Investigations 9637	1997	Publication	Traumatic injuries
Technology News 458 - Development of a Research Facility to Improve Mine Hoisting and Ore Pass Safety NIOSH | Spokane, WA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 458, 1997 May :1-2	1997	Publication	Traumatic injuries
Technology News 470 - Analysis of Hangups and Structural Failure in Underground Mine Ore Passes Stewart-B; Iverson-S; Cullen-E | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 470, 1998 Feb :1-2	1998	Publication	Ground control
Static and Dynamic Loads in Ore and Waste Rock Passes in Underground Mines Beus-M; Iverson-SR; Dreschler-A; Scott-V | Rock Mechanics for Industry, Amadei, Kranz, Scott & Smeallie (eds.), 1999 Balkema, Rotterdam, ISBN 90 5809 052 3, :489-495	1999	Publication	Traumatic injuries
Safety Considerations for Transport of Ore and Waste in Underground Ore Passes Stewart-B; Iverson-S; Beus-M | Min Eng 1999 Mar; 51(3):53-60	1999	Publication	Traumatic injuries
Technology News 479 - Ore Pass Level and Blockage Locator Device NIOSH | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 479, 2000 Jan :1-2	2000	Publication	Traumatic injuries
Static and Dynamic Loads in a Scaled Ore Pass Scott-VA; Drescher-A; Iverson-S; Beus-M | Pacific Rocks 2000. Rock Around the Rim: Proceedings of the Fourth North American Rock Mechanics Symposium (NARMS 2000), ed. By J. Girard, M. Leibman, C. Breeds, and T. Doe (Seattle WA, July 31-Aug. 3, 2000). Balkema, 2000; :381-386	2000	Publication	Traumatic injuries
Design of Ore Passes Beus-MJ; Pariseau-WG; Stewart-BM Iverson-SR | Ch. 71 in Underground Mining Methods: Engineering Fundamentals and International Case Studies, William Hustrulid and Richard Bullock, eds., Society for Mining, Metallurgy, and Exploration, Littleton, CO, 2001; :627-634	2001	Publication	Traumatic injuries

Title	Year	Output Type	Strategic Goal
Investigation of Bulk Solids Engineering Properties and Application of PFC2D to Ore Pass Flow Problems Iverson-SR | In: H. Konietzky, ed., Numerical Modeling in Micromechanics via Particle Methods. Proceedings of the 1st International PFC Symposium (Gelsenkirchen Germany, Nov. 6-8, 2002), Balkema, Rotterdam, Netherlands, 2002; :252-258	2002	Publication	Traumatic injuries

Potential Intermediate Outcome for Traumatic Injuries

Forklift Operating Warning System (FLOWS)

Background

Instrumented lift truck with operator warning system

A common danger in the mining, agriculture, and construction industries is that mobile equipment is often unknowingly operated in an unsafe manner. Operator errors are frequently the result of inadequate training, complacency regarding equipment operation, and taking shortcuts. Many times an operator unknowingly operates the equipment beyond its safe operating limits or fails to recognize dangers in the work environment. Unsafe operation can result in injuries and the deaths of both drivers and pedestrian workers; over 100 fatalities and 20,000 lift truck injuries occur yearly in the United States. Seventy percent of these accidents were caused by operator error. In 2000, the leading causes of lift truck fatalities were lift truck overturns (23%), pedestrians and workers struck by lift trucks (39%), and falls from lift trucks (10%). During 1999-2003, over 181 lift truck traumatic injuries were recorded at mining operations where seven or more fatalities had already occurred.

NIOSH, in collaboration with the North American Coal Company (NACCO), the manufacturer of Yale and Hyster lift trucks, is investigating ways to reduce the high number of injuries and deaths related to dangerous lift truck operating practices. A prototype forklift operating warning system (FLOWS) was developed by NIOSH researchers. This system continuously monitors the critical operating parameters of a lift truck to alert the operator when the vehicle is being operated unsafely. When a critical operating parameter is exceeded, a digital voice warning message is activated that can be heard by both the lift truck operator and any nearby workers. The warning can, for example, alert the operator when he or she is traveling or cornering too fast, nearing pedestrian workers or obstacles, lifting too heavy of a load, and approaching the edge of a loading dock. The sensor-based monitoring system can also be used a tool to improve lift truck operator training, evaluate training programs, and identify areas in need of additional training.

Potential Outcome

The expected impact of this research will be to reduce the 20,000 yearly lift truck accidents in the United States by 20% by 2010.

Outputs

2 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
High-Tech System to Reduce Forklift Injuries Owens-JK | eNews, Volume 2, Number 2, June 2004, http://www.cdc.gov/niosh/enews/enewsV2N2.html#s	2004	Web document	Traumatic injuries
Development of first generation forklift operating warning system (FLOWS), Employee Invention Report (EIR)	2006	Patent	Traumatic injuries

Potential Intermediate Outcome for Traumatic Injuries

High-Voltage Continuous Mining Machines

Background

Typical continuous miner

The demand for larger, more-powerful mining equipment stimulated the need for increased voltages for coal mine face machinery. Higher-voltage equipment can supply more power without requiring larger, heavier trailing cables. Special design, use, and maintenance precautions are needed to ensure an equivalent level of safety when high-voltage systems are used in permissible areas. Since 1997, which was before each continuous mining machine operating above 1000-V ac could be put into use, MSHA required a Petition for Modification, and each individual machine was then scrutinized prior to approval.

NIOSH research indicated that higher voltages were indeed feasible with appropriate precautions. Several NIOSH research reports provided technical information used by MSHA to help formulate new regulations that would allow the use of high-voltage longwall machines in coal mines (Final Rule, 30 CFR Parts 18 and 75, "Electric Motor-Driven Mine Equipment and Accessories and High-Voltage Longwall Equipment Standards for Underground Coal Mines" on March 11, 2002. Published in *Federal Register*, Vol. 67, No. 47, March 11, 2002, Rules and Regulations, pp. 10972-11005). These reports also provided technical information critical to the development of the proposed high-voltage continuous miner rule. Such information included enclosure pressures developed during electrical arcing up to 15 kV in methane-air atmospheres, as well as recommendations for high-voltage electrical creepage and clearance distances, design criteria for explosion-proof enclosures, and permissibility hazard reduction.

Potential Outcome

The proposed rule "High-Voltage Continuous Mining Machines," RIN 1219-AB34, published by MSHA in the *Federal Register* of July 16, 2004 (Vol. 69, No. 136, Proposed Rules, pp. 42811-42840), is anticipated to become law by 2010. The new rule will eliminate the need for each new high-voltage continuous mining machine to undergo the Petition for Modification process. The proposed rule draws on the results of NIOSH research to allow the safe use of explosion-proof continuous miners. The ability to accept high-voltage, continuous-mining-type machines removes a significant barrier to safer, more efficient, and economic coal mining in the United States.

Outputs

6 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Development of High-Voltage Permissible Loadcenter Berry-DR; Gillenwater-B | U.S. Bureau of Mines contract no. H0308093. NTIS No. PB 86-215803	1986	Publication	Traumatic injuries
Mine Electrical Systems Evaluation: Explosion-Proofing of Mine Containers Stefanko-R; Morley-LA | University Park, PA: The Pennsylvania State University, College of Earth and Mineral Sciences. U.S. Bureau of Mines Contract Report No. G0-133077, OFR 76(2)-75, NTIS Number: PB/245-928/As, 76 pp	1974	Publication	Traumatic injuries
A Study of Explosion-Proof Enclosures Cox-PA; Burnside-OH; Esparza-ED; Lin-FD; White-RE | San Antonio, TX: Southwest Research Institute. USBM contract No. H0-377052. OFR 96-83, NTIS No. PB 83-205450; :426 pp	1982	Publication	Traumatic injuries
A Design Guide for Explosion-Proof Electrical Enclosures - Part 3: Final Technical Report Cox-PA; Schick-WR | Southwest Research Institute, USBM Contract Report No. H0-387009, OFR 47c-86, NTIS: PB 86-209525; :353pp	1985	Publication	Traumatic injuries
Mine Power Systems Morely-LA | Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, Information Circular 9258. NTIS No. PB 91-241729	1990	Publication	Traumatic injuries
Final rule for High-Voltage Continuous Mining Machines	2010	Standards	Traumatic injuries

Potential Intermediate Outcome for Traumatic Injuries

Power Line Proximity Warning Alarms

Background

A mobile crane working near power lines

During the 1990's, approximately 20% of all electrocutions in the mining industry resulted from high-reaching mobile equipment, such as cranes, dump trucks, and drill rigs, coming in contact with overhead power lines. In these accidents, 56% of the injured miners were unaware of the shock hazard and contacted both the equipment and ground simultaneously after a power line contact had occurred. An overhead power line contact alarm was developed to supplement existing proximity warning systems. While not designed to prevent all related injuries, a contact alarm can warn workers when a piece of mobile equipment becomes energized by a power line. Two manufacturers plan to supplement their proximity warning alarm systems with contact alarm technology.

Proximity warning systems, advertised as having the capability of alerting operators when they approach too close to a power line, have been commercially available for 30 years. Such systems have not found widespread acceptance due to perceived performance deficiencies and, in part, to a lack of regulatory requirements. The only known comprehensive study of power line proximity warning systems was published by the U.S. Bureau of Mines in 1982. It documented some serious performance limitations. Proximity warning system manufacturers claim to have substantially improved product performance since then. Recent OSHA efforts are underway to improve the 29CFR Crane and Derrick Standard. The proposed language allows the use of proximity warning alarm systems as a means of maintaining OSHA's (and MSHA's) required clearance distances from power lines, provided such systems are approved by a nationally recognized testing laboratory. To allow approval by a third-party testing laboratory, objective performance data must exist from which to develop a standard for use by such laboratories. NIOSH-sponsored work will provide technical data for such a national standard.

Potential Outcome

An American National Standards Institute (ANSI) standard that sets minimum performance and operational criteria for power line proximity alarms is anticipated by 2010. Building on past and current NIOSH power line proximity research, the standard will allow the use of power line proximity warning alarms to protect workers against accidental contact between power lines and high-reaching mobile equipment. The technology can also be applied to reduce power-line-related electrical injuries in the construction industry. Based on an estimated worldwide market of 45,000 proximity warning systems, the overall potential impact on the reduction of power line contact accidents is high.

Outputs

10 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Alarm System for Detecting Hazards Due to Power Transmission Lines Sacks-HK; Yenchek-MR; Homce-GT; Cawley-JC | U.S Patent #6,600,426 (granted July 29, 2003)	2003	Patent	Traumatic injuries
Heavy Equipment Near Overhead Power Lines? New Safety Research May Save Your Life: New Safety Research May Save Your Life Homce-GT; Cawley-JC; Sacks-HK; Yenchek-MR | Engineering and Mining Journal, (203)4, 2002 Apr :36-39	2002	Publication	Traumatic injuries
Electrical Safety for Water Well Drillers An invited, 90-minute workshop held at the National Ground Water Association annual meeting in Las Vegas, NV, December 12, 2004	2004	Workshop, Seminar, or OIB	Traumatic injuries
Electrical Safety for Water Well Drillers NIOSH | An invited, 90-minute workshop held twice at the South Atlantic Water Well Driller's Jubilee, Myrtle Beach, SC, July 30-31, 2005	2005	Workshop, Seminar, or OIB	Traumatic injuries
Development of an Overhead Power Line Contact Alarm for Mobile Equipment Homce-GT; Cawley-JC; Sacks-HK; Yenchek-MR | International Journal of Heavy Vehicle Systems, (12)4, 2005 Apr; :87-103	2005	Publication	Traumatic injuries
Electrical Safety for Water Well Drillers Homce-GT; Cawley-JC; Yenchek-MR | Water Well Journal, 59(8); :12,14	2005	Publication	Traumatic injuries
An American National Standards Institute standard that sets minimum performance and operational criteria for power line proximity alarms	2010	Standards	Traumatic injuries
Power line proximity warning alarm test results. IEEE Trans. on Ind. App.	2007	Publication	Traumatic injuries
Design and performance criteria for power line proximity and contact alarm systems. IEEE Trans. on Ind. App.	2008	Publication	Traumatic injuries
Trends in overhead power line electrocution accidents statistics - IEEE Trans. on Ind. App	2009	Publication	Traumatic injuries

Potential Intermediate Outcome for Traumatic Injuries

Electrical Arc Burns

Background

Simulated electrical arcing accident

Between 1990 and 2001, 2,146 traumatic electrical injuries occurred in the mining industry, of which 846 (39%) were burns resulting from electrical arcing. Fifty-five percent of these injuries occurred in bituminous coal, 21% in stone, 10% in sand and gravel, 9% in metal, and 5% in nonmetal mining. No specific guidelines yet exist with which to combat electric arc burn injuries in mining.

A significant amount of industrial safety research has focused on protecting workers from electrical arcing hazards. The result has been the National Fire Protection Association's (NFPA) national standard 70E-2004, "Standard for Electrical Safety in the Workplace." The scope of NFPA 70E explicitly excludes underground mining. A true need exists to identify the relevant parts of NFPA 70E that can be applied to mining to reduce serious burn injuries.

Potential Outcome

NIOSH research is bringing relevant aspects of NFPA 70E into the mining workplace to afford miners better protection from electrical arcing injuries. This work will use computer simulations to quantify the short-circuit energy available in representative mine electrical systems. Recommendations for the use of arc-rated electrical personal protective equipment (PPE) in mining situations analogous to its use in other industries are being formulated. Advancements in PPE technology have the potential to mitigate the number and severity of arc burn injuries. Training to raise miners' awareness of electric arc burn hazards will be developed. Hazardous tasks commonly encountered by mine electricians are being identified. Task-appropriate, arc-rated fire-retardant clothing, electrical tools, meters, and work practices will be recommended. The anticipated industry impact is expected to be a substantial reduction in the number of arc burn injuries.

Outputs

8 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Protection from arcing injury in the coal industry - IEEE Trans. on Ind. App.	2007	Publication	Traumatic injuries
Protection from arcing injury in the aggregates industry - SME Journal (peer-reviewed)	2008	Publication	Traumatic injuries
An arc burn training video	2007	Video	Traumatic injuries
Arc burn safety for use in MSHA-required refresher training - NIOSH Information Circular	2007	Publication	Traumatic injuries
Electrical arcing-fault safety measures for mining. IEEE Trans. on Ind. App.	2007	Publication	Traumatic injuries
Selection and use of electrical meters in mining - Min. Engr.	2008	Publication	Traumatic injuries
Tools for safer mine electrical maintenance - Min. Engr.	2008	Publication	Traumatic injuries
Safer mine electrical maintenance - NIOSH Information Circular	2010	Publication	Traumatic injuries

Potential Intermediate Outcome for Traumatic Injuries

Roof Bolter Health and Safety Guidelines

Background

Roof bolting in underground coal

Hazards arise from work environments and improperly designed workstations, equipment, or work methods. Mine work hazards include machine and human-body appendage collisions and operator errors. Tasks related to boom arm movement have a high degree of hazardous acts, and no data exist on safe speeds for booms operating close to workers in a confined work environment such as is found in underground mines. Incident investigation reports do not usually contain enough information to aid in studying this problem. Laboratory and field experiments with human subjects are not feasible because of safety and ethical issues.

Work-related musculoskeletal disorders (MSD) include awkward postures, repetitive and forceful motions, and excessive jarring and jolting. MSHA injury/incident data from 1993 to 2004 showed a total of 139,222 nonfatal lost time injuries. Repetitive MSD injuries composed 46% of the reported incidents and machinery and powered haulage composed 24%. Research is being conducted to assess and reduce the presence of underground mine work hazards to which the work environment, equipment, and performance of work contribute significantly to roof bolter operations. The fundamental issues being addressed are-What boom appendage speed(s) maximize the operators´ chances of escaping injuries while still allowing the operators to perform bolting functions effectively? What equipment design modifications are needed? What job-task-procedure changes are needed to reduce the risk of low back pain unique to the postural and lifting circumstances of roof bolters?

Potential Outcome

This research will suggest changes to roof bolting equipment that would have a direct impact on how the bolting task is performed. Guidelines and control interventions relating to boom speed ranges and procedural modifications of work postures to reduce injuries in the back and other parts of the body are expected. For example, in typical bolting activities, a tray is provided on which to stack material handled during the bolting operation. A guideline that suggests different locations for the materials tray has the potential to reduce low back stress by limiting bending, twisting, and lifting motions. Another example addresses the current situation in which operators can operate a boom arm´s speed and direction with one hand. A control intervention, such as redesigning the controls to require the operator to use two hands, has the potential to reduce injuries by keeping the body and hands clear of a moving boom arm. Most impacts resulting from modifications to roof bolting equipment are expected to take place by 2008.

Outputs

11 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
A Simulation Approach Analyzing Random Motion Events Between a Machine and its Operator Ambrose-DH | In: Proceedings of the Digital Human Modeling for Design and Engineering Conference and Exposition, Dearborn, Michigan, June 6-8, 2000. Paper No. 2000-01-2160. Warrendale, PA: SAE International, 2000 Jun; :1-11	2000	Publication	Traumatic injuries
Machine Injury Prediction by Simulation Using Human Models Ambrose-DH; Bartels-JR; Kwitowski-AJ; Helinski-RF; Gallagher-S | Warrendale, PA: Society of Automotive Engineers, Inc., technical paper 2003-01-2190, 2003; :1-11	2003	Publication	Traumatic injuries
Mining Roof Bolting Machine Safety: A Study of the Drill Boom Vertical Velocity Ambrose-DH; Bartels-JR; Kwitowski-AJ; Helinski-RJ; Gallagher-S; McWilliams-LJ; Battenhouse-TR Jr | Pittsburgh, PA: U.S. Department of Heatlh and Human Service,s Public Health Service, Centers for Disease Contorl and Prevention, NIOSH, DHHS (NIOSH) Pub No. 2005-128, Information Circular 9477, 2005	2005	Publication	Traumatic injuries
Random Motion Capture Model for Studying Events Between a Machine and its Operator Ambrose-DH | Proceedings of the Advanced Simulation Technologies Conference. ASTC 2001, July 15-19, 2001, Orlando, Florida. San Diego, CA: Society for Computer Simulation International 2001 Jan; :127-134	2001	Publication	Traumatic injuries
Technology News 480 - Controlled Start for Drill Motors on Roof Bolting Machines DuCarme-JP | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Technology News 480, 2000 Feb :1-4	2000	Publication	Traumatic injuries
Verification and Validation of Roof Bolter Simulation Models for Studying Events Between a Machine and its Operator Bartels-JR; Ambrose-DH; Wang-RC | Society of Automotive Engineers, Inc., technical paper 2001-01-2088, 2001 Jan; :1-14	2001	Publication	Traumatic injuries
Verification of a Roof Bolter Simulation Model Bartels-JR; Kwitowski-AJ; Ambrose-DH | Warrendale, PA: Society of Automotive Engineers, Inc., Technical Paper 2003-01-2217, 203; :1-7	2003	Publication	Traumatic injuries
Computer Simulations Help Determine Safe Vertical Boom Speeds for Roof Bolting in Underground Coal Mines Ambrose-DH; Bartels-JR; Kwitowski-AJ; Gallagher-S; Battenhouse-TR | Safety Res 2005 Oct-Dec; 36(4):387-397	2005	Publication	Traumatic injuries
Comparing Estimated Low Back Loads from Control Interventions for Underground Mine Roof Bolter Operators Ambrose-DH; Cole-GP | KOMAG, KOMTECH Conference, Nov. 14-17, 2005, Zakopane, Poland, 10 pp.	2005	Publication	Traumatic injuries
Survival analytic approach to evaluating struck-by accidents using a virtual human model - Journal of Human Factors	2006	Publication	Traumatic injuries
Roof bolter operator low back stress analysis - Journal of Safety Research	2006	Publication	Traumatic injuries

Potential Intermediate Outcome for Traumatic Injuries

Reducing Blast Area Security and Flyrock - Related Injuries and Fatalities in Mining

Background

Flyrock injuries and fatalities can result when a worker is struck by rock thrown much further than expected. An indirect cause of flyrock injuries and fatalities is a lack of blast area security prior to a blast. Such incidents result when a worker who was supposed to have left the area of a blast remains within the area and is injured by flyrock. Between 1994 and 2003, flyrock and a lack of blast area security were responsible for 12.8% of the fatalities and 41.6% of the injuries related to blasting.

Flyrock damage to a haul truck

Miners must be made aware of the importance of blast area security and the hazards of flyrock, as well ways to protect personnel. Training materials to raise blasters' awareness of flyrock hazards and the importance of good blast area security have been developed and will be distributed during FY05.

Potential Outcome

As miners are alerted to the hazards of flyrock and poor blast area security, the frequency of this type of accident will decrease. Since flyrock represents the majority of blasting-related injuries and fatalities, the training materials being developed are expected to result in a significant reduction in accidents.

Outputs

6 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Blasting Safety - Revisiting Site Security Bajpayee-TS; Verakis-HC; Lobb-TE | Proc 31st Ann Conf Explos Blasting Tech, Orlando, FL, February 6-9, 2005, 2005 Feb 6; 2:1-13	2005	Publication	Traumatic injuries
An Analysis and Prevention of Flyrock Accidents in Surface Blasting Operations Bajpayee-TS; Verakis-HC; Lobb-TE | Proc 30th Ann Conf Explos Blasting Tech, New Orleans, LA, February 1-4, 2004, 2004 Feb; :1-10	2004	Publication	Traumatic injuries
A Summary of Fatal Accidents Due to Flyrock and Lack of Blast Area Security in Surface Mining, 1989 to 1999 Bajpayee-TS; Rehak-TR; Mowrey-GL; Ingram-DK | Proc 28th Ann Conf Explos Blasting Tech, ISEE, Las Vegas, Nevada, February 10-13, 2002, 2002 Feb 2:105-118	2002	Publication	Traumatic injuries
Flyrock Issues in Blasting Rehak-TR; Bajpayee-TS; Mowrey-GL; Ingram-DK | Proc 27th Ann Conf Explos Blasting Tech, ISEE, Cleveland, Ohio, 2001 Feb, 1:165-175	2001	Publication	Traumatic injuries
Flyrock brochures and video. NIOSH Toolbox Training Materials	2006	Publication	Ground control
Reinforcing the Importance of Maintaining Good Blast Area Security	2006	Video	Ground control

Potential Intermediate Outcome for Traumatic Injuries

Remotely-Controlled Bulldozer on Coal Stockpiles

Background

Voids in coal stockpiles can entrap bulldozer operators

Approximately 500 bulldozers in the U.S are used to facilitate drawdown at the top of coal stockpiles. Environmental conditions, coal compaction, and other factors can result in voids in stockpiles which can entrap these machines. Since 1980, there have been 19 fatalities at coal stockpiles, the majority being bulldozer operators. Efforts by MSHA and others have led to the development of improved cab designs, high strength windows, and communications which have proven to save operator lives during dozer cover-ups. Providing remote control of the dozer has the potential to totally eliminate the danger to the operator by removing him/her from the machine. Previous attempts in the U.S. to remotely control the dozer were never fully implemented due to a variety of issues. One drawback was that the operator, when removed from the dozer, lost the feel of the machine. This resulted in significant inefficiencies during remote operation compared with on-board control.

Addressing this, NIOSH is engaged in research aimed at mimicking the feel of the machine by adding visual, audio, and vibratory feedback. The approach is to provide the remote operator with sufficient sensory cues so that he/she thinks they are actually operating the dozer on-board. The research project is a collaborative effort with a dozer manufacturer, Caterpillar, and a coal operator, ConsolEnergy. Caterpillar has provided the bulldozer with remote-controls and ConsolEnergy has provided access to their Eighty-Four stockpile. The hypothesis to be tested is that a simulated environment with visual, audio and motion feedback will enhance acceptance of remote control operation of dozers on coal stockpiles.

Potential Outcome

Upon project conclusion, recommendations will be formulated that can be used as guidance for stockpile operators contemplating conversion to remote-control. It is envisioned that the prototype hardware developed by NIOSH will be adapted and sold commercially by bulldozer manufacturers. A successful demonstration could ultimately lead MSHA to recommend remote control of dozers on stockpiles and in the long term, to an increased adoption of this method. This would result in a reduction of incidents and fatalities from dozer cover-ups by removing the dozer operator from the stockpile.

Outputs

1 Planned or completed output

Title	Year	Output Type	Strategic Goal
Recommendations for conversion of bulldozers to remote control - peer reviewed publication, SME Transactions	2007	Publication	Traumatic injuries

Potential Intermediate Outcome for Mine Disasters

Advanced Methane Control in Underground Coal Mines

Background

Methane ignition in the laboratory

The mining industry´s use of advanced mining technologies has resulted in an increase in methane emissions and the associated risk of explosions or fire. The inability to forecast the potential for hazardous emissions and accumulations of methane or frictional ignitions has led to injuries and deaths among coal miners in underground coal mine explosions. Recent major explosions have occurred in Utah (2 fatalities) in 2000, in Alabama (13 fatalities) in 2001, and in West Virginia (3 fatalities) in 2003.

Rates of methane emission are unpredictable as a result of changing geologic conditions, in situ gas content, and constantly evolving mining practices, methods, and equipment. In addition, the interaction among these variables is not well known. Methane reservoir simulation software will be used to design and evaluate methane control technologies and strategies for longwall gobs. This software will be combined with commercially available mine ventilation modeling software to help predict methane emissions.

Frictional ignitions of methane and other gases are still relatively common in U.S. coal mines. Numbers have averaged about 60 per year from 1995 to 2004. Coal-measure rocks from both ignition-prone and non-ignition-prone basins will be used to create an index of incendivity that will be forwarded to industry.

Potential Outcome

In 2007, a systematic set of best practices for methane control, as well as premining and active mining evaluation techniques, will be made available to mine operators. Mine engineers will be able to use these techniques in combination with the methane reservoir model to optimize mine design and methane control technology. This will enable a mine operator to better predict methane emissions throughout a mine and design appropriate methane control measures to reduce the risk of methane explosions.

By 2007, the NIOSH-developed modified direct-method apparatus will become commercially available, which will allow mine operators to obtain reliable data on gas content. This will improve the accuracy of the methane reservoir model and further reduce the potential for methane gas explosions.

A qualitative index of incendivity will also become available in 2007. It will provide the industry and regulatory personnel with guidance on the character and likelihood of frictional ignition events and is expected to reduce the number of events leading to mine fires and explosions.

Outputs

9 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Remote Gob Gas Venthole Monitoring and Cellular Telephone-Based Real-Time Data Transmission System Garcia-F; Diamond-WP; Marshall-JK | In: De Souze E, ed. Proceedings of the North American/Ninth U.S. Mine Ventilation Symposium (Kingston, Ontario, Canada). Lisse, Netherlands: Balkema, 2002; :324-329	2002	Publication	Mine disasters
Application of Numerical Models to Investigate Permeability Changes and Gas Emissions Around Longwall Mining Panels Esterhuizen-G; Karacan-CO | Proceedings of the 40th US Rock Mechanics Symposium (Anchorage, Alaska), CD-ROM, paper 05-744; :13 pp	2005	Publication	Mine disasters
Numerical Analysis of the Impact of Longwall Panel Width on Methane Emissions and Performance af Gob Gas Ventholes Karacan-CO; Diamond-WP; Esterhuizen-GS; Schatzel-SJ | In: Proceedings of the International Coalbed Methane Symposium (Tuscaloosa, AL; May 18-19, 2005). University of Alabama, 2005; :28 pp	2005	Publication	Mine disasters
Occurrence of Frictional ignitions in US underground coal mines, NIOSH RI	2006	Publication	Mine disasters
Kissell, F (ed.) - Methane Control Handbook - DPRB researchers prepared three chapters for this handbook: Explosion Hazards of Coal Dust in the Presence of Methane; Geologic Features and their Influence on Mine Gas Emissions; Forecasting Gas Content, Gas Emissions, and Gas Production from Coalbeds, NIOSH numbered publication	2006	Publication	Mine disasters
The influence of Geologic Factors on in situ Methane Contents and Gas Emissions - Proceedings, 11th US/North American Ventilation Symposium, State College	2006	Publication	Mine disasters
Numerical Modeling of Gas Flows in the Longwall Mining Environment for Methane Drainage and Ventilation Planning - Proceedings, 11th US/North American Ventilation Symposium, State College	2006	Publication	Mine disasters
Reservoir Simulation-based Modeling for Characterizing Longwall Methane Emissions and Gob Gas Venthole Production - International Journal of Coal Geology, peer reviewed	2006	Publication	Mine disasters
A Comprehensive Mine-Wide Gas Flow and Emissions Model - NIOSH RI	2009	Publication	Mine disasters

Potential Intermediate Outcome for Mine Disasters

Reducing Fire Hazards in the Metal-Nonmetal Mining Industry

Background

Full-scale test of noise abatement material in a cab

Between 1990 and 2001, 519 fires broke out in the metal and nonmetal segment of the mining industry, resulting in 308 injuries and 5 fatalities. These fires involved a diverse range of flammable materials, equipment, and ignition sources. Although much progress has been made in preventing and controlling fires in the U.S. mining industry, fires within the metal-nonmetal sector still occur at an average rate of about 40 per year. Every fire has the potential to cause significant numbers of injuries and loss of life. The metal-nonmetal mining industry lacks requirements for mandatory fire detection systems or devices that could warn miners of fire. Research on the causes of fires and the resultant fire hazards is being conducted as a basis for developing strategies, techniques, and products for detection, control, and prevention of fires. Fire safety and fire emergency preparedness training is being developed to address the unique problems of the metal-nonmetal mining industry.

Potential Outcome

In 2006, this project will develop simple, easily deployed, low-cost smoke sensors that could result in earlier fire detection and reduce worker exposure to fire hazards, smoke, and airborne contaminants. Strategies and guidelines for deploying these sensors will also be developed.

By 2007, combustible materials used in metal-nonmetal mines that should be subject to more stringent fire resistance ratings will be identified. Tests and guidelines for use of these materials will be developed. This will impact roughly 80% to 90% of all fires and injuries due to fire within the metal-nonmetal mining industry and will result in reductions in the number of fires and in injuries and fatalities due to fire.

Fire safety training programs and workshops will be developed and conducted from 2005 through 2007 using materials already developed for the coal mining industry as a guide. This will create and increase worker awareness about the hazards of fire and appropriate techniques for response.

A fire preparedness and response checklist for underground metal-nonmetal mines has been developed and is currently being field tested. The list will provide improved strategies and capabilities to prevent and respond to fire emergencies at underground metal-nonmetal mines. The Mine Safety and Health Administration is expected to adopt portions of the checklist for its training materials and for conducting mine fire prevention audits.

Outputs

7 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Flammability of Noise Abatement Materials Used in Cabs of Mobile Mining Equipment Litton-CD; Mura-KE; Thomas-RA; Verakis-HC | Proc: Fire & Materials 2003. London: Interscience Communications, 2003 Feb; :297-306	2003	Publication	Mine disasters
Fire Safety in Metal and Nonmetal Mines Workshop Smith-AC | Presented at the 10th Annual Safety Seminar for Underground Stone Mines, Dec. 6-7, 2005, Louisville, KY - 58 attendees.	2005	Workshop, Seminar, or OIB	Mine disasters
Fire detection and suppression systems for cabs of large mining equipment - peer reviewed publication, Fire Safety Journal	2006	Publication	Mine disasters
Mine Fire Preparedness and Response Checklist for Underground Metal and Non-Metal Mines - NIOSH IC	2006	Publication	Mine disasters
Fire safety training manual for M/NM mines - NIOSH RI	2007	Publication	Mine disasters
Fire detector evaluation for use in M/NM mines - peer-reviewed journal publication	2007	Publication	Mine disasters
Recommendations and guidelines for selection and use of flammable materials in the M/NM mining industry, NIOSH RI	2007	Publication	Mine disasters

Potential Intermediate Outcome for Mine Disasters

Managing Mine Fires

Background

Mine fires continue to be a major hazard in the coal mining industry. Between 1990 and 1999, 152 fires - 87 underground and 65 on the surface - were reported at underground coal mines. These fires resulted in one death and 47 injuries. During the same period, 51 underground fires (nine injuries) were reported in noncoal mines. Although the number of fires and injuries is relatively low, fires that break out in confined spaces have potentially catastrophic consequences.

Smoke reversal from a mine fire experiment

The dynamics of a mine fire - its initiation and growth and its interaction with ventilation, smoke movement, and the effectiveness of fire control methods - are not well understood.

Smoke reversal in a mine entry can pose hazardous consequences for mine evacuation and miner rescue. Inhalation of toxic fire-generated combustion products can be injurious or fatal to miners. The low visibility associated with smoke impedes safe miner escape and rescue. Smoke reversal in a mine entry is complicated by connections (open crosscuts and leakage paths) between the entry and other entries. The smoke layer that accumulates near the roof can migrate into parallel airways, depending on air velocity and the amount of leakage.

An important aspect of controlling a mine fire is to understand how rapidly a fire might spread. Using computational methods, it is possible to model fire spread in a mine entry by paying particular attention to entry dimensions, ventilation air velocity, fuel combustion properties, and char formation processes. This information can be used to develop ventilation control measures to retard or prevent fire spread.

Potential Outcome

By 2008, this research will result in a mine fire simulator that, in response to fire sensor data entered in real time, can determine appropriate smoke management methods and recommend safe escape routes for miners. Using the mine fire simulator in combination with commercially available atmospheric mine monitoring systems will enable mine operators to better plan and execute mine rescue and recovery activities, enhancing safety for escaping miners and mine rescue workers.

Outputs

6 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
The Critical Ventilation Velocity in Tunnel Fires - A Computer Simulation Hwang-CC; Edwards-JC | Fire Safety Journal, 2005 Apr; 40(3):213-244	2005	Publication	Mine disasters
CFD Modeling of Fire Spread Along Combustibles in a Mine Entry -Transactions, Society for Mining, Metallurgy and Exploration, Denver, peer reviewed	2006	Publication	Mine disasters
Fire Generated Smoke Reversal Through Crosscuts From Return to Intake---Experimental and Computational Study, Proceedings, 11th U. S. Mine Ventilation Symposium, State College	2006	Publication	Mine disasters
CO Dispersion From a Coal Mine Fire in a Mine Entry, Proceedings, 11th U. S. Mine Ventilation Symposium, State College	2006	Publication	Mine disasters
A mathematical model to determine the effect of ventilation on fire spread in underground coal mines, peer reviewed publication, Fire Safety Journal	2007	Publication	Mine disasters
A real-time mine fire simulator for smoke management in underground mines, NIOSH RI	2008	Publication	Mine disasters

Potential Intermediate Outcome for Mine Disasters

Reducing Fire Hazards in Underground Coal Mines

Background

Analyses of fires in the U.S. coal mining industry for the period 1990-2002 indicated that 110 of the 560 reported fires (both underground and surface) were the result of either a flame cutting or a welding operation. These fires resulted in 70 injuries and 2 fatalities. In a 2003 mine accident, a shaft explosion in West Virginia caused by flame cutting resulted in three fatalities and three injuries. The data also show that 17% of the reported underground mine fires were caused by spontaneous combustion. Three of these fires resulted in subsequent methane explosions.

Fire at an underground coal mine in Colorado

The root causes of fires and injuries caused by flame cutting or welding operations will be investigated. New and improved methodologies and technologies are being developed to prevent such fires. Promising direct interventions to prevent flame cutting and welding fires are being evaluated in field tests at underground coal mines. Recent spontaneous combustion occurrences in U.S. underground coal mines are being studied to determine the causative factors and the role of ventilation. These results are being used to develop computational fluid dynamic models to evaluate ventilation schemes to control spontaneous combustion, and to describe ventilation pathways through the immediate gob and the effect of methane control systems on these pathways.

Potential Outcome

Recommendations for changes to flame cutting and welding standards and regulations will be made during 2007. This will reduce the number of mine fires caused by cutting and welding operations. These recommendations will be easily applicable to the metal/nonmetal sector of the mining industry as well.

The project will also identify the best technologies and practices in mine ventilation and spontaneous combustion control to reduce spontaneous combustion, particularly in underground mines that have appreciable levels of methane. By 2009, this work will result in a better understanding and implementation of ventilation schemes as a dual process: control of both methane and spontaneous combustion, leading to a reduction in the number of spontaneous combustion events in underground coal mines.

Outputs

5 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Numerical modeling of gas flow in U.S. coal mine gob areas with bleeder ventilation systems - 11th U.S./North American Mine Ventilation Symposium	2006	Publication	Mine disasters
Root causes of flame cutting and welding fires in the U. S. coal mining industry - Transactions, Society for Mining, Metallurgy and Exploration Annual Meeting, peer-reviewed	2006	Publication	Mine disasters
Workshops and training aids to transfer flame cutting and welding research findings to the coal mining industry [2007-2008]	2008	Workshop, Seminar, or OIB	Mine disasters
Guidelines for flame cutting and welding and fire prevention in underground coal mines - NIOSH RI	2008	Publication	Mine disasters
Gob ventilation computer model to optimize the ventilation schemes to control spontaneous combustion in the U.S. underground coal industry [2009], Transactions, Society for Mining, Metallurgy and Exploration Annual Meeting, peer reviewed	2009	Publication	Mine disasters

Potential Intermediate Outcome for Mine Disasters

Communications and Decision Making During Mine Emergencies

Background

Decision-making during a simulated mine emergency

It is often during the first crucial minutes of a mine emergency, such as a fire or an explosion, that the activities and decisions determine the outcome. Inaccurate information and less-than-optimum decision-making contributed to the deaths of 13 miners in a coal mine explosion in Alabama in 2001.

Research is being conducted to gain a better understanding of initial responses during the first critical minutes of a mine emergency and to evaluate outcomes with respect to those responses. Focus groups are being conducted across the country with individuals who have been closely involved in emergency situations at mines to obtain their perspectives on the optimum strategies to pursue. Topics covered include initial communications, available information, judgments, and decision-making. The analysis of the data will result in training protocols and interventions to enhance initial response in the first crucial minutes of a mine emergency.

Potential Outcome

By 2008, this research is expected to result in a better understanding of the appropriate behavior of the mining workforce during emergencies. This will translate into a better understanding of the potential hazards posed by a mine emergency and will enable a quicker response and a more positive outcome to the emergency. Mine operators, government agencies, and emergency responders will be better trained and equipped to plan for emergencies. They will be able to incorporate successful strategies, improve response behaviors, and enhance decision-making skills during mine emergency and rescue operations. This research will thus reduce the exposure of miners to the hazards encountered in these situations. In addition, the sharing of this information on behaviors in the first critical moments of a mine emergency has application to the broader emergency response community.

Outputs

4 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
The Emergency Communication Triangle Mallett-L; Vaught-C; Brnich-MJ | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 99-157, 1999 Oct; :1-16	1999	Publication	Mine disasters; Surveillance and training
The First Critical Hours: Before the Mine Rescue Team Arrives, Proceedings, Sixth International Conference on Occupational Stress & Health "Making a Difference in the Workplace"	2006	Publication	Mine disasters
Communications and decision making during the initial phase of a mine emergency, Transactions, Society for Mining, Metallurgy and Exploration Annual Meeting, peer reviewed	2007	Publication	Mine disasters
Videotapes, workbooks and similar training interventions to transfer research findings to the mining industry - NIOSH communications	2007	Training	Mine disasters

Potential Intermediate Outcome for Mine Disasters

Utilization of Engineered Ventilation Systems in Large Opening Mines

Background

Propeller fans installed in a large-opening mine

Continuing and emerging air quality issues in meta-nonmetal mines deal with the presence of silica dust, diesel particulate matter (DPM), noxious gases (from diesel equipment, cutting and welding, and production blasts), and the lack of visibility due to fog. A study by the Mine Safety and Health Administration (MSHA) in 2003 found that nearly 22% of metal mines and over 16% of stone mines in the United States had air samples that exceeded the DPM regulatory limit of 400 $\mu g/m^3$ total carbon. Underground stone miners are frequently exposed to respirable crystalline silica dust in addition to DPM. Chronic overexposure to silica dust can lead to silicosis, a progressive, irreversible condition caused by deposition of silica dust in lung tissues. Analysis of MSHA´s compliance dust-sampling data collected from 1993 to 1998 showed that 15% of the dust samples from underground stone mines exceeded the permissible exposure limit (PEL) for silica dust. Certain occupations, namely truck drivers, crusher operators, front-end loader operators, and rotary drill operators, had a higher risk of exposure and, on average, 20% to 25% of the samples exceeded the PEL.

These issues are of particular importance in mines with large openings. However, these contaminants can be effectively reduced by using engineering controls such as cleaner engines and filters and proper ventilation methods. Adequate ventilation in these mines generally requires a combination of large air quantities and effective planning and placement of ventilation control devices, such as auxiliary fans and stoppings.

Potential Outcome

This project will lead to the use of flexible ventilation stoppings and various auxiliary fan types to increase face ventilation efficiencies. Highly efficient mine ventilation layouts will improve the delivery of ventilation airflow to the working face, thereby reducing worker exposure to airborne contaminants. By 2009, a comprehensive toolbox of ventilation guidelines in the form of a ventilation design handbook for large-opening underground mines will be available. These guidelines will lead to a significant increase in the percentage of large-opening mines that use a highly efficient, engineered ventilation system that provides improved air quality to miners.

Outputs

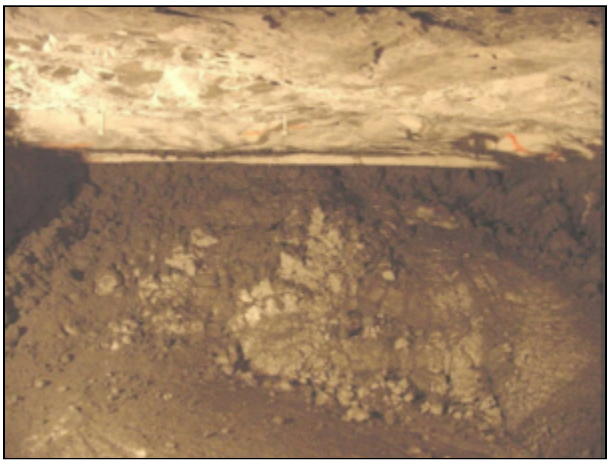
9 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Practical Techniques to Improve the Air Quality in Underground Stone Mines Grau-RH; Mucho-TP; Robertson-SB; Smith-AC; Garcia-SF | In: De Souze E, ed. Mine Ventilation: Proceedings of the North American/Ninth U.S. Mine Ventilation Symposium (Kingston, Ontario, Canada) Lisse, Netherlands: A. A. Balkema, 2002 Oct; :123-129	2002	Publication	Mine disasters; Respiratory diseases
NIOSH Ventilation Research Addressing Diesel Emissions and Other Air Quality Issues in Nonmetal Mines Grau-RH III; Robertson-SB; Mucho-T; Garcia-F, Smith-AC | Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., Transactions 2004, Vol. 316; :149-158	2004	Publication	Mine disasters
A Computer Software Program that Estimates Air Quantity Requirements in Large Opening Stone Mines Robertson-SB; Grau-RH; Dolgos-JG; Mucho-TP | In: Ganguli R, Bandopadhyay S, eds. Mine ventilation: Proceedings of the 10th U.S./North American Mine Ventilation Symposium (Anchorage, Alaska, May 16-19, 2004). Leiden, Netherlands: Balkema, 2004 May; :363-369	2004	Publication	Mine disasters
Novel Stopping Designs for Large Opening Metal/nonmetal Mines - Aggregate Manager Magazine	2006	Publication	Mine disasters
Working Mine Ventilation Layouts for Large Opening Stone Mines - Proceedings, 11th US/North American Ventilation Symposium, State College	2006	Publication	Mine disasters
Overview of Improved Mine Ventilation Practices in Large Opening Mines - Proceedings, 11th US/North American Ventilation Symposium, State College	2007	Publication	Mine disasters
Designing a Large Opening Mine using Ventilation Considerations - Aggregate Manager Magazine	2007	Publication	Mine disasters
Improving Face Ventilation in Large Opening Mines - Society for Mining, Metallurgy and Exploration Annual meeting, peer reviewed	2009	Publication	Mine disasters
Ventilation Design for Large-Opening Mines - NIOSH IC	2009	Publication	Mine disasters

Potential Intermediate Outcome for Mine Disasters

Remote Construction of Seals for Fire Control and Abatement

Background



Complete closure of a mine void using improved remote sealing technology

Since 2000, 18 underground coal mine fires have been reported in the United States. On average, three mine fires have occurred each year, and from 2000 to the present, a maximum of five mine fires have occurred in a 1-year period. It is thought that remotely constructed mine seals could have been used in over 60% of the fires as a safer means to control the fire and reduce hazards to mine emergency responders.

The direct approach to fighting and sealing off a mine fire places miners in proximity to the fire and exposes them to deadly hazards such as toxic combustion gases, heat, and deteriorating mine roof conditions. To reduce this exposure, an indirect approach of sealing and isolating the atmosphere or flooding the fire area is preferred.

Where safe underground access is impossible, fire seals must be constructed remotely. However, remote sealing often fails to close off the mine entry adequately. In this situation, the seals do not provide effective barriers to airflow or cannot be used to impound water. This research will improve the state of the art for construction of reliable and effective mine seals through engineering design and full-scale testing at the Lake Lynn Experimental Mine. A technology transfer program will disseminate research results to the mining industry.

Potential Outcome

By 2007, several remote-sealing alternatives will be available for mine fire emergencies. The successful use of these technologies will lead to efficient mine fire management and will reduce exposure of miners and mine rescue workers to the hazards of firefighting and rescue operations. If miners are trapped or barricaded inside a mine during a fire, remote sealing can provide an effective way to isolate them from the fire zone, improving their chances for survival and rescue.

Outputs

4 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Technology For Remote Mine Seal Construction Trevits-MA; Urosek-JE | 2002 SME Annual Meeting, Feb 25-27, Phoenix, Arizona, preprint 02-185. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2002 Feb; :1-4	2002	Publication	Mine disasters
Demonstration of Remote Mine Seal Construction Gray-TA; Trevits-MA; Crayne-LM; Glogowski-P | 2004 SME Annual Meeting, Feb 23-25, Denver, Colorado, preprint 04-194. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2004 Feb; :1-8	2004	Publication	Mine disasters
Remotely Installed Mine Seals for Mine Fire Control - Transactions, Society for Mining, Metallurgy and Exploration, Inc. Annual Meeting, St. Louis, peer reviewed	2006	Publication	Mine disasters
Evaluation of Remotely Installed Mine Seals for Fire Control, Proceedings, 11th U. S. Mine Ventilation Symposium, State College	2006	Publication	Mine disasters

Potential Intermediate Outcome for Mine Disasters

Prevention of Catastrophic Coal Dust Explosions in Mines

Background

Although much progress has been made in preventing disasters in mines, explosions still occur, sometimes producing multiple fatalities. There were serious underground coal mine explosions in 2000 in Utah (2 fatalities and 8 injuries), in 2001 in Alabama (13 fatalities and 3 injuries), and in 2003 in West Virginia (3 fatalities and 3 injuries). These events show that the mine explosion problem has not yet been solved.

Mapping debris from a partially destroyed stopping

Underground explosions can be prevented by minimizing methane concentrations through ventilation and methane drainage, by adding sufficient rock dust to stabilize coal dust, and by eliminating ignition sources.

A handheld coal dust explosibility meter (CDEM) is being developed as a more rapid and objective method to verify the rock dust content of coal and rock dust mixtures. Measurements are based on optical reflectivity for rapid in situ determination. Several commercial prototypes have been built, and in-mine evaluations by the Mine Safety and Health Administration (MSHA), the United Mine Workers of America, and various mine operators will continue through 2006.

Explosion effects can be mitigated by (1) the use of passive and active barriers to suppress explosions and (2) the use of high-strength seals to prevent the propagation of gob explosions into working areas of the mine. Research on the causes and mechanisms of gas and dust explosions, as well as on the use of passive and active barriers, will be conducted at the Lake Lynn Experimental Mine as a basis for developing techniques and strategies for explosion prevention, suppression, and mitigation in underground mines and surface facilities.

Potential Outcome

This research will reduce the likelihood of explosions in coal mines by providing the following:

- Recommendations on best practices to prevent and/or mitigate explosions in the mining industry by 2007.
- Improvements in the knowledge base of mining personnel regarding the recognition and prevention of explosions through presentations and videos to the mining industry, including training courses at MSHA´s National Mine Health and Safety Academy during 2006-2007.

- Recommendations for improved forensic accident investigation procedures for MSHA through discussions with and briefing reports to MSHA and through joint publications with MSHA (to be completed in 2006).
- The widespread use of the CDEM by the mining industry will improve management of day-to-day rock-dusting operations. This will help the operator quickly identify accumulations of combustible coal dust and reduce the risk of catastrophic coal dust explosions.

Outputs

10 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Experimental Mine and Laboratory Dust Explosion Research at NIOSH Sapko-MJ; Weiss-ES; Cashdollar-KL; Zlochower-IA | J Loss Prev Process Ind 2000 May; 13(3) :229-242	2000	Publication	Mine disasters
Coal Dust Inerting and Postexplosion Dust Sampling Research in a 1-M3 Laboratory Chamber and an Experimental Mine Cashdollar-KL; Going-JE | In: Proceedings of the 2003 Technical Meeting of the Eastern States Section of the Combustion Institute (The Pennsylvania State University, University Park, PA, October 26-29, 2003). Pittsburgh, PA: The Combustion Institute, 2003; :97-100	2003	Publication	Mine disasters
Weiss ES, Cashdollar KL, Harteis SP, Shemon GJ, Beiter DA, Urosek JE - Explosion Evaluations of Ventilation Stoppings. NIOSH RI	2006	Publication	Mine disasters
Technical evaluation of the coal dust explosibility meter - Transactions, Society for Mining, Metallurgy and Exploration Annual Meeting, peer reviewed	2006	Publication	Mine disasters
Explosion Evaluations of Mine Ventilation Stoppings - Proceedings, 11th U.S./North American Mine Ventilation Symposium, State College	2006	Publication	Mine disasters
Training Materials for MSHA and the mining industry on explosion hazard recognition and preventive measures for underground coal mines - NIOSH RI	2006	Publication	Mine disasters
Determination of the Sizes of Coal Dust in Intakes and Returns of Underground Mines - peer reviewed journal publication	2007	Publication	Mine disasters
Post-Explosion Dust Analyses as a Method of Studying Coal Dust Explosions - journal publication	2007	Publication	Mine disasters
Summary of LLEM Explosion Research, 1999 to 2004 - NIOSH RI	2007	Publication	Mine disasters
Explosion Temperatures of Metals and Other Elemental Dusts - Combustion and Flame, peer reviewed	2008	Publication	Mine disasters

Potential Intermediate Outcome for Ground Control

Improved Highwall Stability to Reduce Surface Mine Hazards

Background

Highwall failure at surface mine

Between 1995 and 2004, 44 miners died in slope failure accidents at surface mines in the United States. While less than 1% of reported accidents are associated with slope stability problems, slope failures were responsible for about 13% of surface mine fatalities. Research was conducted to reduce injuries and fatalities associated with slope failures in surface mines by investigating ways to minimize hazards associated with ground movements.

New technologies to improve slope stability information have been one focus of slope stability research. Hyperspectral imaging, interferometric radar, and time-lapse and video monitoring systems were developed and field tested in collaboration with other researchers (e.g., Dr. Louis Denes, Carnegie Mellon Research Institute; Dr. David Long, Brigham Young University). Prototype instruments were used to demonstrate that slope conditions and rock movements can be detected and recorded. Building on these technologies will result in practical commercial instruments to reduce hazards associated with unstable highwalls. One vendor (SiteWatch Systems, Irving, TX) now offers a trailer-mounted, solar-powered video surveillance system to mine operators after working with NIOSH researchers to develop a prototype.

A second focus of research has been to develop computer programs to assess the effectiveness of rock slope designs. Programs designed in collaboration with Dr. Stan Miller, University of Idaho, use fracture data collected by cell or line mapping on the slope to provide a probability as to whether a useful bench of a given width will be retained to catch rocks falling from upper levels.

A third focus has been to find ways to improve practices for working around mine slopes. A slope safety training video (*The Sky Is Falling*) was produced to improve worker awareness of the hazards associated with mine slopes. As industry uses the training materials (more than 600 copies of the video and trainer guides have been disseminated) the occurrence of injuries related to rock falls and slope failures in surface mining will decrease.

Potential Outcome

By 2010, the highwall monitoring technologies, computer programs, and user's guide promoted and developed with this research should improve the safety and reliability of slope design in fractured rocks, especially in conjunction with advances in automated fracture mapping. One immediate impact of the research has been the use of imagery to collect geotechnical data on mine slopes (Dr.

John Kemeny, University of Arizona). In addition, we expect that improved effectiveness of catch benches will result in fewer injuries in mines. Special emphasis will be to continue to work with academia, particularly mining and engineering schools where design and construction of catch benches are taught.

Outputs

10 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Advances in Remote Sensing Techniques for Monitoring Rock Falls and Slope Failures Girard-JM; Mayerle-RT; McHugh-EL | Proc 17th Intl Conference on Ground Control in Mining, 1998 Aug :326-331	1998	Publication	Ground control
A Portable Spectro-Polarimetric Imager: Potential Mine Safety and Geologic Applications Sabine-C; Denes-LJ; Gottlieb-M; Kaminsky-B; Metes-P; Maycrle-RT; Girard-JM | Proceedings of the Thirteenth International Conference, Applied Geologic Remote Sensing, Vancouver, British Columbia, Canada, 1-3 March 1999; 1:I190-I194	1999	Publication	Ground control
Current Research on Slope Movement in Mines: Use of Hyperspectral Imagery McHugh-EL; Girard-JM; Denes-LJ; Metes-P; Sabine-C | 14th International Conference on Applied Geologic Remote Sensing, 2000 Nov Las Vegas, NV :1-8	2000	Publication	Ground control
Computer Modeling of Catch Benches to Mitigate Rockfall Hazards in Open Pit Mines Miller SM; Girard JM; McHugh E | Pacific rocks 2000: Rock Around the Rim: Proceedings of the Fourth North American Rock Mechanics Symposium (NARMS 2000), ed. By J Girard, M. Leibman, C. Breeds, and T. Doe (Seattle WA, July 31-August 3, 2000). Balkema, :539-545	2000	Publication	Ground control
Simplified Hyperspectral Imaging for Improved Geologic Mapping of Mine Slopes McHugh-EL; Girard-JM; and Denes-LJ | In: Meech JA, Veiga SM, Viega MM, LeClair SR, Maguire JF, eds. Proc Third International Conference on Intelligent Processing and Manufacturing of Materials, 2001, (Vancouver, BC, July 29-Aug 2, 2001); CD-ROM (available from author)	2001	Publication	Ground control
Evaluating Techniques for Monitoring Rock Falls and Slope Stability McHugh-E; Girard-J | 21st Intl Conf on Ground Control in Mining. Morgantown, WV: West Virginia University, 2002 Aug; :335-343	2002	Publication	Ground control
Video Motion Detection for Real-Time Hazard Warnings in Surface Mines McHugh-E | 2004 SME Annual Meeting, Feb 23-25, Denver, Colorado, preprint 04-74. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2004 Feb; :1-9	2004	Publication	Ground control
Applications of the Point Estimation Method for Stochastic Rock Slope Engineering Miller-S; Whyatt-J; McHugh-E | Gulf Rocks 2004: Proceedings, Rock Mechanics Across Borders & Disciplines, 6th North American Rock Mechanics Conference, June 5-10, 2004, Houston, Texas. Report No. ARMA/NARMS 04-517. Alexandria, VA: American Rock Mechanics Association, 2004 Jun; :1-12	2004	Publication	Ground control
Analysis of Bench Crest Performance at the Yellowstone Mine: A Case Study Whyatt-J; McLaughlin-M; Miller-S | Proceedings of the 39th Symposium on Engineering Geology and Geotechnical Engineering: Research to Practice, May 18-19, 2004. M. McLaughlin and R. McNearny, eds., Butte, MT: Montana Tech of the University of Montana, 2004 May; :149-163	2004	Publication	Ground control
NIOSH Computer Programs for Bench Crest Failure Analysis in Fractured Rock Whyatt-J; Miller-S; Dwyer-J | In: Dessureault SD, Ganguli R, Kecojevic V, Dwyer JG, eds. Application of Computers and Operations Research in the Mineral Industry. Proceedings of the 32nd International Conference (APCOM) (Tucson, AZ, March 30-April 1, 2005). Balkema, 2005; :439-446	2005	Publication	Ground control

Potential Intermediate Outcome for Ground Control

Reducing Injuries by Improving Shotcrete Design Criteria

Background

Portable shotcrete panel tester

Falls of ground are one of the leading causes of injuries and fatalities in underground mines. During the 1990´s, gold mining expanded significantly in Nevada. Most of the geological formations are in weak rock, and the occurrence of injuries caused by rock falls doubled.

NIOSH collaborated with several underground gold mines in Nevada to evaluate the use of fiber-reinforced shotcrete against the standard application of steel screen and shotcrete. The amount of fibers was varied to determine the amount that would produce optimum support performance. To conduct this work, an Australian round panel testing system was designed, built, and tested. This system gives mines the capability of testing shotcrete in situ to optimize the design and engineering parameters of the support application. The field test confirmed there were statistically significant improvements in ground control when fiber-reinforced shotcrete was used and subsequently improvements in the safety of the underground miners. Several other mines in Nevada have utilized these tests to improve their underground support. The panel tests conducted at the mine showed positive results for initial failure and energy absorption. With this testing program, mine engineers can determine the characteristics of the shotcrete on site.

Potential Outcome

The application of fiber-reinforced shotcrete as an alternative to shotcrete reinforced with steel screen reduces worker exposure to potential rock falls and to materials-handling injuries by eliminating the time and manual labor involved in placing screen panels during installation. Research results also indicate that fiber is more effective in reinforcing shotcrete and thus improves the performance of primary support. When this research is completed, design criteria will be published to guide selection and application of shotcrete as a means of rock support. As this technology is adopted and applied by the mining industry over the next 5 years, fewer injuries caused by rock falls should result.

Outputs

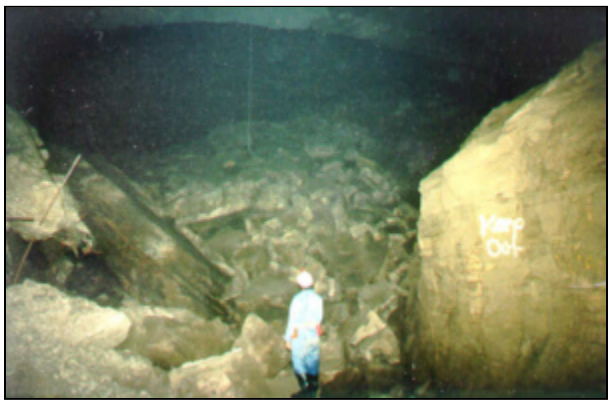
3 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Tests of Fibre-Reinforced Shotcrete at the Chief Joseph Mine, Butte, Montana Martin-L; Dunford-J; MacLaughlin-M; Cronoble-R | Presentation at annual meeting of SME, Salt Lake City, UT, Feb. 28-Mar. 2, 2005. Preprint 05-20, 2005; :6 pp	2005	Publication	Ground control
New Methods to Determine Shotcrete Adhesion in Mines - International Journal of Rock Mechanics and Mining Science	2006	Publication	Ground control
Effects of Fiber Types on Resin Reinforced Shotcrete Panels - International Conference on Ground Control in Mining	2007	Publication	Ground control

Potential Intermediate Outcome for Ground Control

Improved Pillar Design in Metal and Industrial Mineral Mines to Reduce Ground Control Hazards

Background



Roof failure in a lead mine

Room-and-pillar mining is the most widely used underground mining method in the world and, in practice, is utilized in one form or another in most other procedures, particularly during mine development. In the United States, various types of room-and-pillar methods have been used to mine a broad range of mineral commodities, including lead and zinc in Missouri, trona in Wyoming, potash and uranium in New Mexico, and limestone, coal, and salt throughout the country. Accurate design of pillars left in place to support the roof is critical to maintaining a safe mine. If the dimensions of these remnant support pillars and the room spans between pillars are not designed properly, the long-term stability of underground workings can be compromised, resulting in catastrophic chain pillar failures and dramatic collapses of large areas underground. Stability problems are often exacerbated through attempts to increase resource recovery by reducing the size of support pillars and/or mining high-grade remnant ore pillars, which can create large unsupported roof spans or spans that depend on backfill to carry the overburden load. During the last 10 years, roof falls have been the fifth leading cause of mining accidents, resulting in over 1,500 accidents per year.

Research is being conducted at underground lead mines to gain a better understanding of the conditions that cause roof and support pillar failures and to develop engineering practices that will reduce these ground fall hazards. Data are currently being collected and analyzed from instruments installed in support pillars in a retreat section. Another section has been targeted for additional instrumentation because a wide roof span will be supported with cemented backfill. In conjunction with instrument data, numerical modeling results are being used to analyze the pre- and post-yield stress-versus-strain behavior of pillars to quantify their capability of supporting the mine roof before and after they fail.

Potential Outcome

Collaborative research with the Doe Run Co. in one of the company´s seven mines in the Missouri New Lead Belt has addressed concerns regarding the safe extraction of support pillars. By using visual observations, numeric modeling, and instruments to evaluate remnant pillar extraction in a test section of the mine, safety guidelines for maximum roof span, required backfill strength, and instrument placement design were established and published in conference proceedings. The mine staff´s goal of no lost-time injuries during pillar extraction was met the first 9 years after guidelines from the test section were implemented.

The future impact from this research will be to use measurements of pillar behavior to develop more precise guidelines for pillar design. This will immediately benefit the seven operating mines in the New Lead Belt, and the methodology can be applied to all pillar mines. This research received the Applied Rock Mechanics award from the American Rock Mechanics Association in 2004.

Outputs

12 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Stability of Backfilled Cross-Panel Entries During Longwall Mining Seymour-B; Tesarik-D; Larson-M; Shoemaker-J | Proc 17th International Conference on Ground Control in Mining, 1998 Aug :11-20	1998	Publication	Ground control
Material Properties Affecting the Stability of a 50-Year-Old Rock Dump in an Active Mine Tesarik-DR; McKibbin-RW | NIOSH Report of Investigations 9651, 1999 Dec; :1-28	1999	Publication	Ground control
Long-Term Stability of a Backfilled Room-and-Pillar Mine Tesarik-D, Seymour-B, Yanske-T | Field Measurements in Geomechanics. Proceedings of the 5th International Symposium on Field Measurements in Geomechanics, Singapore, Dec. 1-3, 1999, C. F. Leung, S. A. Tan, and K. K. Phoon eds., Balkema, 1999 Dec; :431-435	1999	Publication	Ground control
Determination of In Situ Deformation Modulus for Cemented Rockfill Tesarik-DR; Seymour-JB; Jones-FM | Technology Roadmap for Rock Mechanics, 10th Congress, International Society for Rock Mechanics (Sandton [Johannesburg], S. Africa, Sept. 8-10, 2003), S. African Institute of Mining and Metallurgy Symp. Series, S33, Vol. 2, 2003 Sep; :1209-1220	2003	Publication	Ground control
Post-Failure Behavior of Two Mine Pillars Confined with Backfill Tesarik-DR; Seymour-JB; Yanske-TR | International Journal of Rock Mechanics and Mining Sciences, vol. 40, 2003; :221-232	2003	Publication	Ground control
Temperature Corrections to Earth Pressure Cells Embedded in Backfill Tesarik-DR; Seymour-JB; Williams-TJ; Martin-LA; Jones-FM | NIOSH Report of Investigations # 9665, Spokane, WA, December, 2005. 32pp.	2005	Publication	Ground control
Deformation in Undercut Backfill Cap - CIM	2006	Publication	Ground control
Backfill Span Stability Study at the Turquoise Ridge Mine, NV - Proceedings of the U.S. Rock Mechanics Symposium	2006	Publication	Ground control
Long-term Rock and Backfill Monitoring Using Vibrating Wire Instruments - paper in Field Measurements in Geomechanics	2007	Publication	Ground control
Practical Guidelines for Monitoring the Ground Support Behavior of Cemented Backfill - SME Transactions Paper	2007	Publication	Ground control
Support Pillar Behavior During Retreat Mining in a Lead/Zinc Mine - paper at International Backfill Symposium	2008	Publication	Ground control
Monitoring Regional Ground Conditions During Pillar Extraction - paper at U.S. Rock Mechanics Symposium	2009	Publication	Ground control

Potential Intermediate Outcome for Ground Control

Avoiding Inundations: Developing Guidelines for Mining near Bodies of Water

Background

Rock bursts, coal bumps, and other large-scale dynamic failures represent serious ground control problems facing miners in certain industry sectors. These low-probability/high-consequence events often result in severe injuries or death and have the potential to affect an entire underground workforce. When mining near bodies of water, dynamic strata failure also poses potential hazards as a result of changes in rock mass permeability and shaking-induced damage to impoundment structures. An inability to address these problems effectively can result in resource abandonment and/or mine closure and a significant economic impact on entire communities.

Surface seismometer installation

Potential Outcome

Research personnel are engaged in joint demonstration and research projects with the mining industry using seismic monitoring tools to advance worker safety through several different avenues. Expected results include:

- Providing quantitative understanding of dynamic failure processes for developing effective hazard mitigation techniques.
- Providing data that can be used to develop empirical ground motion relations for establishing guidelines for safe mining near bodies of water.
- Facilitating adoption of technology and/or guidelines by industry to avoid or mitigate hazards.

By 2010, the results of this research will provide mine operators with the techniques needed to mine safely around bodies of water.

Outputs

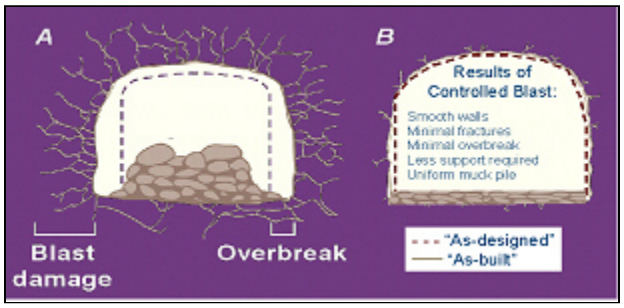
9 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Automated-PC-Networked-Based Seismic Monitoring Systems Applied to Mining Hazards Research Swanson-P | Seismological Research Letters, 71(1), 2000; :234	2000	Publication	Ground control
Development of an Automated PC-Network-Based Seismic Monitoring System Swanson-P | Proceedings of the 5th International Symposium on Rockbursts and Seismicity in Mines (Johannesburg, S. Africa, Sept. 17-19, 2001), G. van Aswegen, R.J. Durrheim, and W.D. Orlepp, eds., S. African Institute of Mining and Metallurgy, Johannesburg, S. Africa, 2001 Dec; :11-17	2001	Publication	Ground control
Feasibility of Using Laser-Based Vibration Measurements to Detect Roof Fall Hazards in Underground Mines Swanson-P | In: Proceedings of the Fifth International Conference on Vibration Measurement by Laser Techniques: Advances and Applications. Bellingham, WA: International Society for Optical Engineering (SPIE), Vol. 4827, 2002 :541-552	2002	Publication	Ground control
Seismic Event Data Acquisition and Processing: Distribution and Coordination Across PC-Based Networks Swanson-P; Kenner-B; Krahenbuhl-T | In Application of Computers and Operations Research in the Mineral Industry: Proceedings of the 30th International Symposium (APCOM 2002), ed. By S. Bandopadhyay (Feb. 25-27, 2002, Phoenix, AZ). Soc. Of Min. Metall., and Explor., Littleton, CO, 2002 Feb; :637-647	2002	Publication	Ground control
Damage Delineation in Structures Using Laser Vibrometry and Remote Excitation Swanson-P; Rettkowski-J | Proc 2004 SEM X Intl Congress and Exposition on Experimental and Applied Mechanics (Costa Mesa, CA, June 7-10, 2004). Bethel, CT: Society for Experimental Mechanics, 2004 Jun; :1-7	2004	Publication	Ground control
Monitoring Longwall Coal Mine Seismicity With a Wireless Strong-Motion Accelerometer Network- Paper in the Proceedings of the U.S. Rock Mechanics Symposium	2006	Publication	Ground control
Relationship Between Ground Motions, Seismic Event Magnitude and Distance at a Western Longwall Coal Mine - peer reviewed paper in the Journal of Geophysical Research	2007	Publication	Ground control
Seismically Determined Longwall Coal Mine Failure Mechanisms - peer reviewed paper in the International Journal of Rock Mechanics and Mining Science	2008	Publication	Ground control
Real-time Seismic Monitoring of a 100-Square Mile Longwall Coal Mining District - Paper in the Proceedings of the International Conference on Ground Control in Mining	2009	Publication	Ground control

Potential Intermediate Outcome for Ground Control

Improved Mine Safety through Optimized Extraction

Background



Rock excavated with (A) excessive blasting and (B) controlled blasting

Falls of ground are a significant hazard for miners and a leading cause of fatalities. MSHA data from 1998-2002 indicate that 61 of 141 (43%) of the underground fatalities during that period were caused by fall of ground. Where drill-and-blast techniques are used to excavate rock, poor blasting design or practices can exacerbate support problems, increasing worker exposure to hazards. Heavily damaged rock surrounding excavations requires more scaling, more support, and hence more rock bolt drilling than less-damaged rock. Substantial damage to the rock mass and poor blasting practices can also contribute to rock falls even after support systems have been put in place and may contribute to additional health and safety hazards involving:

1. Secondary breaking of oversize rock, manually or by drilling and blasting,
2. Undetonated explosives in muck piles, blast hang-ups, or an increase in noxious fumes,
3. Overbreak resulting in irregular opening surfaces that negatively impact ventilation and create uneven roadways, or
4. Ground shocks of sufficient intensity to damage mine equipment and infrastructure.

A number of cases of successful controlled blasting trials at mining operations have been published. However, even though techniques to minimize blasting damage exist, they are not systematically being applied throughout the U.S. mining industry. The goal of the proposed research is to provide the design criteria for optimizing blast designs and to demonstrate that better perimeter control and support system designs for excavations that incorporate advanced fragmentation techniques can significantly decrease the number of accidents associated with ground fall injuries from blast-damaged rock. Major project tasks include:

1. Evaluation of both laboratory and field of blast damage models to validate those that realistically predict the relationship between charge density, explosive energy, distance, rock material properties, rock structure, and rock damage in a spectrum of rock types,
2. Building a database of dynamic rock properties and developing laboratory and field analytical methods to assist industry in predicting the extent of blast damage,
3. Developing a fragmentation/support index that uses geological and geotechnical assessments to estimate rock blastability, rock mass quality, and support requirements,
4. Assessing current industry blasting practices at cooperating mines to quantify results of varying blast designs,
5. Conducting field demonstrations of optimized rock extraction that include improved support application, and

6. Conducting a thorough cost analysis to evaluate and compare costs of industry´s current practices to the NIOSH-optimized rock extraction systems.

Results of the research will be communicated to the mining community and the effectiveness of this research in changing blasting practices and reducing injury rates due to ground-control-related accidents will be assessed.

Potential Outcome

This research will develop new, scientifically valid, yet practical methods to provide recommendations on blast design, blast damage assessment, safer scaling, rehabilitation, and ground support installation. The efficiencies gained by integrating the design of the excavation/support process will result in a reduction of fatalities and traumatic injuries when rock is blasted in underground mines. The results of this research will be available to industry by 2010.

Outputs

11 Planned or completed outputs

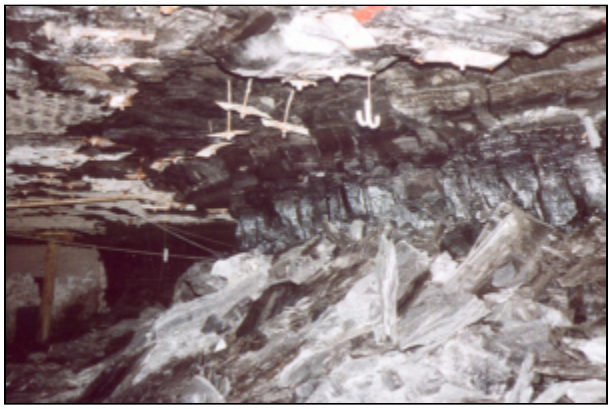
Title	Year	Output Type	Strategic Goal
Near Field Effects Due to Blasting - Paper in the Proceedings of the Symposium on Engineering Geology and Geotechnical Engineering	2006	Publication	Ground control
Sprayable Liner Flexibility Tests on Low RMR Rock Types - Paper in the Proceedings of the International Conference on Mechanics of Jointed and Faulted Rock	2006	Publication	Ground control
Overview of Current and Emerging Technologies for Performing Blast Damage Assessment in Underground Mines - Paper in the Proceedings of the International Conference on Ground Control in Mining	2006	Publication	Ground control
Theoretical Fundamentals of the New NIOSH Controlled Blasting Software - Paper in International Journal of Rock Mechanics and Mining Science	2006	Publication	Ground control
A Description of the NIOSH Software for Controlled Blasting in Tunneling - Paper in Journal of Safety Research	2006	Publication	Ground control
A Comparison of Cylindrical Charge Models - Paper in the International Journal for Blasting and Fragmentation	2006	Publication	Ground control
An Economic Evaluation of Perimeter Control Blasting in Drifting - Paper at the annual meeting of Soc. For Mining, Metallurgy, and Exploration	2006	Publication	Ground control
Laboratory Determination of Dynamic Rock Properties - Paper in the International Journal of Rock Mechanics and Mining Science	2006	Publication	Ground control
A New Procedure for Damage Zone Prediction in Rock - Ph.D. dissertation	2006	Publication	Ground control
Blasting Response in a Weak Rock Mass and Its Effect on Ground Support/Ground Instability - Paper in the Proceedings of the International Conference on Mechanics of Jointed and Faulted Rock	2007	Publication	Ground control
The NIOSH Initiative for Promoting Safer, More Economic Drifting in Underground Metal/Non-Metal Mines, Proceedings of the International Symposium Fragblast -8, Santiago, Chile, 2006 (abstract accepted)	2006	Publication	Ground control

Potential Intermediate Outcome for Ground Control

Multiple-Seam Mining Design Guidelines

Background

Studies show that 70% of underground coal mines face multiple-seam mining situations where the likelihood of encountering hazardous ground conditions is high. Knowing the location of prior mining, planning engineers may seek to access and mine new reserves above or below old workings. In such situations, two common questions arise:



Ground control problems created in the seam 170 feet above an extracted longwall panel

1. Will workings above or below cause excessive stresses in the proposed workings that could lead to rock falls, pillar bumps, or water inundations?
2. Will subsidence from workings below cause destructive ground control conditions in the upper seam?

Whether an adverse multiple-seam mining situation exists or not depends on numerous factors, including mining geometry, mine design, and geology. Project researchers have collected well over 250 case histories of multiple-seam mining interactions. Case parameters include geometric factors (depth, seam thickness, and interburden thickness), geologic factors (roof rock CMRR, percentage of sandstone in interburden), mining factors (Analysis of Retreat Mining Pillar Stability factor, or ARMPS, panel width, percentage of extraction), and finally a rating that describes the degree of interaction, from "none" to "mining abandoned." Using the boundary-element program LaModel, project researchers are presently examining numerous case histories to quantify the stress and displacement conditions that may lead to adverse multiple-seam mining interactions.

Potential Outcome

Based on statistical analyses of the case history database and numerical models of failure mechanics, design tools will be developed for evaluating and controlling potential multiple-seam mining interactions in 1 year. This design tool will take information about mining geometry, mine design, and geology and evaluate the potential for a multiple-seam mining interaction. In addition, the design tool will forecast the likely magnitude of the interaction. This tool will likely take a form similar to the successful ARMPS program and is tentatively named ARMPS-MSM (for multiple-seam mining).

These design tools will be widely distributed to our stakeholders through classes at the MSHA Academy and open-industry briefings throughout the coal fields. It is expected that many mines exposed to multiple-seam interactions will employ ARMPS-MSM to recognize hazardous conditions before an event occurs, and either avoid them or implement control strategies.

Outputs

9 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Using Site Case Histories of Multiple Seam Coal Mining to Advance Mine Design Ellenberger-JL; Chase-FE; Mark-C; Heasley-KA; Marshall-JK | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 22nd Intl Conf on Ground Control in Mining. Morgantown, WV: West Virginia University, 2003 Aug; :59-64	2003	Publication	Ground control
Collaborative Study of Multiple Seam Experience at Harris Mine Chase-FE; Worley-P; Mark-C | Paper in Proc. 24th Intl. Conf. on Ground Control in Mining, West Virginia University, Morgantown, WV, 2005, pp. 79-85	2005	Publication	Ground control
Failure Mechanics of Multiple Seam Mining Interactions Zipf-RK | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 24th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University; :93-106	2005	Publication	Ground control
Multiple Seam Design Software - Open Industry Briefing to be held in Beckley, WV; Norton, VA; Pikeville, KY; and Grand Junction, CO	2006	Workshop, Seminar, or OIB	Ground control
Multiple Seam Design Software - Open Industry Briefing to be held in Beckley, WV; Norton, VA; Pikeville, KY; and Grand Junction, CO	2007	Workshop, Seminar, or OIB	Ground control
Multiple Seam Design Software - Open Industry Briefing to be held in Beckley, WV; Norton, VA; Pikeville, KY; and Grand Junction, CO	2008	Workshop, Seminar, or OIB	Ground control
Extreme Multiple Seam Mining in the US - SME Annual Meeting	2006	Publication	Ground control
Design for Predicating, Preventing, and Controlling Multiple Seam Interactions - 25th International Conference on Ground Control in Mining	2006	Publication	Ground control
Software Package: ARMPS-MSM (multiseam mining)	2006	Software	Ground control

Potential Intermediate Outcome for Ground Control

Design of Mine Ventilation Stoppings

Background

Failure of mine ventilation stopping from inadequate transverse load capacity

Stoppings play a key role in controlling ventilation throughout an underground mining complex. The law requires that they provide a minimum transverse load capacity (the force acting on the face of the stopping) of 39 pounds per square foot of area. This requirement is based on a freestanding analysis of the stopping, meaning that, by itself and without any restraint on the ends of the wall, the wall must be able to take pressure without failing. Investigators believe that this assumption inaccurately addresses the in-mine service load condition and as such, endangers mine workers by allowing structures with low transverse load capacities to be employed anywhere in a mine. These stoppings are more prone to failure from pressure spikes caused by roof falls or ground pressures that squeeze the stoppings beyond their capacity. In addition, premature failures of stoppings pollute mine air with dangerous gases and dusts that can contribute to catastrophic explosions. If an explosion does occur, widespread damage to inadequately designed stoppings can make it more difficult to contain the fire. Efforts to reestablish ventilation can also put miners and rescue workers in danger following an explosion.

NIOSH is conducting research to show that arching is a more valid loading condition for stopping design and is working to develop a test protocol to evaluate the true loading capacity and limitations of block stoppings under arching conditions. Research to date has shown that transverse loading under arching conditions can be an order of magnitude higher than that considered in freestanding wall analysis and is directly dependent on block strength and wall geometry, not sealant properties. Since the current trend is toward the use of lightweight block materials to reduce the amount of physical strength required during construction (which in turn reduces handling injuries), it is imperative to understand that lower-strength, lightweight block materials will also significantly degrade the transverse load capacities of stoppings.

Potential Outcome

Proper design guidelines will ensure that stopping capacity matches the conditions in which they will be used in a mine. The impact of these guidelines will be to move the United States toward ratings for stoppings that are more indicative of their true transverse load capacity rather than one design for all applications as now permitted by mining law. Ultimately it is expected

that the mining law itself will be modified to recognize the design factors (currently ignored) needed to achieve a more appropriate design goal. Another future impact of this work will be the development of strain-softening materials that can preserve the transverse load capacity of the stopping at an acceptable level.

Outputs

5 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Numerical Modeling for Increased Understanding of the Behavior and Performance of Coal Mine Stoppings Burke-LM; Iannacchione-AT; Barczak-TM; Westman-EC | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining (August 3-5, 2004). Morgantown, WV: West Virginia University, 2004; :112-118	2004	Publication	Ground control
Load and Deflection Response of Ventilation Stoppings to Longwall Abutment Loading: A Case Study Oyler-DC; Hasenfus-G; Molinda-GM | In: Peng SS, Mark C, Khair AW, eds. Proceedings of the 20th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2001 Aug; :34-41	2001	Publication	Ground control
Transverse Load Capacities of Dry-Stacked Block Mine Ventilation Stoppings Under Rigid Arching Loading Conditions - 11th U.S./North American Mine Ventilation Symposium, Penn State University, June 5-7, 2006	2006	Publication	Ground control
Evaluation of the Transverse Load Capacity of Block Stoppings for Mine Ventilation Controls (PhD dissertation)	2006	Publication	Ground control
Establishing More Appropriate Design Criteria for Mine Ventilation Stoppings - Annual SME Meeting, February 2007	2007	Publication	Ground control

Potential Intermediate Outcome for Ground Control

Roof Span and Pillar Layout Guidelines for Stone Mines

Background

Pillar rib failure in a limestone mine

The room-and-pillar method is used in all operating underground stone mines in the United States. The dimensions of the pillars and roof spans in these mines are largely chosen on the basis of past experience without consideration of the local geological conditions that affect stability. A consequence is that unexpected rock falls from the roof and ribs of the workings can lead to injuries and fatalities among mine workers, and, in fact, have been the largest single cause of fatalities in underground stone mines over the past decade. This project will provide guidelines for roof spans and pillar layouts so that mine designers and operators can proactively design stable excavations to reduce the hazards associated with uncontrolled rock falls.

The project is being carried out using empirical methods in which case histories of stable and unstable mine workings (roof spans and pillars) in limestone mines in the eastern United States are evaluated to establish relationships between rock characteristics and stability. At each site, data on rock mass properties causes of instability, support techniques, and mining practices are being collected. These case histories will form a database for the development of design guidelines.

The case histories are being supplemented by numerical models and laboratory tests on rock samples from the mines to provide additional information on rock strength. The numerical modeling is being conducted to better understand the failure mechanics of pillars in hard, brittle rock and as part of the evaluation of the case studies.

Potential Outcome

The research will reduce the risk of rock falls in the more than 100 operating underground limestone mines. Project impacts will be achieved following 4 years of research by providing:

1. A methodology for assessing rock mass strength in underground stone mines based on current rock classification methods. In situ stress issues will also be addressed.
2. Design guidelines for pillar dimensions and pillar layouts based on local rock mass characteristics. Emphasis will be on slender pillars, which are more likely to be unstable than wider pillars.

3. Guidelines for designing stable roof spans to suit local rock mass and rock stress conditions.

Outputs

8 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Pillar Stability Issues Based on a Survey of Pillar Performance in Limestone Mines - International Conference on Ground Control in Mining	2006	Publication	Ground control
Proposed Design Procedures for Pillars in Limestone Mines - Mining Engineering (refereed journal)	2007	Publication	Ground control
Survey of Roof Stability in Limestone Mines - 2007 meeting of the Society for Mining, Metallurgy, and Exploration (SME)	2007	Publication	Ground control
Roof Stability Mechanics in Limestone Mines - 2007 U.S. Rock Mechanics Symposium	2007	Publication	Ground control
Design Procedures for Stable Roof Spans in Underground Limestone Mines - Mining Engineering (refereed journal)	2008	Publication	Ground control
Design Issues Related to the Strength of Slender Limestone Pillars - 2006 meeting of the Society for Mining, Metallurgy, and Exploration (SME)	2006	Publication	Ground control
Development of Design Guidelines for Stable Roof Spans in Limestone Mines - 2008 U.S. Rock Mechanics Symposium	2008	Publication	Ground control
Survey of Pillar Performance in Underground Limestone Mines - Open Industry Briefing (OIB) Underground Stone Safety Conference	2006	Workshop, Seminar, or OIB	Ground control

Potential Intermediate Outcome for Ground Control

Reducing Ground Fall Hazards in Coal Mines with Low Strength Roof

Background

Analysis of MSHA statistics indicates that mines accounting for just 20% of underground coal production were responsible for 60% of all roof falls reported to MSHA between 1995 and 2003. These mines are located primarily in the Illinois and northern Appalachian coal basins. Reducing the number and rate of ground falls at these mines is a major concern for MSHA and for the mine operators.

Ground fall in low-strength roof resulting from roof bolt failure

Underground coal miners face two significant hazards associated with falls of ground: roof collapse and flying pieces of rock. Both types of hazards are more likely when roof strength (uniaxial compressive strength, or UCS) is less than 5,000 psi and the Coal Mine Roof Rating (CMRR) value is less than 40. Unfortunately, many of the ground control safety technologies developed for the broad range of U.S. mining conditions, such as CMRR and the Analysis of Roof Bolt Systems (ARBS), tend to be less useful when applied to mines with extremely weak roof.

This 4-year project will begin in FY 2006, with Peabody Energy, Black Beauty Coal, RAG Coal, and Anker Energy expressing interest in collaborating with NIOSH. The research will

1. develop techniques for characterizing the strength and moisture sensitivity of weak roof,
2. suggest guidelines for panel orientation, length, and duration while considering the time-dependent strength of the roof,
3. develop methodologies for integrating supplemental and primary supports for maximum effectiveness, and
4. enhance the use of roof screens through ergonomic evaluations, machine modifications, economic evaluations, and educational and information transfer programs.

Potential Outcome

The project will culminate in a comprehensive set of design technologies for operating in weak roof while addressing exploration, mine layout, roof support, and rock fall prevention. Project results will be transferred to the mining community in a series of open-industry briefings. Implementation of these design technologies should result in a 50% reduction in the number of roof falls at the target mines, which will in turn reduce the overall number of roof falls in the United States by 30%. The enhanced use of roof screening should reduce the number of rock fall injuries by 25% nationwide.

Outputs

10 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Preventing Falls of Ground in Coal Mines With Exceptionally Low-Strength Roof: Two Case Studies Mark-C; Molinda-GM; Burke-LM | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proc 23rd Intl Conf on Ground Control in Mining, Morgantown, West Virginia, August 3-5, 2004. West Virginia University, 2004 Aug; :220-227	2004	Publication	Ground control
Make it Safer With Roof Screen NIOSH | NIOSH 2004 Jan; :Video (VHS format)	2004	Video	Ground control; Surveillance and training; Traumatic injuries
Ground Control in Australian Weak Roof Mines - US-Canada Rock Mechanics Symposium, Vancouver, Canada	2007	Publication	Ground control
Effect of Time and Moisture on the Strength of Coal Measure Rocks - US-Canada Rock Mechanics Symposium, Vancouver, Canada	2007	Publication	Ground control
Application of the Personal Bolter Screen for Roof Control. 26th International Conference on Ground Control in Mining	2007	Publication	Ground control
Economic Analysis of Roof Screen Installation in the Underground Coal Mines. Annual Meeting of the American Society of Safety Engineers	2008	Publication	Ground control
Evaluation of Geophysical Techniques for Predicting Rock Strength from Boreholes - 27th International Conference on Ground Control in Mining	2008	Publication	Ground control
Numerical Modeling of Primary and Supplemental Support Interaction - SME Annual Meeting	2008	Publication	Ground control
Comprehensive Ground Control Design Methodology for Weak Roof - 28th International Conference on Ground Control in Mining	2009	Publication	Ground control
The Coal Mine Roof Rating (CMRR) - A Decade of Experience. J. of Coal Geology, in press	2006	Publication	Ground control

Potential Intermediate Outcome for Ground Control

Highwall Mining Stability Guidelines

Background

Highwall mining is an important coal mining method in the United States and may account for approximately 4% of the total U.S. coal production. Highwall stability is the major ground-control-related safety concern in highwall mining. Studies have shown that three of the nine fatalities connected with auger and highwall mining in the last 20 years were caused by highwall collapse, and the only fatality in the last 5 years was due to highwall collapse. Thus, ensuring highwall stability through proper ground control engineering is of paramount importance to safe highwall mining operations.

Typical web and barrier pillar used in highwall mining

MSHA recognizes the safety concerns associated with highwall mining and requires each portable auger or highwall mining operation to develop and follow an appropriate highwall ground control plan that addresses web spacing and other measures necessary for safe recovery of the resource at high rates of recovery. A proper ground control plan for highwall mining should usually specify web pillar width, barrier pillar width, and number of holes between barriers given site-specific conditions, such as seam thickness, hole width, maximum hole depth, and maximum overburden depth.

Potential Outcome

To help mine operators address the new MSHA requirements, ground control researchers developed design charts and a new software package to specify required web and barrier pillar widths for highwall mining. The design charts have been reproduced in several publications and provide estimates of necessary web and barrier pillar widths. The highwall mining design software, available next year, has a form similar to the successful Analysis of Retreat Mining Pillar Stability (ARMPS) program and is named ARMPS-HWM (High Wall Mining). The interactive software package provides web and barrier pillar widths at given depths of cover and mining heights.

The design tools developed from the project will be widely distributed to stakeholders through classes at the MSHA Academy and open-industry briefings throughout the coal fields.

Outputs

6 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Analysis of Practical Ground Control Issues in Highwall Mining Zipf Jr-RK; Bhatt-SK | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining. Morgantown, WV, August 3-5, 2004: West Virginia University, 2004 Aug; :210-219	2004	Publication	Ground control
Ground Control Design for Highwall Mining Zipf-RK | 2005 SME Annual Meeting, February 28 - March 2, Salt Lake City, Utah, SME preprint 05-82. Littleton, CO, Society for Mining, Metallurgy, and Exploration, Inc., 2005 Feb; :1-7	2005	Publication	Ground control
Analysis of Highwall Mining Stability - The Effect of Multiple Seams and Prior Auger Mining on Design Newman-D; Zipf-RK | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 24th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University; :208-217	2005	Publication	Ground control
Ground Control for Highwall Mining in the U.S. Zipf-RK; Mark-C | International Journal of Surface Mining, Reclamation and Environment 19(3):188-217	2005	Publication	Ground control
ARMPS-HWM Software for Highwall Mining Design - Hands-on training workshop at the National Mine Safety and Health Academy, May 2006	2006	Workshop, Seminar, or OIB	Ground control
Software Package: ARMPS-MSM (multiseam mining)	2006	Software	Ground control

Potential Intermediate Outcome for Ground Control

Increase Roof Fall Forecast Times with Sensor-Based Monitoring Techniques

Background

Monitoring rock failures and roof movement to warn of roof falls

Currently, miners have little, if any, warning of impending roof falls. NIOSH is in the process of deploying several monitoring systems at mines with known roof fall problems so that an extensive database of measurements of microseismic emissions, roof-to-floor convergence, and roof beam sag can be compiled. These mines have very diverse geologic conditions and stress regimes and are mined with different methods. Several years will be needed to collect enough data to prove or disprove adequately the validity and feasibility of this technology. Field sites will be added in the future to broaden NIOSH´s database. This exhaustive scientific study will identify the precise trends capable of forecasting roof falls and define their limitations.

The goals of this project are to:

1. Increase our fundamental knowledge of how roof falls behave,
2. Develop and evaluate sensor-based roof fall warning technology, and
3. Document the amount of time available to warn miners prior to a roof fall.

This research is aimed at increasing roof fall forecast times and location accuracy.

Potential Outcome

A sensor-based system composed of microseismic emission and roof beam deflection monitoring instruments has been developed. To date, this technology has successfully forecast events approximately 50 minutes ahead. Two field trials are currently underway.

Currently, all our research is being focused on the following research question: Can monitoring technology be used to increase the time between the recognition that a particular area of unstable roof rock is going to fall and the actual moment it begins to fall?

The research will be successful if it shows that a forecast window does exist and can be lengthened using a sensor-based monitoring system. Project results will then be formulated as guidelines for installing and using roof fall monitoring systems. With these systems, mine operators will be better able to identify those areas at high risk for roof falls and remove workers or take other corrective action before a roof fall occurs. The result will be to lower miner exposures to hazardous conditions and decrease roof fall injuries.

Outputs

13 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Forecasting Roof Falls with Monitoring Technologies - A Look at the Moonee Colliery Experience Iannacchione-AT; Bajpayee-TS; Edwards-JL | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 24th International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University; :44-51	2005	Publication	Ground control
Characteristics of Mining-Induced Seismicity Associated with Roof Falls and Roof Caving Events Iannacchione-AT; Esterhuizen-GS; Bajpayee-TS; Swanson-PL; Chapman-MC | Proceedings of the 40th U.S. Symposium on Rock Mechanics, ARMA/USRMS paper 05-678, Anchorage, AK, June 27-29, 2005; 10 pp	2005	Publication	Ground control
Characterizing Roof Fall Signatures from Underground Mines Iannacchione-AT; Burke-LM; Chapman-MC | In: Proceedings of the Sixth International Symposium on Rockburst and Seismicity in Mines (Perth, Australia, March 9-11, 2005). Nedlands, Australia: Australian Centre for Geomechanics, 205; :619-629	2005	Publication	Ground control
Relationship of Roof Movement and Strata-induced Microseismic Emissions to Roof Falls Iannacchione-AT; Coyle-PR; Prosser-LJ Jr; Marshall-TE, Litsenberger-J | Min Eng 56(12):53-60	2004	Publication	Ground control
Mapping Hazards with Microseismic Technology to Anticipate Roof Falls - A Case Study Iannacchione-AT; Batchler-T; Marshall-TE | In: Peng SS, Mark C, Finfinger GL, Tadolini SC, Heasley KA, Khair AW, eds. Proceedings of the 23rd International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University,2004 Aug; pp. 327-333	2004	Publication	Ground control
Safer Mine Layouts for Underground Stone Mines Subjected to Excessive Levels of Horizontal Stress Iannacchione-AT; Marshall-TE; Burke-L; Melville-R; Litsenberger-J | Mining Engineering, 55(4), 2003 Apr; :25-31	2003	Publication	Ground control
100 Years of Improvement in Aggregate Worker Safety Iannacchione-A; Mucho-T | Stone, Sand and Gravel Review 2003 Mar; :28-34	2003	Publication	Surveillance and training
An Examination of the Loyalhanna Limestone's Structural Features and their Impact on Mining and Ground Control Practices Iannacchione-AT; Coyle-PA | In: Peng SS, Mark C, Khair AW, Heasley KA, eds. Proceedings of the 21st International Conference on Ground Control in Mining. Morgantown, WV: West Virginia University, 2002 Aug; :218-227	2002	Publication	Ground control
High Stress Mining Under Shallow Overburden in Underground U.S. Stone Mines Iannacchione-AT; Dolinar-DR; Mucho-TP | In: Proceedings of the First International Seminar on Deep and High-Stress Mining. Nedlands, Australia: Australian Centre for Geomechanics, section 32, 2002 Nov; :1-11	2002	Publication	Ground control
Using Monitoring Technologies to Warn of Roof Fall Occurrences - SME Annual Meeting, St. Louis	2006	Publication	Ground control
Analysis of Microseismic data from the Burning Springs Mine. Published and presented at the 25th International Conference on Ground Control in Mining	2006	Publication	Ground control
Analysis of Microseismic data from the Graymont Mine, The 26th International Ground Control Conference in Mining. Published and presented at the 26th International Conference on Ground Control in Mining	2007	Publication	Ground control

Title	Year	Output Type	Strategic Goal
Develop Guidelines for Installing and Using a Sensor-Based Roof Fall Warning System. International Journal of Rock Mechanics and Mining Science	2008	Publication	Ground control

Potential Intermediate Outcome for Ground Control

Reducing Ground Fall Hazards in Metal Mines with Weak Rock

Background

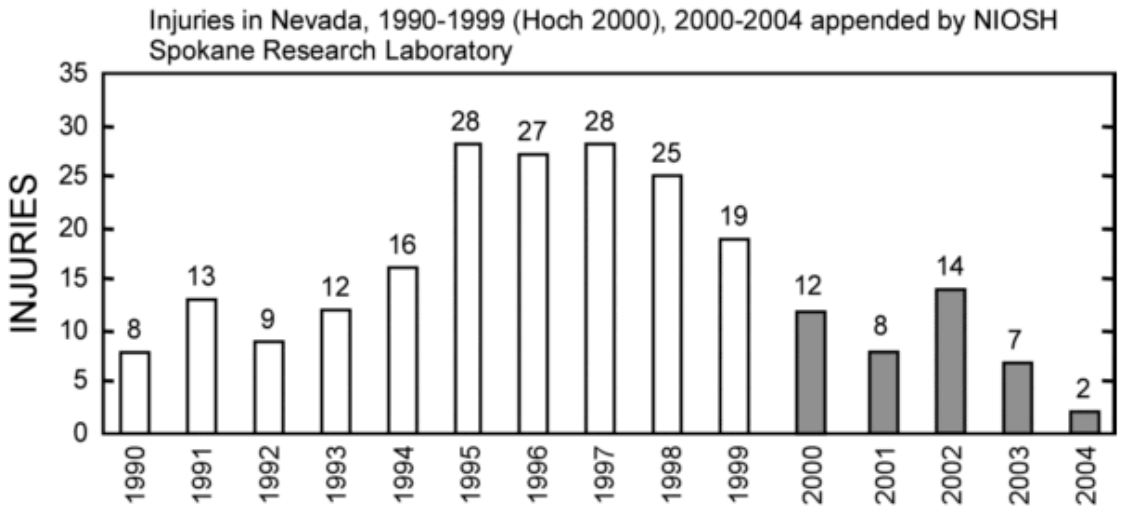
In the mid-1990´s, the number of injuries from rock falls increased. This increase could be attributed to (1) an increase in new, inexperienced miners, who have shown to have a much higher rate of accidents than older, experienced miners, (2) an increase in the total number of underground workers, and (3) mining in weak rock surrounding the ore deposits, which resulted in an increase in rock falls.

A research project was started in 2002 to develop tools to evaluate the relationship between geology, opening span, and support requirements. Thirty-four data collection points were established at eight mines in Nevada and four mines in Idaho and Montana. A manual of underground mine design for weak rock masses in hard-rock mines was developed. This manual contains information that relates span curves, rock mass rating (RMR) values, stope design curves, and equivalent linear overbreak/slough (ELOS) values and is used to select adequate support for the particular mining geology and selected opening span. It is being used by 75% of the active underground mines in Nevada and 50% of the underground mines in Montana and Idaho.

During 1999-2005, the mine design curves and applicable nomograms resulting from this research were transferred to the mining industry through 11 technical papers and 9 presentations. This research was also the focus of three workshops. A handbook was developed that is being used to design openings and select supports.

Potential Outcome

Since 2002, the critical information for mine design and the nomograms contained in the design manual have been adopted at most mines in Nevada, Idaho, and Montana. After these interventions began in 2002, ground fall injuries in Nevada mines have dropped, as shown in the bar graph. This injury reduction was due to the improved methods for the design of mine openings and selection of supports for metal mines with weak rock. Although many other factors must also be considered as contributors to this trend, the intervention by NIOSH was a factor for the reduction in ground fall injuries.


Injuries in Nevada, 1990-1999 (Hoch 2000), 2000-2004 appended by NIOSH Spokane Research Laboratory
INJURIES
35
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Outputs

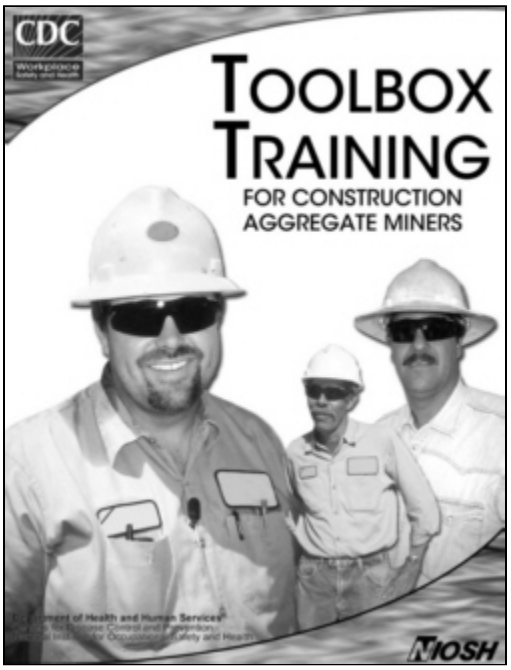
9 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Empirical Approaches for Weak Rock Mass Brady-T; Martin-L; Clark-L | CIM Mining Industry Conference and Exhibition, Montreal, Quebec, Canada: Canadian Institute of Mining, Metallurgy, and Petroleum	2003	Publication	Ground control
UDEC Modeling of an Underground Opening in a Rock Mass of Varying Quality Lasich-TJ; MacLaughlin-MM; Brady-TM | In: McLaughlin M, McNearny R, eds. Proceedings of the 39th Symposium on Engineering Geology and Geotechnical Engineering: Research to Practice (Butte, MT, May 18-19, 2004). Butte, MT: Montana Tech of the University of Montana, 2004	2004	Publication	Ground control
Tests of Fibre-Reinforced Shotcrete at the Chief Joseph Mine, Butte, Montana Martin-L; Dunford-J; MacLaughlin-M; Cronoble-R | Presentation at annual meeting of SME, Salt Lake City, UT, Feb. 28-Mar. 2, 2005. Preprint 05-20, 2005; :6 pp	2005	Publication	Ground control
Design in Weak Rock Masses: Nevada Underground Mining Operations Brady-T; Pakalnis-R; Clark-L | Presentation at annual meeting of SME, Salt Lake City, UT, Feb. 28-Mar. 2, 2005. Preprint 05-43, 2005; : 9 pp	2005	Publication	Ground control
Design Spans: Underhand Cut-and-Fill Mining Pakalnis R, Caceres C, Clapp K, Morin M, Brady T, Williams T, et al. | Montreal, Quebec, Canada: Canadian Institute of Mining, Metallurgy, and Petroleum, pp. 1-9. [http://www.cim.org/meetings/techpapers/44/s44a2214p1883.pdf]	2005	Publication	Ground control
A Distinct Element Parametric Study of Failure Modes Around an Underground Opening in Rock Masses of Varying Quality MacLaughlin-MM; Pakalnis-R; Brady-TM | American Rock Mechanics Association, 40th U.S. Symposium of Rock Mechanics, Anchorage, Alaska June 25-29, 2005, ARMA/USRMS 05-747	2005	Publication	Ground control
Update of Span Design Curve for Weak Rock Masses Ouchi-A; Pakalnis-R; Brady-T | CIM Mining Industry Conference and Exhibition, Edmonton, Alberta, Canada, Canada Institute of Mining	2004	Publication	Ground control
Empirical Approaches for Opening Design in Weak Rock Masses Brady-T; Martin-L; Pakalnis-R | Mining Technology (Transactions of the Institute for Mining and Metallurgy Section A), 2005, vol. 114, No. 1, March, 2005; :A13-A20	2005	Publication	Ground control
Influence of Intermediate Principle Stress on Rock Mass Quality Li-G; Vongpaisal-S; Pakalnis-R; Brady-T | CAMI 2005 (Fifth International Conference on Computer Applications In Mineral Industries, November 1-3, 2005, Banff, Alberta, Canada	2005	Publication	Ground control

Potential Intermediate Outcome for Surveillance and Training

Improving Miner Safety by Developing Toolbox Training Sets

Background



Toolbox training, defined as short (usually 10- to 15-minute) weekly sessions conducted with work crews on site prior to work shifts, is a popular mode of worker occupational safety and health training used by field-based companies. Thousands of small U.S. mining companies do not have the number of employees nor the resources to warrant supporting even one on-site safety professional to identify hazards and apply relevant risk and prevention information. In particular, these small companies seldom possess the facilities or resources to provide their workers on-going training programs to address workplace safety and health. Many aggregate mines fit this small-company profile. In 2001, sand and gravel mines had a median of three employees per mine site in scattered locations that made training at centralized offices difficult. Between 1998 and 2002, the average fatality rate for sand and gravel miners was 31.1 per 100,000 FTE employees compared to 34.1 for coal, 21.3 for metal, 7.0 for nonmetal, and 17.8 for stone miners.

A set of 52 one-page toolbox training topics relevant to the aggregate industry was developed with input from health and safety specialists in the industry. In 2004, the toolbox training modules were requested by MSHA for inclusion in the Small Mines manuals. The manuals are meant for distribution to all small mines visited by MSHA´s Small Mines Office personnel. Since ending the toolbox training research project, MSHA´s Web page now includes a set of one-page toolbox training topics (http://www.msha.gov/smallmineoffice/toolbox/tboxtalks.htm) developed by the Small Mines Office.

Potential Outcome

Mines that operate in remote locations with limited work crews can significantly raise the health and safety awareness of their employees by using these short training modules. The modules are available online for downloading from the NIOSH publications and mining Websites. The format of the training includes hazard identification, best practices, accident stories, and directed discussion among the work group to encourage sharing experiences and site-specific information. Preliminary evaluations of the effectiveness of this type of adult learning indicate that this training format is more effective for young miners, who are an increasing portion of the workforce as baby boomers retire. A large segment of the aggregate industry is expected to adopt toolbox training methods by 2010, making future reductions in occupational injuries and illnesses likely.

Outputs

5 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Evaluating Toolbox Training for Construction and Mining: Sand and Gravel Boldt-CMK | Workshop at the National Holmes Safety Association Conference, San Antonio, TX, Jun. 6-7, 2001	2001	Workshop, Seminar, or OIB	Surveillance and training; Traumatic injuries
Developing Toolbox Training Materials for Mining Varley-FD; Boldt-CMK | In: Peters R, ed. Strategies for Improving Miners' Training. Pittsburgh, PA, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2002-156, Information Circular 9463, 2002 Sep :39-44	2002	Publication	Surveillance and training; Traumatic injuries
Developing Toolbox Training for Aggregate Miners Boldt-CMK | Workshop at the Western TRAM Conference, Reno, NV, June 16-20, 2003	2003	Workshop, Seminar, or OIB	Surveillance and training; Traumatic injuries
Toolbox Training For Construction Aggregate Miners Boldt-CKM | US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication Number 2004-162; 2004 Aug: 1-108	2004	Publication	Surveillance and training; Traumatic injuries
Evaluating Toolbox Training for Construction and Mining Boldt-CMK | NIOSH OIB, 107th annual meeting of Northwest Mining Association meeting, Dec. 2, 2001	2001	Workshop, Seminar, or OIB	Surveillance and training; Traumatic injuries

Potential Intermediate Outcome for Surveillance and Training

Improving Miner Safety by Developing Interactive Computer Simulation Training

Background

Mining is a dangerous occupation, and while disasters are not common, miners need to know what to do when the unthinkable happens. It is not generally possible nor legal for them to receive first-hand experience of disasters in a training format, however. The Virtual Reality Miner Safety Training (VRMST) format allows trainees to operate in a simulated disaster without actually being exposed to the inherent dangers. Preliminary evaluations show that this is an effective way to get and keep the interest of trainees and expose them to learning without harm.

Computers allow development of innovative miner training

Potential Outcome

The VRMST software is designed to allow mine safety professionals to augment traditional miner safety training with state-of-the-art computer simulations. The broad adoption of this new training technology enables safety trainers to provide an experiential learning environment for mine workers rather than traditional classroom training.

Outputs

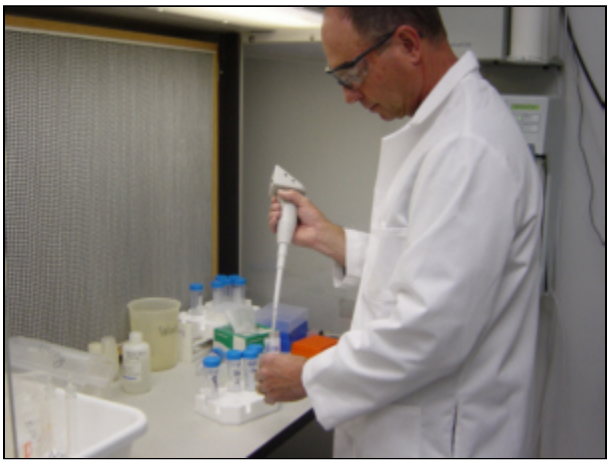
8 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Computerized Accident Reconstruction and Training for Metal/Non-Metal Mines Filigenzi-MT; Orr-TJ; Ruff-TM | Am J Ind Med, 1999 Sep 36(S1):116-118	1999	Publication	Surveillance and training
Hazard Recognition Computer Based Simulation Orr-TJ; Filigenzi-MT; Ruff-TM | In: Jenkins FM, Langton J, McCarter MK, and Rowe B, eds. Proceedings: Thirtieth Annual Institute on Mining Health, Safety, and Research (Salt Lake City, UT, Aug. 8-11, 1999). Blacksburg, VA: Department of Mining and Minerals Engineering, Virginia Polytechnical Institute, 2001 Aug; :21-28	2001	Publication	Surveillance and training
Virtual Reality for Mine Safety Training Filigenzi-MT; Orr-TJ; Ruff-TM | Applied Occupational and Environmental Hygiene, vol. 15, no. 6, 2000; :465-469	2000	Publication	Surveillance and training
Mine Escapeway Multiuser Training with Desktop Virtual Reality Orr-TJ; Girard-JM | In: Bandopadhyay S, ed. Application of Computers and Operations Research in the Mineral Industry: Proceedings of the 30th International Symposium (APCOM 2002) (Phoenix, AZ, Feb. 25-27, 2002). Littleton, CO: Society of Mining, Metallurgy, and Exploration	2002	Publication	Surveillance and training
Annual International Workshop on VR Mining Applications and Collaboration (held in conjunction with another mining-related annual meeting)	2007	Workshop, Seminar, or OIB	Mine disasters
Evaluation of the VR and CBT Map Reading Training, Journal of Safety Research	2006	Publication	Mine disasters
Guidelines and Seminars: implementing CBT and VR mine safety training	2007	Workshop, Seminar, or OIB	Mine disasters
Evaluation of the VR Mine Evacuation Training Module, International Journal of Emergency Management	2009	Publication	Mine disasters

Potential Intermediate Outcome for Surveillance and Training

Improving the Accuracy of Determining Worker Exposure to Airborne Silver

Background



Analysis of samples in the laboratory

Currently, analytical methods to determine silver in workplace air samples measure total silver, which includes both the soluble and insoluble species. A method has not been available to differentiate between total silver and the more toxic soluble silver compounds. Both insoluble (i.e., metallic) and small amounts of soluble silver (i.e., silver nitrate) can be found in smelters and refineries; however, the metallic fraction is not considered a health risk. The current MSHA permissible exposure limit (PEL) for an 8-hour shift is 10 µg/m3 total silver (adopted from the American Conference of Governmental Industrial Hygienists´ [ACGIH] 1973 Threshold Limit Values [TLV´s]). However, in 1981, ACGIH changed the TLV´s to 10 µg/m3 for soluble silver compounds and 100 µg/m3 for insoluble silver compounds. This research served to validate a method for determining water-soluble silver in workplace air samples.

The results of this research have been published and were presented at the Fifth International Symposium on Modern Principles of Air Monitoring. The organizing committee invited NIOSH to present a summary of this method for measuring soluble silver at its annual symposium held in Loen, Norway, in June 2005.

Potential Outcome

Improving the methodology for delineating the presence of different species of airborne silver will provide more accurate measures of worker exposures to its most harmful forms. MSHA and mine and mill operators can now concentrate their efforts on protecting workers from soluble silver compounds. The Health Division of MSHA´s Metal and Nonmetal Safety and Health program has been contacted to discuss reassessing the MSHA PEL for silver within the next few years.

Outputs

3 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Exposure-Related Health Effects of Silver and Silver Compounds: A Review Drake-PL; Hazelwood-KJ | The Annals of Occupational Hygiene, Vol. 49, No. 7; :575-585	2005	Publication	Surveillance and training
Soluble Silver Method - Peer-reviewed paper in the Journal of Environmental Monitoring. Expected publication date - January 2006	2006	Publication	Surveillance and training
Soluble Silver Method, NIOSH Manual of Analytical Methods	2007	Publication	Surveillance and training

Potential Intermediate Outcome for Surveillance and Training

New Miner Training

Background

A key industry need is effective integration of new miners

The U.S. coal mining industry will face a critical shortage of workers within the next five years as the majority of the present mine workers reach retirement age. At the same time, America´s need for coal will increase. To mine this coal, the industry will have to turn to a young, inexperienced workforce. Unfortunately, young inexperienced workers are injured at a much higher rate than are older workers who, presumably, have more experience. This trend has been repeatedly documented during the past 20 years. A 1982 National Academy of Sciences study of 15 large coal companies found a very marked correlation between age and disabling injury rates among underground coal miners. A worker between the ages of 18 and 24 was about three times more likely to be injured than was a miner 45 years or older. A similar pattern was observed in 2002 study using MSHA injury data and Bureau of Labor Statistics estimate of ages. To break this pattern, the new cohort of workers will need to be better trained and exposed to large sets of proficiencies, key ones being good technical skills matched with judgment and decision-making skills. NIOSH personnel are assisting United Mine Workers Career Centers, Inc., in developing a pilot project to establish an apprentice training center to service the southwestern Pennsylvania/northern West Virginia coal fields. This innovative project will not only provide an efficient means of developing a trained workforce, but will also create career opportunities for workers displaced from other industries. Once completed, this pilot can then serve as a model throughout U.S. coal fields.

Potential Outcome

By 2009, the apprentice miner training program will provide insights into a variety of important topics associated with the recruitment, training, and retention of young people for the mining industry. Recommendations can be made regarding (1) strategies for improving the methods and materials used to train new miners, (2) strategies for facilitating the transfer of vocational training to the job, and (3) methods for assessing students´ competency at performing critical mining tasks. The program will also influence the use of new technologies for delivering training. Just as important, a company hiring one of the program´s graduates would acquire a highly trained person with proven work habits who could quickly become a productive miner. The likelihood of injury would be significantly reduced for this worker, thus keeping compensation costs down. A more productive miner with a better chance of going home safe at the end of the shift is both socially and economically beneficial.

Outputs

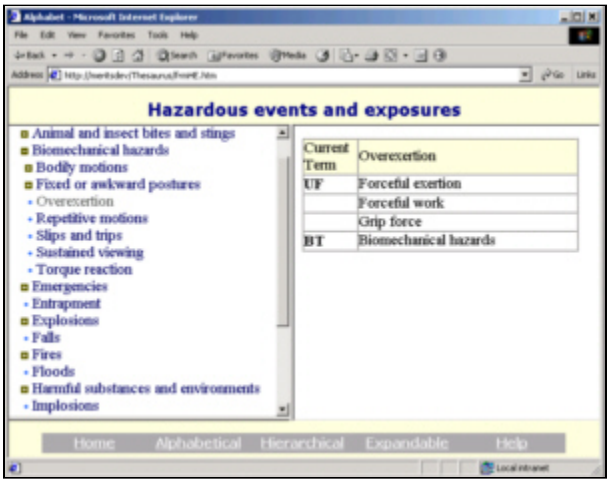
4 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
The use of new technologies to train new miners	2007	Training	Surveillance and training
How well do new miners perform critical mining tasks? - Journal of Safety Research	2008	Publication	Surveillance and training
Guidelines for a new miner curriculum	2008	Video	Surveillance and training
A training intervention to instill a safety and health value in young/inexperienced underground coal miners - Safety Science	2010	Publication	Surveillance and training

Potential Intermediate Outcome for Surveillance and Training

Improved Technology Transfer Via the Web

Background



The Mining Safety and Health Thesaurus - terms related to "Hazardous events and exposures"

The Internet is an efficient and cost-effective resource for disseminating public information. However, as the amount of Internet content increases, it´s increasingly difficult to find information. Reducing the complexity of locating information is a high priority research area. For example, the World Wide Web Consortium (W3C) envisions a future "Semantic Web" (http://www.w3.org/2001/sw/) where information can be processed by automated tools as well as humans. Towards that goal, new web technologies are being developed and combined with knowledge management and artificial intelligence techniques. Many technologies can be used now to improve searches on individual web sites or portals. For example, effective indexing of content is crucial to information discovery. ANSI/NISO/ISO standards specify how to track metadata ("information about information") for web resources, and a W3C Recommendation (Resource Description Framework) specifies how to exchange that knowledge on the Web.

This effort focuses on improving the dissemination of safety and health information on the NIOSH Mining web site. Methods will be researched and developed for indexing content based on emerging standards. Techniques such as "faceted navigation" will be implemented to leverage this metadata to improve access to web content. One project deliverable will be a faceted, hierarchical thesaurus of indexing terms compiled by content experts. This thesaurus will have potential use beyond the NIOSH Mining web site. Additionally, the techniques developed for this project could serve as a common indexing structure that allows organizations to share safety and health information.

Potential Outcome

One outcome of this research will be a better organized and highly indexed web site of mining safety and health information for our stakeholders. For example, users will be able to explore content in a hierarchical and faceted manner, with multiple paths leading to the same content (e.g. the ability to browse by hazard, target audience, date of publication, or format of the web content). Users of the new web site will experience an increase in ease of use and accuracy when searching for specific information. This, in turn, will increase the knowledge transfer of the latest NIOSH Mining research results and products to our stakeholders. Instant and accurate access to this wealth of information via the web will allow them to immediately apply it in their work place and improve mine worker health and safety.

In addition, if the "Semantic Web" is realized, this research will have an even greater impact. The NIOSH Mining web site will be in a position to participate in the next phase of the Internet, where semantic search engines will target information much more precisely. This would significantly improve NIOSH's ability to disseminate information as well as provide a template for other safety and health organizations to follow.

Outputs

5 Planned or completed outputs

Title	Year	Output Type	Strategic Goal
Advanced website for mining information	2006	Software	Surveillance and training
NIOSH Mining Safety and Health Thesaurus Users Manual (Glowacki, Unger) - NIOSH numbered publication	2007	Publication	Surveillance and training
Development of a Taxonomy for Indexing Web-based Mining Safety and Health Research (Glowacki, Unger) - Journal of Digital Information (peer-reviewed)	2007	Publication	Surveillance and training
A Taxonomy-based Navigation System for Mining Safety and Health Research (Unger, Glowacki) - APCOM 2007 (Santiago, Chile)	2007	Publication	Surveillance and training
Improving Access to Mining Safety and Health Information (Glowacki, Unger) - SME Annual Meeting	2007	Publication	Surveillance and training

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4.3 Planned Outputs

A total listing of 587 **Planned Outputs** under the Mining Program for the next five years is presented in this section. Each item in this database includes a title, year produced, type of output, and the strategic goal toward which it is directed. The majority planned of outputs in the Mining Program are publications (77.3%), followed in smaller numbers by workshops, web documents, and other output types.

At the end of this section is a series of tables and pie charts showing planned outputs broken down by strategic goal, year produced and output types. There is also an explanation of how planned outputs are categorized.

587 planned outputs

Title	Year	Output Type	Strategic Goal
1st generation sensor-based system for monitoring critical operating parameters of forklifts (EIR)	2006	Patent	Traumatic injuries
25 Years of Roof Bolting Research - Art or Science? Published and presented at the 25th International Conference on Ground Control in Mining	2006	Publication	Ground control
A Case-Control Study of Mining Injuries Using Surveillance Data - peer reviewed journal article	2006	Publication	Surveillance and training
A Comparative Analysis of Safety & Health Improvements Associated with Controlled Underground Blasting - SME conference	2009	Publication	Ground control
A Comparative Analysis of Safety and Risk Potential Associated with Advances in Blasting Techniques, Processes, Technology, and Design - Ph.D. dissertation	2009	Publication	Ground control
A Comparison of Cylindrical Charge Models - Paper in the International Journal for Blasting and Fragmentation	2006	Publication	Ground control
A Comprehensive Mine-Wide Gas Flow and Emissions Model - NIOSH RI	2009	Publication	Mine disasters
A Computerized Technique for Drift Blast Round Design - peer reviewed journal article	2007	Publication	Ground control
A Continuous Personal Diesel Emission Exposure Monitor - Engineering & Mining Journal	2009	Publication	Respiratory diseases
A Description of the NIOSH Software for Controlled Blasting in Tunneling - Paper in Journal of Safety Research	2006	Publication	Ground control
A Differential Pressure Method used to Monitor Efficiencies of Diesel Emission Control Technologies - NIOSH RI	2007	Publication	Respiratory diseases
A Direct Method to Measure Relative Levels of Engine Tailpipe Diesel Particulate Matter - Journal of Aerosol Science	2006	Publication	Respiratory diseases
A field study for estimating landing forces required to exit mobile equipment, International Journal of Industrial Ergonomics	2008	Publication	Cumulative injuries
A GIS analysis of commercial vehicle crashes on Northwestern state highways - peer reviewed journal article	2006	Publication	Surveillance and training

Title	Year	Output Type	Strategic Goal
A History of Pillar Design Formulas - presented at the Ground Control Conference	2006	Publication	Ground control
A mathematical model to determine the effect of ventilation on fire spread in underground coal mines, peer reviewed publication, Fire Safety Journal	2007	Publication	Mine disasters
A New Analysis of the SveDeFo Vånga Quarry Tests - International Journal of Rock Mechanics and Mining Sciences	2007	Publication	Ground control
A new method to clean dust from soiled work clothes - Proceeding of 11th US/North American Mine Vent Symposium	2006	Publication	Respiratory diseases
A New Procedure for Damage Zone Prediction in Rock - peer reviewed journal article, ISEE Journal	2007	Publication	Ground control
A New Procedure for Damage Zone Prediction in Rock - Ph.D. dissertation	2006	Publication	Ground control
A novel approach in seat design for reducing vibration, Journal of Safety Research	2007	Publication	Cumulative injuries
A real-time mine fire simulator for smoke management in underground mines, NIOSH RI	2008	Publication	Mine disasters
A series of workshops for coal mine operators explaining the "Guidelines to Reduce Diesel Particulate Matter in Coal Mines"	2009	Workshop, Seminar, or OIB	Respiratory diseases
A series of workshops for metal/nonmetal mine operators explaining the "Guidelines to Reduce Diesel Particulate Matter in Metal, and Nonmetal Mines	2009	Workshop, Seminar, or OIB	Respiratory diseases
A Software Tool for Implementation and Evaluation of Administrative Noise Controls in Mining (Bauer, Cole) - SME 2008	2008	Publication	Hearing loss
A study of electrical injury noting long term and emerging trends, IEEE Trans. On Ind. App.	2006	Publication	Traumatic injuries
A Taxonomy-based Navigation System for Mining Health and Safety Research (Unger, Glowacki), APCOM 2007	2007	Publication	Surveillance and training
A Taxonomy-based Navigation System for Mining Safety and Health Research (Unger, Glowacki) - APCOM 2007 (Santiago, Chile)	2007	Publication	Surveillance and training
A training intervention to instill a safety and health value in young/inexperienced underground coal miners - Safety Science	2010	Publication	Surveillance and training
A training module for general inside laborers	2007	Training	Surveillance and training
Administrative Noise Control Evaluation and Implementation Tool for the Mining Industry (Bauer, Cole), Mining Engineering Magazine/Transactions (peer reviewed)	2008	Publication	Hearing loss
Advanced Hydraulic (Waterjet) Scaling Techniques - Ph.D. dissertation	2009	Publication	Ground control
Advanced website for mining information	2006	Software	Surveillance and training
Aerosol sampling as a strategy for improving worker health	2006	Workshop, Seminar, or OIB	Respiratory diseases

Title	Year	Output Type	Strategic Goal
Age Awareness Training for Miners: A Holistic Approach to Injury Reduction - peer-reviewed SME Journal	2007	Publication	Cumulative injuries
Age awareness training module - website and CD package	2006	Training	Surveillance and training
Aging and Musculoskeletal Injuries in the US Mining Industry - Journal of Safety Research	2006	Publication	Cumulative injuries
Air spray nozles to improve capture of dry dust collectors on surface drills, Coal Age	2008	Publication	Respiratory diseases
Airborne Dust Capture and Induced Airflow of Various Spray Nozzle Designs - Journal of Occup & Environmental Hygiene	2007	Publication	Respiratory diseases
ALPS Stability Factors for Deep Western Mines. Published and presented at the 27th International Conference on Ground Control in Mining	2008	Publication	Ground control
An Alternative Means of Assessing Blasting Productivity - Safety, Stability, Size & Speed - peer reviewed journal article, Journal of Mining Research	2007	Publication	Ground control
An American National Standards Institute standard that sets minimum performance and operational criteria for power line proximity alarms	2010	Standards	Traumatic injuries
An Analysis of Engineering Design Procedures Associated with Controlled Underground Blasting - peer reviewed journal article, Engineering and Mining Journal	2007	Publication	Ground control
An arc burn training video	2007	Video	Traumatic injuries
An Economic Evaluation of Perimeter Control Blasting in Drifting - Paper at the annual meeting of Soc. For Mining, Metallurgy, and Exploration	2006	Publication	Ground control
An Engineer-friendly Technique for Perimeter Blast Design in Drifting - Frag Blast conference	2009	Publication	Ground control
An Engineering Analysis of Controlled Underground Blasting and Performance - Ph.D. dissertation	2009	Publication	Ground control
An Epidemiological Study of Knee Injuries in Low Seam Coal Mining - to be submitted to SME (peer-reviewed)	2007	Publication	Cumulative injuries
An Evaluation of Training on Trenching and Excavation Injuries - peer reviewed journal article	2006	Publication	Surveillance and training
An MSHA arc burn safety refresher training module	2006	Training	Traumatic injuries
An Overview of Standing Support Practices and Developments. The International Journal of Rock Mechanics and Mining Science	2007	Publication	Ground control
An Update on the Metal and Nonmetal Diesel Particulate Filter Selection Guide - web based publication	2008	Web document	Respiratory diseases
Analysis of airflow data collected with an ultrasonic anemometer using Excel and Anemvent 2003, Transactions, Society for Mining, Metallurgy and Exploration Annual Meeting, peer reviewed	2007	Publication	Mine disasters

Title	Year	Output Type	Strategic Goal
Analysis of Microseismic data from the Burning Springs Mine. Published and presented at the 25th International Conference on Ground Control in Mining	2006	Publication	Ground control
Analysis of Microseismic data from the Graymont Mine, The 26th International Ground Control Conference in Mining. Published and presented at the 26th International Conference on Ground Control in Mining	2007	Publication	Ground control
Analysis of Trends in Mining Injuries, 1983-2004 - peer review journal article	2006	Publication	Surveillance and training
Analyzing vibration using current available standards	2007	Software	Cumulative injuries
Annual International Workshop on VR Mining Applications and Collaboration (held in conjunction with another mining-related annual meeting)	2006	Workshop, Seminar, or OIB	Mine disasters
Annual International Workshop on VR Mining Applications and Collaboration (held in conjunction with another mining-related annual meeting)	2007	Workshop, Seminar, or OIB	Mine disasters
Annual International Workshop on VR Mining Applications and Collaboration (held in conjunction with another mining-related annual meeting)	2008	Workshop, Seminar, or OIB	Mine disasters
Annual International Workshop on VR Mining Applications and Collaboration (held in conjunction with another mining-related annual meeting)	2009	Workshop, Seminar, or OIB	Mine disasters
Apparatus to determine approximate support capacity of borehole (EIR)	2007	Patent	Ground control
Application of Systematic Safety Analysis to Improvement of Mine Safety - peer review journal article	2007	Publication	Surveillance and training
Application of the Personal Bolter Screen for Roof Control. 26th International Conference on Ground Control in Mining	2007	Publication	Ground control
Applied Ergonomics IMA-NIOSH Workshop	2006	Workshop, Seminar, or OIB	Cumulative injuries
Arc burn safety for use in MSHA-required refresher training - NIOSH Information Circular	2007	Publication	Traumatic injuries
Arc burn safety training for MSHA inspectors	2006	Workshop, Seminar, or OIB	Traumatic injuries
Arc-rated safety clothing and PPE for mine use. IEEE Trans. on Ind. App.	2008	Publication	Traumatic injuries
ARMPS-HWM Software for Highwall Mining Design - Hands-on training workshop at the National Mine Safety and Health Academy	2007	Workshop, Seminar, or OIB	Ground control
ARMPS-HWM Software for Highwall Mining Design - Hands-on training workshop at the National Mine Safety and Health Academy, May 2006	2006	Workshop, Seminar, or OIB	Ground control
Assessment of exposure of underground miners to diesel particulate matter, RI	2008	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
Assessment of Research Impact on Mining Injuries and Illnesses - peer reviewed journal article	2010	Publication	Surveillance and training
Assessment tool for low-back exposure - Journal of Applied Ergonomics	2008	Publication	Cumulative injuries
Audio version of NIOSH IC Getting to Zero-The Human Side of Mining	2006	Publication	Surveillance and training
Audio version of NIOSH RI: Tell Me A Story	2006	Publication	Surveillance and training
Babich DR [2007], Identification and Ranking of noise sources on longwall mining machines - Proceedings of NOISE-CON 2007, In: Institute of Noise Control Engineering of the USA	2007	Publication	Hearing loss
Babich DR [2008] The Relationship of Longwall Mining Systems to Workers Noise Exposure - Journal of Acoustical Society of America, Submitted to Journal. (refereed)	2007	Publication	Hearing loss
Babich DR, Bauer ER [2006], Underground bituminous coal mine noise surveys, Mining Engineering Magazine, 2006. (refereed)	2006	Publication	Hearing loss
Backfill Span Stability Study at the Turquoise Ridge Mine, NV - Proceedings of the U.S. Rock Mechanics Symposium	2006	Publication	Ground control
Bag design characteristics and the reduction of ergonomic risk factors - Journal of Applied Ergonomics	2007	Publication	Cumulative injuries
Barrett EA, Calhoun RA. Noise and hearing protection training for drillers. Professional Safety, In review, Dec, 2005: 18 pages. (refereed)	2006	Publication	Hearing loss
Bauer ER, Babich DR [2006]. Administrative controls for reducing worker noise exposures. Trans Soc Min Eng, Vol. 318. (refereed)	2006	Publication	Hearing loss
Bauer ER, Babich DR [2007]. Guidelines for measuring noise levels of longwall mining machines in underground coal mines - Trans Soc Min Eng (refereed)	2007	Publication (guidelines)	Hearing loss
Bauer ER, Babich DR, [2006], Limestone - Is it noisy or not?, Society of Mining Engineering Annual Meeting, preprint, Mar 2006	2006	Publication	Hearing loss
Bauer ER, Babich DR, Vipperman JS [2006]. Equipment noise and worker exposure in the coal mining industry. Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No., IC, In review.	2006	Publication	Hearing loss
Behavior of Nitrogen Oxides in the Product Gases from Explosive Detonations, Published and presented at the 32nd Annual ISEE Conference	2006	Publication	Traumatic injuries
Benching Effects on Roof Stability in an Underground Stone Mine. Peer-reviewed Geotechnical Engineering Journal	2009	Publication	Ground control
Benchmarking Effective Longwall Dust Controls - proceedings of Longwall USA	2007	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
Benefits of using the Low Back Assessment tool and its effectiveness in diagnosing problem areas. To be submitted to Occupational Ergonomics and for a NIOSH Informational Circular	2007	Publication	Cumulative injuries
Best practices for welding with high manganese rods (hardfacing), NIOSH RI	2010	Publication	Surveillance and training
Best Support Practices in Weak Rock. Mining Engineering Journal	2007	Publication	Ground control
Blast Damage Measured From Empirical Viewpoint - ISEE conference	2007	Publication	Ground control
Blast Design and Implementation Based on NIOSH's New Controlled Blasting Program - SME conference	2009	Publication	Ground control
Blasting Response in a Weak Rock Mass and Its Effect on Ground Support/Ground Instability - Paper in the Proceedings of the International Conference on Mechanics of Jointed and Faulted Rock	2007	Publication	Ground control
Bplane, Bstepp, and Bwedge computer programs for catch bench effectiveness analysis	2006	Software	Ground control
Brochure for regional school districts on the Silver Kid Mine	2006	Publication	Surveillance and training
Bugarski, A.D. and Schnakenberg, G.H. Effects of Control Technologies on Diesel Emissions in Underground Mines. NIOSH Report of Investigation. 2008	2008	Publication	Respiratory diseases
Bulkhead Designs and Performance Case Histories - Transactions, Society for Mining, Metallurgy and Exploration Annual Meeting, peer reviewed	2006	Publication	Mine disasters
Byrne DC [2006]. Effectiveness of electronic earmuffs for underground miners. Mining Engineering Magazine (refereed).	2006	Publication	Hearing loss
Byrne DC, Reeves ER [2006]. Analysis of non-standard noise dosimeter microphone positions. Journal of the Acoustical Society of America. (refereed)	2006	Publication	Hearing loss
Cab fire prevention/suppression system for large mining equipment, NIOSH RI	2007	Publication	Mine disasters
Case Study of Web Barrier Pillar Collapse. Annual SME Meeting and Conference, 2009	2009	Publication	Ground control
Causative Factors for Frictional Ignitions in U.S. Coal Mines - Society for Mining, Metallurgy and Exploration Annual Meeting, peer reviewed	2007	Publication	Mine disasters
CFD Modeling of Fire Spread Along Combustibles in a Mine Entry -Transactions, Society for Mining, Metallurgy and Exploration, Denver, peer reviewed	2006	Publication	Mine disasters
Characterizing Dust Exposures and Controls for Mines Operating in the Southern Appalachian Region - Coal Age	2008	Publication	Respiratory diseases
Checklist for evaluating cab design characteristics: a validity and reliability study, Journal of Occupational and Envrionmental Hygiene	2007	Publication	Cumulative injuries
Chemical and physical characterization of nanoparticles emitted from diesel engines - RI	2010	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
CO Dispersion From a Coal Mine Fire in a Mine Entry, Proceedings, 11th U. S. Mine Ventilation Symposium, State College	2006	Publication	Mine disasters
Coal dust exposure and ischemic heart disease mortality among a cohort of underground coal miners, JOEH	2007	Publication	Respiratory diseases
Communications and decision making during the initial phase of a mine emergency, Transactions, Society for Mining, Metallurgy and Exploration Annual Meeting, peer reviewed	2007	Publication	Mine disasters
Comparison of Responses of Instrumented Bolts and Rock Strain Strips in Weak Roof - Paper at Ground Control Conference	2006	Publication	Ground control
Comparison of SEM and Coke Analyses of Post-Explosion Dust Samples - Briefing Report to MSHA	2006	Publication	Mine disasters
Comparison of XRF and wet chemical analysis of air filter samples from a lead/zinc/silver ore concentrator, Journal of Environmental Monitoring	2006	Publication	Surveillance and training
Comparison of XRF and wet chemical analysis of air filter samples from a primary copper smelter, Journal of Environmental Monitoring	2008	Publication	Surveillance and training
Comparison of XRF and wet chemical analysis of air filter samples from a secondary lead smelter, Journal of Environmental Monitoring	2007	Publication	Surveillance and training
Comprehensive Ground Control Design Methodology for Weak Roof - 28th International Conference on Ground Control in Mining	2009	Publication	Ground control
Control of Hazards in Underground Stone Mines. Published and presented at the 27th International Conference on Ground Control in Mining	2008	Publication	Ground control
Control strategies for mobile workers in processing operations, Rock Products Magazine	2007	Publication	Respiratory diseases
Control Technologies Being Used to Control Silica Exposures in Mineral Processing Plants - Aggregates Manager	2008	Publication	Respiratory diseases
Controlling Dust Generation in a Dimension Stone Shop with a Low-Pressure Scrubber - Rock Products Magazine	2006	Publication	Respiratory diseases
Cost modeling in occupational safety and health, NIOSH eNews	2006	Publication	Surveillance and training
Cost models for application to NIOSH safety research of engineering solutions - NIOSH eNews and CDC Connects	2008	Publication	Surveillance and training
Crystalline Silica Analysis: A Comparison of Calibration Materials and Recent Coal Mine Dust Size Distributions - Journal of ASTM Intl	2006	Publication	Respiratory diseases
Damage zone in the Vicinity of a Charge From Model Tests - US Symposium on Rock Mechanics	2008	Publication	Ground control
Dangers of Toxic Fumes from Blasting. Mining Engineering, Refereed Journal	2007	Publication	Traumatic injuries
Data Mining the Mine Safety and Health Database on Mining Injuries and Illnesses - peer reviewed journal article	2006	Publication	Surveillance and training

Title	Year	Output Type	Strategic Goal
Deformation in Undercut Backfill Cap - CIM	2006	Publication	Ground control
Design and performance criteria for power line proximity and contact alarm systems. IEEE Trans. on Ind. App.	2008	Publication	Traumatic injuries
Design Criteria for Dragline Workstations - NIOSH Information Circular	2007	Publication	Cumulative injuries
Design for Predicating, Preventing, and Controlling Multiple Seam Interactions - 25th International Conference on Ground Control in Mining	2006	Publication	Ground control
Design Guidelines for Dry-Stacked Mine Ventilation Stoppings. Published at the North American Ventilation Conference, 2006	2006	Publication (guidelines)	Ground control
Design Issues Related to the Strength of Slender Limestone Pillars - 2006 meeting of the Society for Mining, Metallurgy, and Exploration (SME)	2006	Publication	Ground control
Design of Coal Mine Stoppings. The US Ventilation Symposium	2008	Publication	Ground control
Design Procedures for Stable Roof Spans in Underground Limestone Mines - Mining Engineering (refereed journal)	2008	Publication	Ground control
Designing a Large Opening Mine using Ventilation Considerations - Aggregate Manager Magazine	2007	Publication	Mine disasters
Designing for Maintainability : Guidelines for Designers and Maintenance Personnel - NIOSH Information Circular	2007	Publication	Cumulative injuries
Designing for Maintainability : Guidelines for Designers and Maintenance Personnel - web version	2007	Web document	Cumulative injuries
Designing with a Purpose: Equipment Issues in Mining - SME journal (peer reviewed)	2007	Publication	Cumulative injuries
Detailed application of cost models in occupational safety and health - NIOSH IC	2008	Publication	Surveillance and training
Determination of the Sizes of Coal Dust in Intakes and Returns of Underground Mines - NIOSH RI	2007	Publication	Mine disasters
Determination of the Sizes of Coal Dust in Intakes and Returns of Underground Mines - peer reviewed journal publication	2007	Publication	Mine disasters
Determining blind areas near large surface mining equipment: methods and results - Journal of Safety Research	2007	Publication	Traumatic injuries
Determining the status of mine atmospheres following indication of fire (SME 2006 Annual Meeting Preprint)	2006	Publication	Mine disasters
Develop field portable method for manganese on air filters, Journal of Environmental Monitoring	2007	Publication	Surveillance and training
Develop Guidelines for Installing and Using a Sensor-Based Roof Fall Warning System. International Journal of Rock Mechanics and Mining Science	2008	Publication	Ground control
Develop, evaluate and transfer technologies to enhance the safety and effectiveness of mine emergency responders, such as the Transtek Res-Q-Com communication system for mine rescue teams, directional lifelines, team link lines, novel lighting devices, and thermal imaging cameras [2007], NIOSH RI	2007	Publication	Mine disasters

Title	Year	Output Type	Strategic Goal
Developing a metric for defining and evaluating process element activities and the effects of these activities on MSD incident rates and other outcome measures. To be submitted to Applied Ergonomics	2007	Publication	Cumulative injuries
Development of a Methodology for Tread Study - to be submitted to Human Factors	2007	Publication	Cumulative injuries
Development of a metric that can be used to evaluate the effectiveness of ergonomics processes. To be submitted to Applied Ergonomics	2007	Publication	Cumulative injuries
Development of a Taxonomy for Indexing Web-based Mining Health and Safety Research (Glowacki, Unger), Journal of Digital Information (peer-reviewed)	2007	Publication	Surveillance and training
Development of a Taxonomy for Indexing Web-based Mining Safety and Health Research (Glowacki, Unger) - Journal of Digital Information (peer-reviewed)	2007	Publication	Surveillance and training
Development of an Administrative Noise Control Tool Using LabVIEW (Cole, Bauer), APCOM 2007	2007	Publication	Hearing loss
Development of cost models specifically for application to NIOSH safety research of engineering solutions to reduce workplace injuries and fatalities, Systems Engineering	2008	Publication	Surveillance and training
Development of Criteria for the Evaluation of Ingress/Egress Systems for the Risk of Injuries - Journal of Industrial Ergonomics	2007	Publication	Cumulative injuries
Development of Design Guidelines for Stable Roof Spans in Limestone Mines - 2008 U.S. Rock Mechanics Symposium	2008	Publication	Ground control
Development of first generation forklift operating warning system (FLOWS), Employee Invention Report (EIR)	2006	Patent	Traumatic injuries
Development of sensor-based system into tool to improve forklift operator training	2007	Training	Traumatic injuries
Development of Strain Softening Materials for Coal Mine Stoppings. The US Rock Mechanics Symposium, 2008	2008	Publication	Ground control
Diesel engine emissions research facility at Lake Lynn Laboratory - NIOSH IC	2007	Publication	Respiratory diseases
Differential Pressure Method to Measure Elemental Carbon in Undiluted Diesel Exhaust - Environmental Science & Technology	2006	Publication	Respiratory diseases
Digital Imaging for Mine Slope Monitoring - NIOSH IC	2009	Publication	Ground control
Digital Imaging System for Mine Slope Monitoring - NIOSH RI	2007	Publication	Ground control
Drift Driving Field Studies With Focus on Minimizing Overbreak and Perimeter Damage - International society of explosives engineers symposium on explosive and blasting research proceedings	2009	Publication	Ground control
Dust Control for Mines Operating in the Southern Appalachian Region - workshops in KY, VA and WV	2009	Workshop, Seminar, or OIB	Respiratory diseases

Title	Year	Output Type	Strategic Goal
Dust Control Handbook for Mineral Processing Operations - NIOSH IC	2009	Publication	Respiratory diseases
Dust Controls on Longwalls - Assessment of the State-of-the-Art - proceedings 11th US/North American Mine Vent Symposium	2006	Publication	Respiratory diseases
Dust Dispersion in the 20 L Siwek Chamber - Journal of Loss Prevention in the Process Industries, peer reviewed	2006	Publication	Mine disasters
Economic Analysis of Roof Screen Installation in the Underground Coal Mines. Annual Meeting of the American Society of Safety Engineers	2008	Publication	Ground control
Economic models flowchart, NIOSH IC	2006	Publication (guidelines)	Surveillance and training
Effect of Blast Damage on the RMR for Mining Applications - ISEE Journal (peer reviewed)	2008	Publication	Ground control
Effect of Time and Moisture on the Strength of Coal Measure Rocks - US-Canada Rock Mechanics Symposium, Vancouver, Canada	2007	Publication	Ground control
Effectiveness of Adjustability in Dragline Workstations - SME journal or Applied Ergonomics (peer reviewed)	2007	Publication	Cumulative injuries
Effects of blasting on weak RMR - ISEE conference paper	2007	Publication	Ground control
Effects of Coal Mine Diesel Emission Control Technologies - NIOSH RI	2007	Publication	Respiratory diseases
Effects of Fiber Types on Resin Reinforced Shotcrete Panels - International Conference on Ground Control in Mining	2007	Publication	Ground control
Effects of scrubber usage on intake airflow patterns and intake flow quantities - Proceedings, 11th US/North American Ventilation Symposium, State College, PA	2006	Publication	Mine disasters
Effects of water sprays on airflow movement and methane dilution at the working face - Proceedings, 11th US/North American Ventilation Symposium, State College, PA	2006	Publication	Mine disasters
Electrical arcing-fault safety measures for mining. IEEE Trans. on Ind. App.	2007	Publication	Traumatic injuries
Electrical safety in small mines	2006	Video	Traumatic injuries
Emergency response virtual reality training	2007	Training	Surveillance and training
Emerging Technologies Control Respirable Dust Exposures for Continuous Miner and Roof Bolter Personnel - Accepted for presentation and publication at 11th US/North American Mine Ventilation Symposium, Pennsylvania State University, State College, PA, June 5-7, 2006	2006	Publication	Respiratory diseases
Empirical Ground Support and Blast Design, Book, Hustrulid, SME 2008	2008	Publication	Ground control
Ergonomics awareness training module	2006	Web document	Cumulative injuries

Title	Year	Output Type	Strategic Goal
Establishing More Appropriate Design Criteria for Mine Ventilation Stoppings - Annual SME Meeting, February 2007	2007	Publication	Ground control
Estimation of landing forces at different heights when assuming different postures: a laboratory study, International Journal of Industrial Ergonomics	2008	Publication	Cumulative injuries
Evaluating flow turbulence at the mining face and evaluating its impact on face methane levels - Society for Mining, Metallurgy and Exploration Annual Meeting, peer reviewed	2007	Publication	Mine disasters
Evaluating the Risk of Knee Injury Using a Finite Element Model of the Knee - Occupational Biomechanics journal (peer-reviewed)	2007	Publication	Cumulative injuries
Evaluation of a Continuously Regenerating Diesel Emission Trap for use Underground - proceedings of the Mining Diesel Emission Conference	2007	Publication	Respiratory diseases
Evaluation of Different Boot Tread Designs in Different Environments to Reduce the Risk of Slips and Fall in the Mining Industry - to be submitted to Ergonomics	2007	Publication	Cumulative injuries
Evaluation of Geophysical Techniques for Predicting Rock Strength from Boreholes - 27th International Conference on Ground Control in Mining	2008	Publication	Ground control
Evaluation of Remotely Installed Mine Seals for Fire Control, Proceedings, 11th U. S. Mine Ventilation Symposium, State College	2006	Publication	Mine disasters
Evaluation of SKC Inc. Dust Detective - Journal of Aerosol Science and Technology	2007	Publication	Respiratory diseases
Evaluation of the physiological stress experienced while carrying, raising, and manipulating the bar as well as the subtask of jabbing the bar against the wall - to be submitted to Journal of Safety Research	2007	Publication	Cumulative injuries
Evaluation of the Transverse Load Capacity of Block Stoppings for Mine Ventilation Controls (PhD dissertation)	2006	Publication	Ground control
Evaluation of the VR and CBT Map Reading Training, Journal of Safety Research	2006	Publication	Mine disasters
Evaluation of the VR Mine Evacuation Training Module, International Journal of Emergency Management	2009	Publication	Mine disasters
Evaluation of VR training deployment strategies, NIOSH RI	2007	Publication	Mine disasters
Examples and Strategies for using the PDM to Reduce Miners' Exposures to Respirable Dust - Coal Age	2007	Publication	Respiratory diseases
Explosion Evaluations of Mine Ventilation Stoppings - Proceedings, 11th U.S./North American Mine Ventilation Symposium, State College	2006	Publication	Mine disasters
Explosion Temperatures of Metals and Other Elemental Dusts - Combustion and Flame, peer reviewed	2008	Publication	Mine disasters
Extreme Multiple Seam Mining Conditions in Central Appalachia. Published and presented at the 25th International Conference on Ground Control in Mining	2006	Publication	Ground control
Extreme Multiple Seam Mining in the US - SME Annual Meeting	2006	Publication	Ground control

Title	Year	Output Type	Strategic Goal
Factors Impacting Shield Dust Entrainment in High Velocity Airstreams - SME transactions	2008	Publication	Respiratory diseases
Factors Impacting Successful Dust Control in Small Mines - SME Transactions	2008	Publication	Respiratory diseases
Field Evaluation of a Dust Explosibility Meter - Society for Mining, Metallurgy and Exploration Annual Meeting, peer reviewed	2006	Publication	Mine disasters
Field evaluation of muscle fatigue while using an intervention for low back discomfort among operators of mobile equipment, Journal of Biomechanics	2006	Publication	Cumulative injuries
Field evaluation of the effectiveness of an intervention for reducing low back discomfort among long-haul truck drivers, International Journal of Industrial Ergonomics	2007	Publication	Cumulative injuries
Field evaluation of the effectiveness of an intervention for reducing low back discomfort among operators of mobile equipment, International Journal of Industrial Ergonomics	2006	Publication	Cumulative injuries
Field evaluation of the effects of whole-body vibration on operators´ postural stability, Journal of Occupational and Environmental Hygiene	2008	Publication	Cumulative injuries
Field study to evaluate the effectiveness of an intervention for reducing low back discomfort among long-haul truck drivers, International Journal of Industrial Ergonomics	2008	Publication	Cumulative injuries
Final rule for High-Voltage Continuous Mining Machines	2010	Standards	Traumatic injuries
Fire detection and suppression systems for cabs of large mining equipment - peer reviewed publication, Fire Safety Journal	2006	Publication	Mine disasters
Fire detector evaluation for use in M/NM mines - peer-reviewed journal publication	2007	Publication	Mine disasters
Fire Generated Smoke Reversal Through Crosscuts From Return to Intake---Experimental and Computational Study, Proceedings, 11th U. S. Mine Ventilation Symposium, State College	2006	Publication	Mine disasters
Fire safety training - NIOSH workshop for M/NM mines	2007	Workshop, Seminar, or OIB	Mine disasters
Fire safety training - NIOSH workshop for M/NM mines (April, 2006)	2006	Workshop, Seminar, or OIB	Mine disasters
Fire safety training manual for M/NM mines - NIOSH RI	2007	Publication	Mine disasters
Fitcheck Software	2006	Software	Hearing loss
Flyrock brochures and video. NIOSH Toolbox Training Materials	2006	Publication	Ground control
Forklift Operator Training System, Paper in Journal of Safety Research - peer reviewed journal article	2007	Publication	Traumatic injuries
Fragmentation Methods and Ground Control Safety: A Blast Quality Measurement Trial - M. Sc. Thesis	2006	Publication	Ground control

Title	Year	Output Type	Strategic Goal
Frictional Ignitions of Methane-Air in the Presence of Heavier Hydrocarbons - NIOSH Tech News	2006	Publication	Mine disasters
From Theory to Practice: Examining Diesel Exhaust Filter Implementation and Performance in the Jerritt Canyon Mine - NIOSH RI	2007	Publication	Respiratory diseases
Fundamental Studies of Ground Failure - Report describing method to detect the location and timing of roof falls in underground non-metal mines - Canadian Institute of Mining conference	2008	Publication	Ground control
Gallagher, S., Marras, W.S., Litsky, A.S., and Burr, D., Factors Associated with Specific Failure Modes in Fatigue Testing of Human Lumbosacral Motion Segments, Clinical Biomechanics. In press	2006	Publication	Cumulative injuries
Gallagher, S., Marras, W.S., Litsky, A.S., and Burr, D., in press. Factors Associated with Specific Failure Modes in Fatigue Testing of Human Lumbosacral Motion Segments, accepted for publication in the journal Clinical Biomechanics	2006	Publication	Cumulative injuries
Gallagher, S., Marras, W.S., Litsky, A.S., and Burr, D., in review. The influence of bone mineral content and specimen morphology on the risk of fatigue failure of lumbar motion segments, European Spine Journal	2006	Publication	Cumulative injuries
Gob ventilation computer model to optimize the ventilation schemes to control spontaneous combustion in the U.S. underground coal industry [2009], Transactions, Society for Mining, Metallurgy and Exploration Annual Meeting, peer reviewed	2009	Publication	Mine disasters
Ground Control for Underground Coal Mines Bleeder Systems. Published and presented at the 25th International Conference on Ground Control in Mining	2006	Publication	Ground control
Ground Control in Australian Weak Roof Mines - US-Canada Rock Mechanics Symposium, Vancouver, Canada	2007	Publication	Ground control
Ground-based Radar for Mine Slope Monitoring - NIOSH RI	2006	Publication	Ground control
Guidelines and Seminars: implementing CBT and VR mine safety training	2007	Workshop, Seminar, or OIB	Mine disasters
Guidelines and Seminars: implementing CBT and VR mine safety training	2008	Workshop, Seminar, or OIB	Mine disasters
Guidelines and Seminars: implementing CBT and VR mine safety training	2009	Workshop, Seminar, or OIB	Mine disasters
Guidelines for a new miner curriculum	2008	Video	Surveillance and training
Guidelines for flame cutting and welding and fire prevention in underground coal mines - NIOSH RI	2008	Publication	Mine disasters
Guidelines for optimizing dust control for enclosed cabs on mobile mining equipment - NIOSH RI	2007	Publication (guidelines)	Respiratory diseases

Title	Year	Output Type	Strategic Goal
Guidelines for reducing the risk of injury while working in low seam coal mines - peer-reviewed SME journal	2007	Publication	Cumulative injuries
Guidelines for the development of a new miner training curriculum - NIOSH IC	2006	Publication	Surveillance and training
Guidelines for the Selection of Tread Design and Materials for Mine Worker Boots - peer-reviewed SME journal	2007	Publication	Cumulative injuries
Guidelines for tread design	2007	Video	Cumulative injuries
Guidelines on best support practices in weak roof rock. Published and presented at the 26th International Conference on Ground Control in Mining	2007	Publication (guidelines)	Ground control
Guidelines on designing for ingress/egress from equipment - International Journal of Ergonomics	2007	Publication (guidelines)	Cumulative injuries
Guidelines on effective engineering noise controls for horizontal vibrating screens - NIOSH numbered publication	2008	Publication (guidelines)	Hearing loss
Guidelines on effective engineering noise controls for horizontal vibrating screens - Web content	2008	Web document	Hearing loss
Guidelines on effective engineering noise controls for roof bolting machines - NIOSH numbered publication	2006	Publication (guidelines)	Hearing loss
Guidelines on effective engineering noise controls for roof bolting machines - Web content	2006	Web document	Hearing loss
Guidelines on HASARD technology for underground mining applications, NIOSH IC	2006	Publication (guidelines)	Traumatic injuries
Guidelines on purchasing bags with potential for reduction of ergonomic risk factors - NIOSH Information Circular	2007	Publication	Cumulative injuries
Guidelines on railcar ergonomics in the mining industry - NIOSH Information Circular	2007	Publication	Cumulative injuries
Guidelines to Reduce Diesel Particulate Matter in Coal, Metal, and Nonmetal Mines - NIOSH RI	2009	Publication	Respiratory diseases
Guidelines to Reduce Diesel Particulate Matter in Coal, Metal, and Nonmetal Mines." - NIOSH internet	2009	Web document	Respiratory diseases
Handbook for Methane Control in Mining - NIOSH IC	2006	Publication	Mine disasters
Healthy knee module	2006	Training	Cumulative injuries
Highwall Guidelines - Annual SME Meeting, February 2007	2007	Publication	Ground control
Highwall Web and Barrier Designs for Western Mines. Published and presented at the 27th International Conference on Ground Control in Mining	2008	Publication	Ground control
How well do new miners perform critical mining tasks? - Journal of Safety Research	2008	Publication	Surveillance and training
Hydraulic fluid flammability and fire resistance - Journal of Loss Prevention in the Process Industries, peer reviewed	2006	Publication	Mine disasters
Identification of noise sources on roof bolters - Noise-Con 2006	2006	Publication	Hearing loss
Impact of fan type for reducing respirable dust at an underground limestone crushing facility, SME Transactions	2007	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
Impact of Structural Design on Dust Levels in Mineral Processing Plants - NIOSH RI	2006	Publication	Respiratory diseases
Implementation of an ergonomics process by the Badger Mining Company - SME journal (peer reviewed)	2007	Publication	Cumulative injuries
Implementation of an ergonomics process by the Vulcan Mining Company - SME journal (peer reviewed)	2007	Publication	Cumulative injuries
Implementing Infrared Determination of Quartz Particulates on Novel Filters for a Prototype Dust Monitor - Journal of Occupational and Environmental Hygiene	2007	Publication	Respiratory diseases
Improved external spray systems for longwall shearers, Proceedings of Longwall USA	2008	Publication	Respiratory diseases
Improved System for Insert-Type Hearing Protector Fit-Testing (Kwitowski, Randolph) - Ear and Hearing Magazine (refereed)	2007	Publication	Hearing loss
Improved Utilization of Water Sprays for Reducing Worker Dust Exposure in Mining - Mining Engineering	2009	Publication	Respiratory diseases
Improving Access to Mining Safety and Health Information (Glowacki, Unger) - SME Annual Meeting	2007	Publication	Surveillance and training
Improving Access to Mining Safety and Health Information (Glowacki, Unger) - SME Annual Meeting	2008	Publication	Surveillance and training
Improving Face Ventilation in Large Opening Mines - Society for Mining, Metallurgy and Exploration Annual meeting, peer reviewed	2009	Publication	Mine disasters
In-Mine Evaluation of Firefighting High-Expansion Foam - Proceedings, 11th US/North American Ventilation Symposium, State College, PA	2006	Publication	Mine disasters
Instructor´s manual for the MSD Risk Factor Awareness Train-the-Trainer course (Wiehagen-W, Torma-Krajewski-J, Steiner-L), NIOSH IC	2006	Publication	Cumulative injuries
Instrumentation for DPM emissions research, Journal of Aerosol Science	2007	Publication	Respiratory diseases
Interventions and Recommendations for Roof Meshing	2007	Video	Cumulative injuries
Interventions to reduce MSDs in maintenance tasks	2008	Video	Cumulative injuries
Investigating Criteria for the Evaluation of Ingress/Egress Systems on Wheel Loaders - Conference proceedings, International Ergonomics Association Meeting (Maastrict, Netherlands).	2006	Publication	Cumulative injuries
Journal Article on Why Stories Matter, Journal of Adult and Continuing Education	2006	Publication	Surveillance and training
Journal of Acoustical Society of America: Nonmetal Mine Noise Surveys, 2009. (refereed)	2009	Publication	Hearing loss
Jurovcik P [2007]. Underground evaluation of a jacketed tail roller as an effective engineering noise control for continuous mining machines, Society for Mining, Metallurgy, and Exploration, Inc., 2007 SME Conference	2007	Publication	Hearing loss

Title	Year	Output Type	Strategic Goal
Jurovcik P [2008]. Evaluation of a jacketed tail roller as an effective engineering noise control for continuous mining machines. In: Proceedings of NOISE-CON 2008: Institute of Noise Control Engineering of the USA	2008	Publication	Hearing loss
Kissell, F (ed.) - Methane Control Handbook - DPRB researchers prepared three chapters for this handbook: Explosion Hazards of Coal Dust in the Presence of Methane; Geologic Features and their Influence on Mine Gas Emissions; Forecasting Gas Content, Gas Emissions, and Gas Production from Coalbeds, NIOSH numbered publication	2006	Publication	Mine disasters
Laboratory Determination of Dynamic Rock Properties - Paper in the International Journal of Rock Mechanics and Mining Science	2006	Publication	Ground control
Limiting Oxygen Concentrations for Gases and Gaseous Mixtures - Journal of Loss Prevention in the Process Industries, peer reviewed	2006	Publication	Mine disasters
Locating a Filter Medium Suitable for Quartz Analysis with the Personal Dust Monitor - proceedings SME Annual Meeting	2007	Publication	Respiratory diseases
Long-term Rock and Backfill Monitoring Using Vibrating Wire Instruments - paper in Field Measurements in Geomechanics	2007	Publication	Ground control
Longwall Dust Control Handbook - NIOSH IC	2007	Publication	Respiratory diseases
Lowering respirable dust at an iron ore concentrator plant through improved ventilation practices and other dust control methods - Proceeding of 11th US/North American Mine Vent Symposium	2006	Publication	Respiratory diseases
Machine powered personal cooling system, SME Proceedings	2008	Publication	Surveillance and training
Manganese method, NIOSH Manual of Analytical Methods	2008	Publication	Surveillance and training
Manual for Bulkhead Design, Construction, Operation, Monitoring and Emergency Planning and Management - NIOSH RI	2007	Publication	Mine disasters
Material handling project safety training, CD ROM	2006	Training	Traumatic injuries
Measurement of Anchorage Capacity in Borehole With Simple Device - Ground Control conference	2007	Publication	Ground control
Measuring diesel particulate matter in underground mines using sub micron elemental carbon as a surrogate - Proceeding of 11th US/North American Mine Vent Symposium	2006	Publication	Respiratory diseases
Measuring Job Safety and Health with Injury and Illness Statistics - peer reviewed journal article	2006	Publication	Surveillance and training
Mesh Material - Ergo Trials. Conference proceedings, International Ergonomics Association, 2006	2006	Publication	Ground control
Methane control/emissions modeling, applications for mine safety, and recommendations for control of frictional ignitions - NIOSH Open Industry Briefings	2009	Workshop, Seminar, or OIB	Mine disasters

Title	Year	Output Type	Strategic Goal
Method and apparatus for dozer remote control, IEEE Trans. On Ind. App.	2007	Publication	Traumatic injuries
Mine Accident, Injury, and Illness Data Exploration Tools (MAIIDETS) update	2006	Web document	Surveillance and training
Mine Accident, Injury, and Illness Data Exploration Tools (MAIIDETS) update	2007	Web document	Surveillance and training
Mine Accident, Injury, and Illness Data Exploration Tools (MAIIDETS) update	2008	Web document	Surveillance and training
Mine Accident, Injury, and Illness Data Exploration Tools (MAIIDETS) update	2009	Web document	Surveillance and training
Mine Accident, Injury, and Illness Data Exploration Tools (MAIIDETS) update	2010	Web document	Surveillance and training
Mine Fire Preparedness and Response Checklist for Underground Metal and Non-Metal Mines - NIOSH IC	2006	Publication	Mine disasters
Mine map reading computer-based training	2006	Training	Surveillance and training
Mine rescue training simulations, mine emergency response development (MERD) exercises, and smoke evacuation exercises at Lake Lynn Laboratory and mine sites for over 600 mineworkers	2007	Workshop, Seminar, or OIB	Mine disasters
Mine Slope Monitoring Best Practices - NIOSH IC	2006	Publication (guidelines)	Ground control
Miners' opinions about the PDM and how they can be used to reduce respirable dust exposure - Journal of Intl Society for Respiratory Protection	2007	Publication	Respiratory diseases
Miners' Opinions about the PDM and how they can be used to Reduce Respirable Dust Exposure - proceedings SME conference	2007	Publication	Respiratory diseases
Mining Engineering Journal article: Noise Surveys at Surface and Underground Stone Mines, 2007. (refereed)	2007	Publication	Hearing loss
Mining Fact Sheets (i.e., Mining, Underground Mining, Surface Mining) - NIOSH numbered publication	2006	Publication	Surveillance and training
Mining Fact Sheets (i.e., Mining, Underground Mining, Surface Mining) - NIOSH numbered publication	2007	Publication	Surveillance and training
Mining Fact Sheets (i.e., Mining, Underground Mining, Surface Mining) - NIOSH numbered publication	2008	Publication	Surveillance and training
Mining Fact Sheets (i.e., Mining, Underground Mining, Surface Mining) - NIOSH numbered publication	2009	Publication	Surveillance and training
Mining Fact Sheets (i.e., Mining, Underground Mining, Surface Mining) - NIOSH numbered publication	2010	Publication	Surveillance and training
Mining Fact Sheets for 2004 (i.e., Mining, Underground Mining, Surface Mining) - NIOSH numbered publication	2006	Publication	Surveillance and training
Mining Safety & Health Thesaurus - Users Manual (Glowacki, Unger), NIOSH Numbered Publication	2007	Publication	Surveillance and training
Modifying the Structure of Processing Plants to Reduce Dust Levels - Aggregates Manager	2008	Publication	Respiratory diseases

Title	Year	Output Type	Strategic Goal
Monitoring Longwall Coal Mine Seismicity With a Wireless Strong-Motion Accelerometer Network- Paper in the Proceedings of the U.S. Rock Mechanics Symposium	2006	Publication	Ground control
Monitoring Regional Ground Conditions During Pillar Extraction - paper at U.S. Rock Mechanics Symposium	2009	Publication	Ground control
MSD Risk Factor Awareness Train-the-Trainer Module to safety and health representatives of US Silica (Berkeley Springs, WV)	2006	Training	Cumulative injuries
MSD Risk Factor Awareness Train-the-Trainer Module to safety and health representatives of Vulcan Materials Company	2006	Training	Cumulative injuries
MSD Risk Factor Awareness Training Module at Badger Mining Company (Fairwater and Taylor Mines)	2006	Training	Cumulative injuries
MSHA [2007]. Jacketed tail roller - Program Information Bulletin P04-18 [2007], "Technologically Achievable, Administratively Achievable, and Promising Noise Controls," 30 CFR Part 62	2007	Standards	Hearing loss
MSHA [2007]. Noise treatments for a dust collector fan - Program Information Bulletin P04-18 [2007], "Technologically Achievable, Administratively Achievable, and Promising Noise Controls," 30 CFR Part 62	2007	Standards	Hearing loss
MSHA [2008]. Information Bulletin P04-18, Roof bolting machine engineering controls, "Technologically Achievable, Administratively Achievable, and Promising Noise Controls 30 CFR Part 62	2008	Standards	Hearing loss
MSHA [2009]. Information Bulletin P04-18 Vibrating screen engineering control, "Technologically Achievable, Administratively Achievable, and Promising Noise Controls 30 CFR Part 62	2009	Standards	Hearing loss
MSHA data files (final year-end release) in SPSS, dBaseIV, and SAS formats -- available on the NIOSH Mining Internet	2007	Web document	Surveillance and training
MSHA data files (final year-end release) in SPSS, dBaseIV, and SAS formats -- available on the NIOSH Mining Internet	2008	Web document	Surveillance and training
MSHA data files (final year-end release) in SPSS, dBaseIV, and SAS formats -- available on the NIOSH Mining Internet	2009	Web document	Surveillance and training
MSHA data files (final year-end release) in SPSS, dBaseIV, and SAS formats -- available on the NIOSH Mining Internet	2010	Web document	Surveillance and training
MSHA Fatality Profiles (quarterly releases and final year-end release)	2006	Web document	Surveillance and training
MSHA Fatality Profiles (quarterly releases and final year-end release)	2007	Web document	Surveillance and training
MSHA Fatality Profiles (quarterly releases and final year-end release)	2008	Web document	Surveillance and training
MSHA Fatality Profiles (quarterly releases and final year-end release)	2009	Web document	Surveillance and training
MSHA Fatality Profiles (quarterly releases and final year-end release)	2010	Web document	Surveillance and training
Multi-seam guidelines and NIOSH software support package. Published and presented at the 25th International Conference on Ground Control in Mining	2006	Publication (guidelines)	Ground control

Title	Year	Output Type	Strategic Goal
Multiple Seam Design Software - Open Industry Briefing to be held in Beckley, WV; Norton, VA; Pikeville, KY; and Grand Junction, CO	2006	Workshop, Seminar, or OIB	Ground control
Multiple Seam Design Software - Open Industry Briefing to be held in Beckley, WV; Norton, VA; Pikeville, KY; and Grand Junction, CO	2007	Workshop, Seminar, or OIB	Ground control
Multiple Seam Design Software - Open Industry Briefing to be held in Beckley, WV; Norton, VA; Pikeville, KY; and Grand Junction, CO	2008	Workshop, Seminar, or OIB	Ground control
Multiple Seam Designs for Harlan County, KY. Published and presented at the 26th International Conference on in Mining	2007	Publication	Ground control
Multiple Seam Mining in Western Mines. Published and presented at the 27th International Conference on Ground Control in Mining	2008	Publication	Ground control
National Survey of the Mining Population - Report describing characteristics (e.g., use of independent contractors) of mines - peer reviewed journal article	2008	Publication	Surveillance and training
National Survey of the Mining Population - Report describing the survey methodology - peer reviewed journal article	2007	Publication	Surveillance and training
National Survey of the Mining Population - Survey methodology and workforce characteristics for each mining sector and work locations - NIOSH IC	2008	Publication	Surveillance and training
Near Field Effects Due to Blasting - Paper in the Proceedings of the Symposium on Engineering Geology and Geotechnical Engineering	2006	Publication	Ground control
New Methods to Determine Shotcrete Adhesion in Mines - International Journal of Rock Mechanics and Mining Science	2006	Publication	Ground control
New Training on the Use and Maintenance of the PDM - proceedings SME conference	2007	Publication	Respiratory diseases
New version of Clothes Cleaning Booth, which does not require a dust cleaning baghouse associated with it	2007	Video	Respiratory diseases
New version of the Clothes Cleaning Booth, JOEH	2007	Publication	Respiratory diseases
NIOSH Mining Safety and Health Thesaurus Users Manual (Glowacki, Unger) - NIOSH numbered publication	2007	Publication	Surveillance and training
NIOSH-PRL HLPB [2006]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2006]. Noise workshop in Salt Lake City UT, Hosted by NIOSH-PRL, Mining Hearing Loss Prevention Workshop, April, 2006	2006	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2007]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL. (2 per year)	2007	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2008]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL (2 per year)	2008	Workshop, Seminar, or OIB	Hearing loss

Title	Year	Output Type	Strategic Goal
NIOSH-PRL HLPB [2009]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL (2 per year)	2009	Workshop, Seminar, or OIB	Hearing loss
NIOSH-PRL HLPB [2010]. Coal Noise Partnership Meeting/Workshop, at NIOSH/PRL (2 per year)	2010	Workshop, Seminar, or OIB	Hearing loss
Nitrogen dioxide calibration standards for portable methanometers - 57th Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy, Orlando, FL	2006	Publication	Mine disasters
Novel Stopping Designs for Large Opening Metal/nonmetal Mines - Aggregate Manager Magazine	2006	Publication	Mine disasters
Numerical Model of Dry-Stacked Blocks. The International Journal of Rock Mechanics and Mining Science	2006	Publication	Ground control
Numerical Modeling of Coalbed Gas Reservoirs for Mine Safety Applications - American Association of Petroleum Geologists national meeting, peer reviewed	2007	Publication	Mine disasters
Numerical modeling of gas flow in U.S. coal mine gob areas with bleeder ventilation systems - 11th U.S./North American Mine Ventilation Symposium	2006	Publication	Mine disasters
Numerical Modeling of Gas Flows in the Longwall Mining Environment for Methane Drainage and Ventilation Planning - Proceedings, 11th US/North American Ventilation Symposium, State College	2006	Publication	Mine disasters
Numerical Modeling of Primary and Supplemental Support Interaction - SME Annual Meeting	2008	Publication	Ground control
Occurrence of Frictional ignitions in U.S. Underground Coal Mines - 11th U.S./North American Ventilation Symposium, State College	2006	Publication	Mine disasters
Occurrence of Frictional ignitions in US underground coal mines, NIOSH RI	2006	Publication	Mine disasters
Open Industry Briefing at the 2006 Northwest Mining Association Convention	2006	Workshop, Seminar, or OIB	Surveillance and training
Open Industry Briefing at the 2007 Northwest Mining Association Convention	2007	Workshop, Seminar, or OIB	Surveillance and training
Open Industry Briefing at the 2008 Northwest Mining Association Convention	2008	Workshop, Seminar, or OIB	Surveillance and training
Open Industry Briefing at the 2009 Northwest Mining Association Convention	2009	Workshop, Seminar, or OIB	Surveillance and training
Open Industry Briefing at the 2010 Northwest Mining Association Convention	2010	Workshop, Seminar, or OIB	Surveillance and training
Oral history video and training module on the Farmington No. 9 mine disaster	2006	Video	Surveillance and training

Title	Year	Output Type	Strategic Goal
Ore pass safety - inspection and hang-up removal, CD ROM, PDA Formats	2006	Training	Traumatic injuries
Ore pass safety training - personal protective equipment, CD ROM	2006	Training	Traumatic injuries
OSHA workshop for rollout of NIOSH's HazCom Helper - OSHA version (targets: conferences for oil and gas industry and asphalt batch plants)	2006	Workshop, Seminar, or OIB	Surveillance and training
Overview of Current and Emerging Technologies for Performing Blast Damage Assessment in Underground Mines - Paper in the Proceedings of the International Conference on Ground Control in Mining	2006	Publication	Ground control
Overview of Improved Mine Ventilation Practices in Large Opening Mines - Proceedings, 11th US/North American Ventilation Symposium, State College	2007	Publication	Mine disasters
Patent on filter medium suitable for quartz analysis with PDM	2007	Patent	Respiratory diseases
Patent on procedure to test integrity of enclosed cab filtration systems	2007	Patent	Respiratory diseases
PC game-based training - current trends, NIOSH IC	2006	Publication	Mine disasters
Performance Evaluation of an Exhaust-gas Cooling Device in an Underground Coal Mine - proceedings SME Annual Meeting	2007	Publication	Respiratory diseases
Performance of a light scattering dust monitor at various air velocities: Results of sampling in the active versus passive mode, Journal of Aerosol Science	2007	Publication	Respiratory diseases
Performance of a light scattering dust monitor for use in underground mines, Proceedings of 11th U.S. Mine Ventilation Symposium	2006	Publication	Respiratory diseases
Performance standards and recommended selection criteria for person wearable methane monitors - SME Transactions	2008	Publication (guidelines)	Mine disasters
Personal monitoring system for hot working environments, SME Proceedings	2010	Publication	Surveillance and training
Peterson JS [2006]. Design and Instrumentation of a Large Hemi-Anechoic Chamber. In: Proceedings of NOISE-CON 2006, Institute of Noise Control Engineering of the USA	2006	Publication	Hearing loss
Peterson JS [2007]. Estimating sound power radiated by surfaces on a roof bolting machine using vibration measurements. In: Proceedings of NOISE-CON 2007	2007	Publication	Hearing loss
Peterson JS [2008]. Evaluation of engineering noise controls for a roof bolting machine. In: Proceedings of NOISE-CON 2008	2008	Publication	Hearing loss
Peterson JS [2008]. NIOSH-RI, Summarizing the results related to engineering noise controls for Roof Bolting Machines	2008	Publication	Hearing loss
Peterson JS, Kovalchik PG, Matetic RJ [2007]. Noise source identification on a roof bolting machine using a beamforming technique, Society for Mining, Metallurgy, and Exploration, Inc., 2007 SME Conference	2007	Publication	Hearing loss
Pillar Design Guidelines for Underground Stone Mines. The SME Annual Meeting and Conference, 2007	2007	Publication	Ground control

Title	Year	Output Type	Strategic Goal
Pillar Design in Kentucky Stone Mines with Benching. Published and presented at the 27th International Conference on Ground Control in Mining	2008	Publication	Ground control
Pillar Stability Issues Based on a Survey of Pillar Performance in Limestone Mines - International Conference on Ground Control in Mining	2006	Publication	Ground control
Porter, W, Kerna C, Mcclure, L, Gallagher S., Effects of Target Height and Bar Type on EMG and Force Generated in Simulated Mine Scaling Tasks - to be submitted to Applied Ergonomics	2006	Publication	Cumulative injuries
Post-Explosion Dust Analyses as a Method of Studying Coal Dust Explosions - journal publication	2007	Publication	Mine disasters
Potential for virtual reality training in the mining classroom, NIOSH IC	2007	Publication	Surveillance and training
Power line proximity warning alarm test results. IEEE Trans. on Ind. App.	2007	Publication	Traumatic injuries
Practical Guidelines for Monitoring the Ground Support Behavior of Cemented Backfill - SME Transactions Paper	2007	Publication	Ground control
Pre-driven Longwall Recovery Room Design Guidelines. Published and presented at the 27th International Conference on Ground Control in Mining	2008	Publication (guidelines)	Ground control
Preventing dermatitis among underground miners, NIOSH IC	2007	Publication (guidelines)	Surveillance and training
Preventing injuries in the use of off-highway equipment	2006	Workshop, Seminar, or OIB	Cumulative injuries
Proposed Design Procedures for Pillars in Limestone Mines - Mining Engineering (refereed journal)	2007	Publication	Ground control
Protecting Neighbors and Workers from CO Migrating from Blast Sites - paper by Marcia L. Harris, Michael J. Sapko, and Richard J. Mainiero. Plan to publish in a peer reviewed journal, Journal of Safety Research	2006	Publication (guidelines)	Traumatic injuries
Protection from arcing injury in the aggregates industry - SME Journal (peer-reviewed)	2008	Publication	Traumatic injuries
Protection from arcing injury in the coal industry - IEEE Trans. on Ind. App.	2007	Publication	Traumatic injuries
Prototype machine powered personal cooling system	2007	Patent	Surveillance and training
Prototype personal monitoring system	2009	Patent	Surveillance and training
Proximity warning systems for mining and construction equipment - Association of Equipment Manufacturers safety seminar	2006	Workshop, Seminar, or OIB	Traumatic injuries
Proximity Warning Systems for Surface Mining Equipment - Evaluations and Recommendations - NIOSH RI	2006	Publication (guidelines)	Traumatic injuries
Pumpable Crib Designs for Deep Western Mines. Published and presented at the 28th International Conference on Ground Control in Mining	2009	Publication	Ground control

Title	Year	Output Type	Strategic Goal
Pumpable Cribs - The next paradigm shift in tailgate support. Published and presented at the 26th International Conference on Ground Control in Mining	2007	Publication	Ground control
Quantitative Damage Assessment Techniques Employing Laser Scanning Technology - Ph.D dissertation	2008	Publication	Ground control
Railcar and rail yard ergonomics issues and the reduction of ergonomic risk factors - NIOSH Information Circular	2007	Publication	Cumulative injuries
Randolph RF, Byrne DC, Hudak RL [2006]. Effectiveness of a simplified earplug insertion technique on attenuation performance. Journal of the Acoustical Society of America (refereed)	2006	Publication	Hearing loss
Randolph RF, Hudak RL [2006]. Effect of simplified feedback on earplug insertion performance. Journal of Occupational and Environmental Hygiene. (refereed)	2006	Publication	Hearing loss
Randolph RF, Kissell FN [2006]. The effect of an insertion lubricant on the noise attenuation of foam earplugs. Journal of Occupational and Environmental Hygiene. (refereed)	2006	Publication	Hearing loss
Randolph RF, Reinke DC [2006]. NIOSH hearing loss simulator instruction and training guide. NIOSH numbered publication	2006	Publication	Hearing loss
Randolph RF, Reinke DC, Hudak RL [2007]. Roll-Pull-Hold earplug technique training package (NIOSH numbered publication)	2007	Training	Hearing loss
Randolph RF, Reinke DC, Hudak RL [2008]. Effectiveness of participative teams for hearing loss prevention. Journal of Occupational Environmental Hygiene. (refereed)	2008	Publication	Hearing loss
Randolph RF, Reinke DC, Hudak RL [2008]. Evaluation of hearing loss prevention program. Ear and Hearing. (refereed)	2008	Publication	Hearing loss
Randolph RF, Reinke DC, Hudak RL [2008]. Guidelines for worker empowerment for "best practices" hearing loss prevention program - NIOSH numbered publication	2008	Publication (guidelines)	Hearing loss
Randolph RF, Reinke DC, Hudak RL [2008]. Guidelines for worker empowerment for "best practices" hearing loss prevention program - Web content	2008	Web document	Hearing loss
Randolph RF, Reinke DC, Hudak RL [2008]. Team-based hearing loss communication interventions. Journal of Health Communication. (refereed)	2008	Publication	Hearing loss
Randolph RF, Reinke DC, Unger RL, Byrne DC, Kohler JL [2006]. Needs evaluation of the NIOSH hearing loss simulator. Journal of Occupational Environmental Hygiene. (refereed)	2006	Publication	Hearing loss
Real-time Seismic Monitoring of a 100-Square Mile Longwall Coal Mining District - Paper in the Proceedings of the International Conference on Ground Control in Mining	2009	Publication	Ground control
Recommendation to MSHA and Coal Diesel Partnership on determining diesel engine ventilation rates at simulated high altitudes	2006	Standards	Respiratory diseases
Recommendation to MSHA and Coal Diesel Partnership on the use of insulation to supplement water-jacketing, for permissible diesel engines	2007	Standards	Respiratory diseases

Title	Year	Output Type	Strategic Goal
Recommendations and guidelines for selection and use of flammable materials in the M/NM mining industry, NIOSH RI	2007	Publication	Mine disasters
Recommendations for conversion of bulldozers to remote control - peer reviewed publication, SME Transactions	2007	Publication	Traumatic injuries
Recommendations for scaling bar design and use - NIOSH Information Circular	2007	Publication	Cumulative injuries
Redesigned PRL visitor information package - NIOSH numbered publication	2008	Publication	Surveillance and training
Reducing Roof Bolter Operator Dust Exposures with a Canopy Air Curtain - Mining Engineering	2007	Publication	Respiratory diseases
Reducing the Rock Fall Hazard in Coal Mines with Low Strength Roof - guidelines for combined support systems for weak roof. Published and presented at the 27th International Conference on Ground Control in Mining	2008	Publication (guidelines)	Ground control
Reducing the Rock Fall Hazard in Coal Mines with Low Strength Roof - guidelines for mine layout to control horizontal stress. Published and presented at the 26th International Conference on Ground Control in Mining	2007	Publication (guidelines)	Ground control
Reducing the Rock Fall Hazard in Coal Mines with Low Strength Roof - guidelines for optimum panel lengths to minimize falls. Published and presented at the 26th International Conference on Ground Control in Mining	2007	Publication (guidelines)	Ground control
Reducing the Rock Fall Hazard in Coal Mines with Low Strength Roof - guidelines for rock testing during geological exploration. Published and presented at the 26th International Conference on Ground Control in Mining	2006	Publication (guidelines)	Ground control
Reeves ER [2006]. Noise control in underground metal mining. Pittsburgh, PA: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH IC) Publication No. In review, Dec.	2006	Publication	Hearing loss
Reeves ER [2008]. Guidelines for matching hearing protectors to workers and settings - NIOSH numbered publication	2008	Publication (guidelines)	Hearing loss
Reeves ER, [2006], Errors Made in the Application of Noise Controls, Mining Engineering Magazine, 2006 (refereed)	2006	Publication	Hearing loss
Reformulated Fuels and After Treatment Technology Effectiveness in Controlling Diesel Emissions. Stillwater Mining Co. Nye Mine Study - NIOSH RI	2006	Publication	Respiratory diseases
Reinforcing the Importance of Maintaining Good Blast Area Security	2006	Video	Ground control
Reinke DC, Barrett EA, Jurovcik P, Yantek DS, Ingram DK, Urban C [2006]. Partial Cab: An engineering noise control for drill rigs. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH IC) Publication No. Feb, 2006	2006	Video	Hearing loss
Reinke DC, Ingram DK, [2006], NIOSH´s health and safety materials for water well drillers, National Ground Water Association, Water Well Journal, June 2006	2006	Publication	Hearing loss

Title	Year	Output Type	Strategic Goal
Reinke DC, Jurovcik P, Fotta B [2006]. Recording Workplace Observations in Real Time Using ´PDA´s´. Journal of Health, Safety and Environmental Research, 2006. (refereed)	2006	Publication	Hearing loss
Reinke DC, Randolph RF [2008]. Guidelines on reducing barriers to adoption of noise control technologies - NIOSH numbered publication	2008	Publication (guidelines)	Hearing loss
Reinke DC, Randolph RF [2008]. Guidelines on reducing barriers to adoption of noise control technologies - Web content	2008	Web document	Hearing loss
Relationship Between Ground Motions, Seismic Event Magnitude and Distance at a Western Longwall Coal Mine - peer reviewed paper in the Journal of Geophysical Research	2007	Publication	Ground control
Remotely Installed Mine Seals for Mine Fire Control - Transactions, Society for Mining, Metallurgy and Exploration, Inc. Annual Meeting, St. Louis, peer reviewed	2006	Publication	Mine disasters
Report to Coal Diesel Partnership on the implementation of diesel particulate filters in West Virginia coal mines - Partnership Report	2006	Publication	Respiratory diseases
Report to the partnerships on the results from the Jerritt Canyon mine study - Partnership Report	2007	Publication	Respiratory diseases
Report to the partnerships on the results of the Johnson-Matthey CRT tests - Partnership Report	2006	Publication	Respiratory diseases
Report to the partnerships on the results of the Rohmac heat exchanger tests - Partnership Report	2006	Publication	Respiratory diseases
Reservoir Simulation-based Modeling for Characterizing Longwall Methane Emissions and Gob Gas Venthole Production - International Journal of Coal Geology, peer reviewed	2006	Publication	Mine disasters
Resin Grouted Cable Supports - 15 years and 15,000 miles of Strand. Published and presented at the 27th International Conference on Ground Control in Mining	2008	Publication	Ground control
Results of characterization of welding fume resulting from hardfacing (high manganese welding rods), Injury Prevention Magazine	2008	Publication	Surveillance and training
Results of Field Testing for Controlled Blasting at the CSM Experimental Mine - peer reviewed journal, ISEE Journal	2007	Publication	Ground control
Results of fume formation rates for welding mild steel (hardfacing with high manganese rods), Mining Engineering	2007	Publication	Surveillance and training
Results of Hydrostatically Testing the Micon 550 Seal to Failure - Journal Paper	2006	Publication	Mine disasters
Results of mapping welding fume particle size distribution in real time and location - Applied Occupational and Environmental Hygiene	2010	Publication	Surveillance and training
Results of new methodology for tracking welding fumes in mines, SME Proceedings	2009	Publication	Surveillance and training
Rock Mass Classification System for Limestone Mines. Peer-reviewed Rock Mechanics Journal	2008	Publication	Ground control
Roof bolter operator low back stress analysis - Journal of Safety Research	2006	Publication	Traumatic injuries

Title	Year	Output Type	Strategic Goal
Roof Fall Warning Systems for Underground Stone Mines. SME Annual Meeting, 2007	2007	Publication	Ground control
Roof Screening - Why did it take so long? Published and presented at the 28th International Conference on Ground Control in Mining	2009	Publication	Ground control
Roof Stability Mechanics in Limestone Mines - 2007 U.S. Rock Mechanics Symposium	2007	Publication	Ground control
Root causes of flame cutting and welding fires in the U. S. coal mining industry - Transactions, Society for Mining, Metallurgy and Exploration Annual Meeting, peer-reviewed	2006	Publication	Mine disasters
Ruff, T. [2006] Evaluation of a Radar-based Proximity Warning System for Off-highway Dump Trucks, Accident Analysis and Prevention, 38(1); :92-98	2006	Publication	Traumatic injuries
Safe and Ergonomic Methods to Install Roof Screen	2008	Video	Ground control
Safer mine electrical maintenance - NIOSH Information Circular	2010	Publication	Traumatic injuries
Safety Advances in Roof Bolt Selection. Published and presented at the 28th International Conference on Ground Control in Mining	2009	Publication	Ground control
Safety in Blasting - Frag Blast conference paper	2008	Publication	Ground control
Safety Shorts mine safety video series	2006	Video	Surveillance and training
Seismically Determined Longwall Coal Mine Failure Mechanisms - peer reviewed paper in the International Journal of Rock Mechanics and Mining Science	2008	Publication	Ground control
Selected Technology Effectiveness in Controlling Diesel Emissions in an Underground Mine - Isolated Zone Study at Stillwater Mining Co. Nye Mine - NIOSH RI	2007	Publication	Respiratory diseases
Selection and use of electrical meters in mining - Min. Engr.	2008	Publication	Traumatic injuries
Self-reported musculoskeletal symptoms and psychosocial risk factors among operators of heavy mobile equipment, Scandinavian Journal of Work, Environment, and Health	2007	Publication	Cumulative injuries
Seminar on virtual reality in mine training	2007	Workshop, Seminar, or OIB	Surveillance and training
Significant dust dispersion models for mining operations - NIOSH IC	2006	Publication	Respiratory diseases
Simple solutions ergonomics publication for surface mining - NIOSH IC	2009	Publication	Cumulative injuries
Simple solutions ergonomics publication for underground mining - NIOSH IC	2006	Publication	Cumulative injuries
Simulations of the oxidation of coal in the gob area under different bleeder and bleederless ventilation schemes, Transactions, Society for Mining, Metallurgy and Exploration Annual Meeting, peer reviewed	2007	Publication	Mine disasters

Title	Year	Output Type	Strategic Goal
Slender Pillar Stability in Underground Limestone Mines. Published and presented at the 27th International Conference on Ground Control in Mining	2008	Publication	Ground control
Society for Mining, Metallurgy and Exploration, Inc. Pittsburgh Section, Mine Seal Construction Seminar	2006	Workshop, Seminar, or OIB	Mine disasters
Society of Mining Engineering 2008 Annual Meeting and Exhibit: Sand and Gravel Noise Surveys, 2008	2008	Publication	Hearing loss
Software and users manual for assisting mine operators to select, implement, and evaluate administrative controls, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Pittsburgh, PA: DHHS (NIOSH IC) Publication No., 2007	2007	Software	Hearing loss
Software Package: ARMPS-MSM (multiseam mining)	2006	Software	Ground control
Software Solutions for Coal Mine Bleeder Pillar Designs. Published and presented at the 26th International Conference on Ground Control in Mining	2007	Publication	Ground control
Soluble Silver Method - Peer-reviewed paper in the Journal of Environmental Monitoring. Expected publication date - January 2006	2006	Publication	Surveillance and training
Soluble Silver Method, NIOSH Manual of Analytical Methods	2007	Publication	Surveillance and training
Some New insights Regarding the Application of the Split Hopkinson Bar for Determining the Dynamic Properties of Rock - U.S. symposium on rock mechanics	2007	Publication	Ground control
Sprayable Liner Flexibility Tests on Low RMR Rock Types - Paper in the Proceedings of the International Conference on Mechanics of Jointed and Faulted Rock	2006	Publication	Ground control
Spreadsheet applications in modeling the economic costs of safety applications of engineering controls, NIOSH RI	2007	Publication (guidelines)	Surveillance and training
Standing Supports for Deep Cover. Published and presented at the 27th International Conference on Ground Control in Mining	2008	Publication	Ground control
State-of-the-art Bulkhead Installations and Safety Issues in Underground Mines - Journal publication	2006	Publication	Mine disasters
STE Illumination Model	2006	Software	Traumatic injuries
Stress at work: issues for the mining industry, Journal of Occupational and Environmental Medicine	2006	Publication	Respiratory diseases
Summary data for mines, employment, injuries, and illnesses -- available on the NIOSH Mining Internet	2006	Web document	Surveillance and training
Summary data for mines, employment, injuries, and illnesses -- available on the NIOSH Mining Internet	2007	Web document	Surveillance and training
Summary data for mines, employment, injuries, and illnesses -- available on the NIOSH Mining Internet	2008	Web document	Surveillance and training
Summary data for mines, employment, injuries, and illnesses -- available on the NIOSH Mining Internet	2009	Web document	Surveillance and training

Title	Year	Output Type	Strategic Goal
Summary data for mines, employment, injuries, and illnesses -- available on the NIOSH Mining Internet	2010	Web document	Surveillance and training
Summary of LLEM Explosion Research, 1999 to 2004 - NIOSH RI	2007	Publication	Mine disasters
Summary of LLEM Explosion Research, 2005 to 2008 - NIOSH RI	2009	Publication	Mine disasters
Support Pillar Behavior During Retreat Mining in a Lead/Zinc Mine - paper at International Backfill Symposium	2008	Publication	Ground control
Survey of Pillar Performance in Underground Limestone Mines - Open Industry Briefing (OIB) Underground Stone Safety Conference	2006	Workshop, Seminar, or OIB	Ground control
Survey of Roof Stability in Limestone Mines - 2007 meeting of the Society for Mining, Metallurgy, and Exploration (SME)	2007	Publication	Ground control
Survival analytic approach to evaluating struck-by accidents using a virtual human model - Journal of Human Factors	2006	Publication	Traumatic injuries
Technical evaluation of the coal dust explosibility meter - Transactions, Society for Mining, Metallurgy and Exploration Annual Meeting, peer reviewed	2006	Publication	Mine disasters
The Application of Laser Scanning & Digital Photography in Assessing the Stability of Underground Mine Workings - Mining R&D News	2008	Publication	Ground control
The Coal Mine Roof Rating (CMRR) - A Decade of Experience. J. of Coal Geology, in press	2006	Publication	Ground control
The Costs of Mining Injuries in the Western U.S.: An Economic Analysis - peer reviewed journal article	2008	Publication	Surveillance and training
The Design of Intersections Subjected to High In Situ Stress. Published and presented at the 28th International Conference on Ground Control in Mining	2009	Publication	Ground control
The Development of a Finite Element Biomechanical Model of the Knee - model completed and will be submitted to Clinical Biomechanics journal	2007	Publication	Cumulative injuries
The Development of a Healthy Knee Module for Low Seam Coal Miners - Journal of Safety Research	2006	Publication	Cumulative injuries
The dust control capability of mist drilling for roof bolters, SME Transactions	2007	Publication	Respiratory diseases
The dust control effectiveness of wet-head sprays on a continuous miner, SME Transactions	2008	Publication	Respiratory diseases
The Effect of Resin Insertion Bolting Pressures on Roof Stability. Published and presented at the 27th International Conference on Ground Control in Mining	2008	Publication	Ground control
The Effect of Stress on Weak Roof. Published and presented at the 27th International Conference on Ground Control in Mining	2008	Publication	Ground control
The Effects of Humidity on Sedimentary Rocks. Published and presented at the 26th International Conference on Ground Control in Mining	2007	Publication	Ground control

Title	Year	Output Type	Strategic Goal
The effects of PuroNOx on diesel particulate matter emissions in underground metal/nonmetal mines, Journal of Aerosol Science	2007	Publication	Respiratory diseases
The effects of water spray placement for controlling respirable dust and face gas concentrations, Journal of Mine Vent Soc of SA	2007	Publication	Respiratory diseases
The elemental carbon content in DPM from vehicles in underground mines and the effects of control technologies on those emissions, Proceedings of 11th US/North American Mine Vent Symposium	2006	Publication	Respiratory diseases
The Evaluation of New Knee Pad Designs to Prevent Injuries in Low Seam Coal Miners - to be submitted to peer-reviewed Ergonomics and SME journals	2007	Publication	Cumulative injuries
The First Critical Hours: Before the Mine Rescue Team Arrives, Proceedings, Sixth International Conference on Occupational Stress & Health "Making a Difference in the Workplace"	2006	Publication	Mine disasters
The impact of water application for shield dust control, SME Transactions	2008	Publication	Respiratory diseases
The influence of Geologic Factors on in situ Methane Contents and Gas Emissions - Proceedings, 11th US/North American Ventilation Symposium, State College	2006	Publication	Mine disasters
The NIOSH Initiative for Promoting Safer, More Economic Drifting in Underground Metal/Non-Metal Mines, Proceedings of the International Symposium Fragblast -8, Santiago, Chile, 2006 (abstract accepted)	2006	Publication	Ground control
The Relationship between Muckpile Geometry and Fragmentation with Blasting Performance and Underground Stability - Mining Engineering (peer reviewed journal article)	2008	Publication	Ground control
The relationship between workplace stress and abnormalities of the Hypothalamic-Pituitary-Adrenal (HPA) axis, Journal of Occupational and Environmental Medicine	2007	Publication	Respiratory diseases
The Role of Surveillance in Mining Safety and Health Research - peer reviewed journal article	2007	Publication	Surveillance and training
The use of new technologies to train new miners	2007	Training	Surveillance and training
The Use of String Charges for Perimeter Control in Drifting - Canadian Mining Journal (peer reviewed journal article)	2007	Publication	Ground control
Theoretical Fundamentals of the New NIOSH Controlled Blasting Software - Paper in International Journal of Rock Mechanics and Mining Science	2006	Publication	Ground control
Through Their Eyes: An Oral History of the Sunshine Mine Disaster - NIOSH IC	2006	Publication	Surveillance and training
Tools for safer mine electrical maintenance - Min. Engr.	2008	Publication	Traumatic injuries
Topic page linked to NIOSH Economics Forum Internet page	2008	Web document	Surveillance and training

Title	Year	Output Type	Strategic Goal
Torma-Krajewski, J., Steiner, L., Lewis, P., Gust, P., Johnson, K. Ergonomics and Mining: Charting a Path to a Safer Workplace, NIOSH Information Circular	2006	Publication	Cumulative injuries
Torma-Krajewski, J., Steiner, L., Wiehagen, W., Unger, R., Lewis, P., Gust, P., Johnson, K. Ergonomics and Mining: Oil and Water or Cream and Sugar. Submitted to the International Journal of Industrial Ergonomics. In review, peer reviewed	2006	Publication	Cumulative injuries
Toxicology effects of welding fume from hardfacing, Journal of Occupational and Environmental Medicine	2010	Publication	Surveillance and training
Train-the-Trainer Materials for Building Better Jobs: (1) Concept and implementation; (2) Tool design; (3) Anthropometrics and biomechanics for design; (4) Maintenance; (5) Equipment purchasing and retrofitting; and (6) Control design	2008	Training	Cumulative injuries
Training in Using the ROSS, Profilometer, and/or Anchorage Measurement Device to Optimize Support Design	2007	Training	Ground control
Training interventions for enhancing the communications/decision making process during the initial phase of a mine emergency, such as a fire or explosion - NIOSH IC	2006	Publication	Mine disasters
Training Materials for MSHA and the mining industry on explosion hazard recognition and preventive measures for underground coal mines - NIOSH RI	2006	Publication	Mine disasters
Training Materials for MSHA and the mining industry on explosion hazard recognition and preventive measures for underground coal mines - NIOSH Video	2006	Video	Mine disasters
Training Materials on Preventing Injuries from Operating Mobile Equipment: Focus on Ingress/Egress and Vibration - Industrial Minerals Association of North America workshop (Pittsburgh, PA)	2006	Training	Cumulative injuries
Training Module for Coal Mine Health and Safety Technicians on how to Maintain the PDM - NIOSH IC	2006	Publication	Respiratory diseases
Training Module for Coal Miners on the Purpose and Operation of the PDM - NIOSH IC	2006	Publication	Respiratory diseases
Transverse Load Capacities of Dry-Stacked Block Mine Ventilation Stoppings Under Rigid Arching Loading Conditions - 11th U.S./North American Mine Ventilation Symposium, Penn State University, June 5-7, 2006	2006	Publication	Ground control
Transverse Loading Capacities of Dry-Stacked Blocks. Published and presented at the 26th International Conference on Ground Control in Mining	2007	Publication	Ground control
Trends in overhead power line electrocution accidents statistics - IEEE Trans. on Ind. App	2009	Publication	Traumatic injuries
Underground Stone Design Guidelines for Entry Design. Mining Engineering, Refereed Journal	2008	Publication (guidelines)	Ground control
Underground Stone Design Guidelines for Pillar Design. Mining Engineering, Refereed Journal	2007	Publication (guidelines)	Ground control
Underreporting of Nonfatal Injuries and Disease/Illness in U.S. Mining, Journal of Occupational and Environmental Medicine	2006	Publication	Surveillance and training

Title	Year	Output Type	Strategic Goal
Use of cost modeling in occupational safety and health research, Cost Engineering	2006	Publication	Surveillance and training
Use of cost modeling in safety research, Journal of Safety Research	2007	Publication	Surveillance and training
Use of virtual reality technologies in mine training, NIOSH IC	2008	Publication	Surveillance and training
Users Guide for the Bplane, Bstepp, and Bwedge Computer Programs - NIOSH IC	2006	Publication	Ground control
Using General Linear Models to Analyze Miner Experience vs Injury Frequency and Severity - peer reviewed journal article	2006	Publication	Surveillance and training
Using Monitoring Technologies to Warn of Roof Fall Occurrences - SME Annual Meeting, St. Louis	2006	Publication	Ground control
Using proximate analysis to characterize airborne dust generation from bituminous coals - Coal Age	2006	Publication	Respiratory diseases
Using Zero Incidence to Drive Mining Safety and Health Programs - peer reviewed journal article	2009	Publication	Surveillance and training
Utility of hazard communication inventory lists and EPA TRI reports for estimating chemical hazards in mining, Journal of Environmental Science and Technology	2007	Publication	Respiratory diseases
Utilizing Spot Scrubbers to Reduce Dust Levels on Continuous Mining Machines - SME transactions	2008	Publication	Respiratory diseases
Ventilation Design for Large-Opening Mines - NIOSH IC	2009	Publication	Mine disasters
Video for seat/posture training in mobile equipment	2007	Video	Cumulative injuries
Video motion detection for real-time hazard warnings in surface mines (EIR)	2007	Patent	Ground control
Video Motion Detection for Real-time Hazard Warnings in Surface Mines - peer reviewed journal article	2008	Publication	Ground control
Video motion detection for real-time hazard warnings in surface mines - RI	2007	Publication	Ground control
Video on implementing and development of vibrating screen noise controls, 2009	2009	Video	Hearing loss
Video on implementing and the development of roof bolting machines noise controls, 2008	2008	Video	Hearing loss
Video on maintenance shop safety	2006	Training	Traumatic injuries
Video production on Mobile Equipment Operator Workstations	2007	Video	Cumulative injuries
Videotapes, workbooks and similar training interventions to transfer research findings to the mining industry - NIOSH communications	2007	Training	Mine disasters
Vipperman JS, Bauer ER, Babich DR [2006]. Survey of noise in coal preparation plants. Journal of Acoustical Society of America, Submitted to Journal. (refereed)	2006	Publication	Hearing loss
VR Map Reading Training Module	2006	Software	Mine disasters
VR Mine Evacuation Training at SRL, Mining Engineering	2006	Publication	Mine disasters

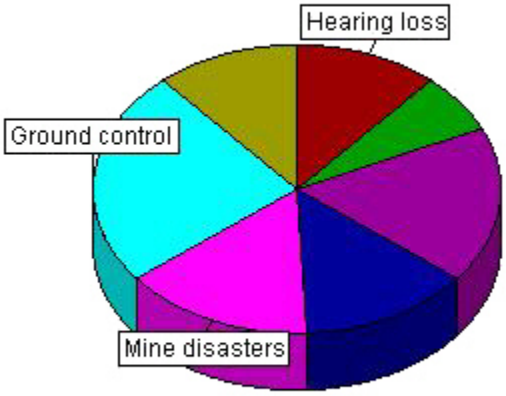
Title	Year	Output Type	Strategic Goal
VR Mine Evacuation Training Module	2009	Software	Mine disasters
Weak Roof Rock and Rock Fall Injuries - Case Study. Published and presented at the 26th International Conference on Ground Control in Mining	2007	Publication	Ground control
Web module: Ergonomic Principles for Better Jobs Design	2009	Web document	Cumulative injuries
Website for VR Miner Safety Training	2007	Web document	Mine disasters
Weiss ES, Cashdollar KL, Harteis SP, Shemon GJ, Beiter DA, Urosek JE - Explosion Evaluations of Ventilation Stoppings. NIOSH RI	2006	Publication	Mine disasters
Working Mine Ventilation Layouts for Large Opening Stone Mines - Proceedings, 11th US/North American Ventilation Symposium, State College	2006	Publication	Mine disasters
Workshop presentation to IMA-NA members on Railcar and Railyard Ergonomics	2006	Workshop, Seminar, or OIB	Cumulative injuries
Workshops and training aids to transfer flame cutting and welding research findings to the coal mining industry [2007-2008]	2008	Workshop, Seminar, or OIB	Mine disasters
Yantek DS [2006]. Noise source identification on horizontal vibrating screens using a beamforming technique, Society for Mining, Metallurgy, and Exploration, Inc., 2006 SME Conference	2006	Publication	Hearing loss
Yantek DS [2007]. Estimating sound power radiated by horizontal vibrating screens, Proceedings of NOISE-CON 2007, In: Institute of Noise Control Engineering of the USA	2007	Publication	Hearing loss
Yantek DS [2008]. Evaluation of engineering noise controls for horizontal vibrating screens. Proceedings of NOISE-CON 2008: Institute of Noise Control Engineering of the USA	2008	Publication	Hearing loss
Yantek DS [2008]. NIOSH-RI, Summarizing the results related to engineering noise controls for horizontal vibrating screens	2008	Publication	Hearing loss

Planned Outputs Summary

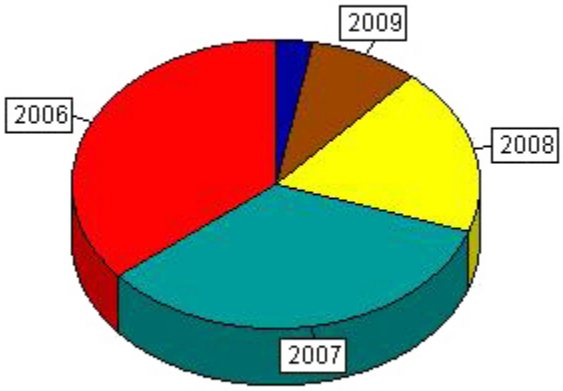
Total Planned Outputs: 587

Note - Percentage totals may not equal 100% due to rounding errors.

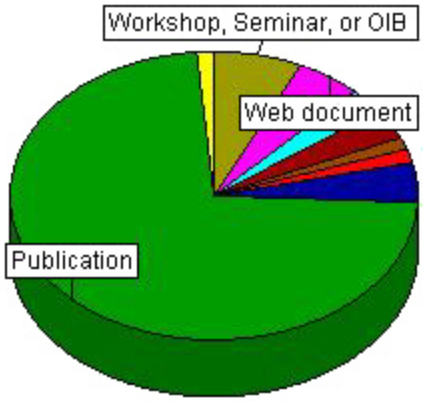
Strategic Goals	N	%
Cumulative injuries	67	11.4
Ground control	142	24.2
Hearing loss	67	11.4
Mine disasters	89	15.2
Respiratory diseases	80	13.6
Surveillance and training	103	17.5
Traumatic injuries	39	6.6



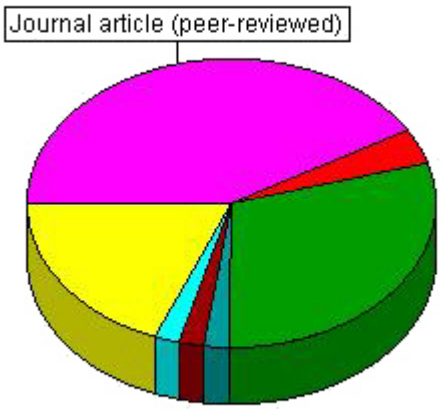
Year	N	%
2006	211	35.9
2007	198	33.7
2008	110	18.7
2009	51	8.7
2010	17	2.9



Output Types	N	%
Patent	8	1.4
Publication	428	72.9
Publication (guidelines)	26	4.4
Software	9	1.5
Standards	8	1.4
Training	20	3.4
Video	17	2.9
Web document	30	5.1
Workshop, Seminar, or OIB	41	7



Publication Type	N	%
Book/book chapter/dissertation	7	1.5
Brochure-flyer	7	1.5
Conference proceedings	138	30.4
Journal article (not peer-reviewed)	16	3.5
Journal article (peer-reviewed)	190	41.9
NIOSH/USBM numbered	85	18.7
Other	10	2.2
Technology News	1	0.2



How Planned Outputs are Categorized

Planned outputs are externally-distributed publications and products that the NIOSH Mining Program expects to develop over the next 5 years. The following taxonomies are used to categorize these outputs:

Strategic Goal

Outputs are categorized according to the Strategic Goal (see Section 1.5) addressed by the research:

- **Respiratory diseases** - Reduce respiratory diseases in miners by reducing health hazards in the workplace associated with coal worker pneumoconiosis, silicosis, and diesel emissions.
- **Hearing loss** - Reduce noise-induced hearing loss (NIHL) in the mining industry.
- **Cumulative injuries** - Reduce repetitive/cumulative musculoskeletal injuries in mine workers.
- **Traumatic injuries** - Reduce traumatic injuries in the mining workplace.
- **Mine disasters** - Reduce the risk of mine disasters (fires, explosions, and inundations); and minimize the risk to, and enhance the safety and effectiveness of, emergency responders.
- **Ground control** - Reduce ground failure fatalities and injuries in the mining industry.
- **Surveillance and training** - Determine the impact of changing mining conditions, new and emerging technologies, and the changing patterns of work on worker health and safety.
- **All** - Outputs related to all strategic goals of the Mining Research Plan. This includes technology transfer / health communications efforts and mining research program planning and tracking.

Output Type

Outputs are also categorized by Output Type:

- **Patent** - A U.S. or foreign patent granted for a NIOSH invention.
- **Publication** - An officially-published document (excludes Web documents.)
- **Publication (guidelines)** - A publication that recommends a policy or procedure.
- **Web document** - A document developed solely for Web distribution that has not been officially published and is currently available on the NIOSH Mining Safety and Health Research web site (obsolete web documents are not listed.)
- **Software** - A computer program.
- **Standards** - Recommended rules or guidelines for conducting an activity or task, utilizing a product, etc. that are approved by a recognized standards organization or accepted as a de facto standard by the industry.
- **Training** - An educational material comprising an instructor's guide with tested educational materials and supporting documents designed to meet stated educational objectives (Note - if published as a government numbered document, a training material is instead classified as a Publication.)
- **Video** - A videocassette, videotape, or electronic video

- **Workshop/Seminar/OIB** - An event organized by the NIOSH Mining program, usually to educate the mining industry on particular safety and health issues or research developments.

Publication Type

All publications (outputs with an Output Type of Publication or Publication (guidelines)) are further classified by the specific type of publication.

Published by NIOSH:

- **Hazard Controls/IDs** - Hazard Controls describe control techniques to reduce hazardous exposures to workers in a particular application/industry process. Hazard IDs summarize results of NIOSH studies at a specific worksite, identify new or current health and safety hazards, and offer the best recommendations for control or prevention. Both are brief, 1-2 page documents.
- **Technology News** - One-page flyers used to announce a milestone in mining health and safety research, technology ready for transfer to industry, or an opportunity for cooperative research and development.
- **NIOSH/USBM numbered** - Documents published by DHHS (NIOSH), including Information Circulars (ICs), Reports of Investigation (RIs), Special Publications, and other numbered publications.

Published by external sources:

- **Book/book chapter/dissertation** - Includes PhD dissertations; however, masters theses are classified as Other.
- **Conference proceedings** - Papers published in conference proceedings in either print or electronic format (e.g., CD-ROM.)
- **Journal article (peer-reviewed)** - Papers published in journals that have undergone a blind peer-review.
- **Journal article (not peer-reviewed)** - Papers published in journals that have not undergone a blind peer-review.

Published by both NIOSH and external sources:

- **Brochure/flyer** - Includes pamphlets, brochures, and flyers. Also includes NIOSH Fact Sheets with surveillance data on fatalities, injuries, and illnesses for various mining commodities.
- **Other** - Other publications not elsewhere classified. Includes contract and MOA reports, MSHA reports, masters theses, bulletins, newsletters, newsletter articles, etc.

4.4 Emerging Issues

Emerging issues are factors or trends, such as commodity demand, workforce and technology changes, that should be considered in planning the future of the NIOSH mining research program. Some of these trends and changes may provide opportunities to develop new and better solutions to existing health and safety problems. Other issues with potentially adverse safety or health consequences need to be identified early enough to allow intervention before workers are affected. The process time between the identification of a problem and the successful development and adoption of an effective solution can be measured in years. Thus our planning processes aim to identify "emerging issues" over the next five-to-ten year horizon. The emerging mining safety and health issues that we have identified are summarized here.

Production Demands

A significant change in the demand for commodities mined in the coal, nonmetal, and metal sectors would likely affect the injury and illness data that characterize the present workforce; and these changes could alter the priorities or direction of the mining research program. The Nation's increased need for energy would suggest a need for increased coal production, as would plans to develop a hydrogen economy, which would probably rely heavily on coal. However, concerns over emissions from fossil fuel use could temper any robust forecast for dramatically increased coal production. Credible forecasts suggest that coal production will grow modestly for years beyond the NIOSH research planning cycle. Hence, for our planning purposes we are assuming that coal mining will continue to be as important five years from now as it is today. Similarly, there is no evidence to suggest that nonmetal mining will change significantly in importance, and given the increasing activity in stone, sand, and gravel mining, this sector may increase in importance. Of the three sectors, metal mining has seen the greatest decline in production and numbers of workers, as operations have moved outside of the U.S. The changes that have occurred suggest that there is no need to increase the current level of health and safety research focused solely on metal mining. However, with material prices near real record levels and a likelihood that these prices may be sustained, it is likely that the level of underground mining in all sectors will increase. The challenges that will accompany any increased mining production from the US in all mining sectors are likely to come from more challenging environments.

Workforce Issues

Significant demographic changes are occurring in the mining workforce because of the impending eligibility for retirement of the Baby-Boomer cohort, limited hiring in many mining sectors over the past fifteen to twenty years, and the current high demand for specific commodities. Some mine sites now have exclusively older workers. While this more experienced worker is less likely to be injured on the job, when he or she is injured the results are often more severe than for a younger person. This severity results in longer recovery time and more lost work days than for younger workers. While the impacts of physically demanding tasks, such as heavy lifting or whole body vibration exposure, may not be apparent to the 30 or 40 year old miner, the musculoskeletal disorders resulting from performing these tasks over a career will be clearly seen in the older population. On the other hand, the demographic changes are and will be bringing many new inexperienced miners into the industry. The difficulty and complexity of the mining workplace necessitates a period of learning and adjustment for the

new hires when they will be at risk and when, through their inexperience, they may put others at risk. Moreover, the same demographic trends can found in the ranks of mine managers, mine engineers, mine inspectors, mining professors, and even mining researchers. The knowledge, skills, and judgment that will be lost with the retirement of the current older workforce have a huge potential for adverse impact on health and safety. Specifically, the following needs are forecast.

Help workers age successfully

We believe that the mining industry will benefit from the retention of older, experienced miners, and that certain changes will be required to minimize their risk of cumulative trauma disorders and traumatic injuries. Research is needed to develop tools and best practices for designing work tasks and processes to accommodate the physical capabilities and limitations of older workers. Workplaces should also be redesigned with considerations to naturally occurring aging changes, such as age-related changes in vision. In many cases, workplaces can be designed to be safer and healthier for employees of all ages.

Train for an evolving workforce

The expected influx of a large number of new and inexperienced miners could lead to a sharp increase in injuries. Since many of the new employees will be coming from a generation with different life and educational experiences than the currently predominant Baby-Boomers, effective training content and methods will have to be tailored to their specific needs. Their strengths and weaknesses should guide the development, implementation, and evaluation of the training that will prepare them for their mining careers. Training innovations will continue to be needed as the new cohort of miners moves through various positions and eventually needs to be prepared for leadership roles. Research to develop training innovations and to evaluate their efficacy will be needed in the short and longer term.

Capture the experience of the retiring workforce

Finding ways to capture and pass the knowledge and skills of the current workforce on to the new generation is a critical current need. The present generation of miners, mine managers, mine inspectors, and mining engineers has accumulated a vast reserve of knowledge, skill, and judgment. Their decades of work in the mines have given them operational wisdom that cannot be easily duplicated. They are undoubtedly responsible for preventing mine explosions, mine fires, and countless traumatic injuries with actions that are not captured in textbooks or regulations. Thus, research is needed to develop mechanisms for capturing and disseminating what they have learned.

Mining Practices

Mining economics generally dictates that the "best" deposits be mined first. However, at some point in time, the "best" are gone, and it becomes necessary to conduct mining activities in more adverse geologic conditions. Some of these conditions increase safety and health risks. Underground mining of gassier coal seams, for example, presents increased risk for explosions, while mining of deposits in weaker ground presents increased risk for fall of ground injuries. These changing conditions and associated risks must be monitored to detect consequential changes. The level of on-going ground control research appears adequate to address the emerging issue, but new ventilation and methane drainage work is envisioned.

Develop improved ventilation and methane drainage practices for gassy coal seams

Gassier deposits and expansive high-production longwalls present special challenges, and given the trend toward more gas and larger panels, we need to better understand through research the interaction of the ground and gas flows from adjacent panels or coal seams above the active panel but within its fracture zone. Research is needed to develop mine ventilation design methodologies and operational practices to prevent dangerous or unexpected accumulations of gas.

Other emerging practices

Remote control, tele-operation, automation and "intelligent" mining equipment will be effective means to prevent injuries. Improved remote sensing and "smart" data processing of roof, ventilation and equipment conditions will lead to better information for miners and mine operators and give them advanced warning of adverse or hazardous conditions. Wireless communication technologies used at the surface today will find their way into the underground mining operations and will help miners and managers improve day-to-day as well as emergency communications, promoting safer working conditions and practices. Further research is needed to fully and effectively integrate these emerging technologies into the underground environment with its requirements for permissibility and a topology that limits the spread or bandwidth of wireless signals.

Overall improvements to mining safety and health, as captured in the injury statistics, have leveled off in recent years. Many have suggested that further reductions in injuries will require "cultural" changes among management and workers and/or different approaches to workplace safety. We have identified two areas that we believe show promise and are consistent with our mission. The first is to examine the merits of a risk-based rather than regulatory-based approach to mine safety. We have funded a pilot study in this area, and found the preliminary results to be promising. As a result, we intend to initiate a program, primarily through research contracts, to conduct more complete analyses of these approaches. The second is to examine quantitatively the effectiveness of individual health and safety interventions that are part of a larger mix of activities within an organization's health and safety program. Again, pilot studies were conducted, and based on the promising findings, a full program will be initiated through research contracts.

Changing work practices, shift length, shift schedules, and "fly-in and fly-out" operations are increasing, and studies conducted by Australian researchers suggest possible adverse health and safety consequences of some practices. Moreover, an increased awareness of workplace stress and cardiovascular disease, depression, and other concerns may necessitate further study of these practices. As a first step in this area, we have begun discussions with Australian researchers aimed at building on their work through possible joint research projects.

The existing mining surveillance program includes components specifically designed to detect events that may signal future problems. For example, the chemical hazards program within mining has been investigating the potential hazards from acrylamide used in coal preparation, methacrylate used in spray-on liners, and welding fumes, among other hazards. Another example is the "CWP Hot Spots" program with NIOSH´s Division of Respirable Disease Studies, in which their surveillance of black lung disease is used to identify areas where

traditional engineering interventions are failing. These areas are then examined by mining researchers to determine the cause of the "hot spot" and to introduce appropriate interventions. The Health Hazards Evaluation program operated by NIOSH's Division of Surveillance, Hazard Evaluation, and Field Studies serves the mining sector and is an effective mechanism for identifying emerging chemical hazards. Examples of current work initiated after identification of an emerging issue are found throughout these briefing documents, as are examples of activities to learn of new issues as they emerge.

NIOSH Mining Program Briefing Book

Improving mine safety and health through research and education.

Appendix A - Project Planning

Procedures for External Peer Review of Intramural Projects 825
FY2006 Project Concept Paper Outline 833
NIOSH FY2006 Project Form 835

Sample Project Forms

Guidelines for Eliminating Hazardous Ground Conditions 839
Dust Control Technology for Black Lung Hot Spots 883

Instructions and Supporting Documents

Intramural Research Project Proposal Instructions 913
Hints for Writing Project Proposals 921
Project Budget Estimate 923
Developing a Protocol 925

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Procedures for External Peer Review of Intramural Projects

(Updated May 26, 2005)

Introduction

The following describes the procedures for using external peer review to help evaluate and improve intramural research projects. The procedures apply to the review of new projects within the first year of initiation. It should help employees to understand the process by which their research will be evaluated by external peers to help validate and improve that research. Topics discussed include the background of new legal requirements for peer review of internal Federal research, relevant policies of CDC and NIOSH, and the procedures initiated in the Mining Program to implement these policies. The procedures are designed to help ensure the quality of the internal research done at the Mining Program laboratories, to satisfy the legal and policy requirements, and to minimize additional administrative burden on researchers and the external reviewers who assist NIOSH with this effort.

Background

The Mining Program has been using external peer reviewers to help evaluate and improve project proposals for new intramural research projects since 2000. External reviewers have also evaluated Mining Program protocols under some major research projects.

In January, 2002, the Office of Management and Budget issued its “Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility, and Integrity of Information Disseminated by Federal Agencies” in response to the Federal Data Quality Act (Public Law 106-554 Section 1(a)(3)[515]) passed by Congress in 2000. These guidelines require all agencies to adopt a basic standard of quality as a performance goal and to incorporate information quality criteria into agency information dissemination practices beginning October 1, 2002. Subsequently, HHS developed a draft of its own data quality guidelines to implement the OMB requirements within the Department. CDC and NIOSH have also developed policy statements on external peer review of intramural research. NIOSH issued an updated policy on external peer review of intramural research projects in May 2005. Most of the responsibilities under the NIOSH policy statement are delegated to the NIOSH Divisions and Laboratories. It is the responsibility of the Divisions to ensure that Division projects receive the appropriate level of review, that the review is conducted and documented according to the guidelines, and that the reviewers’ comments are addressed in a reasonable fashion.

Each NIOSH Division and Laboratory is responsible for,

1. Developing a plan for conducting peer review of Division projects;
2. Identifying on an ongoing basis new projects and continuing projects that require review, and the level and type of review required for each;
3. Conducting the peer review.
    a. Providing the project staff with guidelines in preparing the project proposal or protocol;
    b. Selecting reviewers for the project who are free from conflicts of interest;
    c. Conducting the review by mail, e-mail, or face-to-face meeting;
    d. Providing review comments and critiques to project staff;
    e. Ensure that the review proceedings are in compliance with the Federal Advisory Committee Act (FACA).
4. Determining what follow-up is appropriate to address reviewer comments. Follow-up steps could include any or all of the following:
    a. Follow-up conversations with the reviewer and the project officer to clarify reviewer recommendations and concerns;

   b. Written response from the project officer on major reviewer comments. (Written responses do not need to be sent to the reviewer, but should be included in the review documentation file);
   c. Recruitment of additional reviewers, if necessary;
   d. Modification to the project proposal to address reviewer concerns (with or without a second round of review).
5. Keeping a list of projects receiving review each fiscal year. For projects that are exempted from review (i.e. the project is not reviewed even though it is a new project or an ongoing projects that has not been reviewed in five years), the documentation should state why the project was exempt;
6. Documenting and certifying the review process. Necessary documentation includes:
   a. Qualifications of reviewers;
   b. Any possible conflicts of interest of reviewers, including signed conflict of interest forms for each reviewer;
   c. A copy of the project proposal or protocol;
   d. A brief synopsis of how the review was conducted;
   e. Comments and critiques from the reviewers;
   f. A description of any follow-up steps taken to address review comments, including written response from the project officer on major reviewer comments, and a description of any resulting changes to the project proposal or protocol;

New Projects

All new Mining Program research projects must be peer reviewed by external experts within the first year of the project. Research projects are those projects, which have their own CAN (account number) in IRIS and which are considered primarily research. The only current projects with CAN's in the Mining Program which would be excluded from this policy are the Office of the Director (OD) and Branch CAN's which cover planning and management of research, but do not include research tasks themselves. The Lake Lynn CAN is also excluded, because it covers operation of a facility, and the research done at that facility is included in, and is reviewed under the research projects done at the facility. New pilot projects with planned duration of one year or less may also be excluded at the discretion of the Laboratory Director.

Prior to the beginning of each fiscal year, the Mining Program management solicits and evaluates concepts or mini-proposals for new research projects. Management may decide through their review and evaluation to have some of these concepts developed into detailed project proposals in a format similar to that used for applications for NIOSH research grants (see Related Documets.). The project proposals will be sent out for external peer review prior to the beginning of the new fiscal year. Some new projects may be initiated before external peer review is done. Reasons for this could include need for quick response to a newly identified high priority problem, or that the project requires preparation of a detailed research protocol in the first year. Such projects would prepare either research plans in the grant format, or detailed research protocols, which would be sent for external peer review within the first year after project initiation. A checklist and guide for research protocols can be found in the Related Documents.

Reviewers

The *appearance* of conflict of interest is often as important as any actual bias in the review process. It is important that peer reviewers be chosen to avoid both real and perceived conflicts of interest, whether the conflicts are financial, personal, or professional in nature.

Reviewers are to be avoided for external peer review if they fall into one of the following categories:

1. NIOSH or CDC employees;
2. Current recipients of funding (i.e. contracts or cooperative agreements) involving the project staff;
3. Those who are likely to collaborate or apply for funding under the proposed work;
4. Current collaborators, close personal friends, or family members of the project staff;

In addition to the categories listed above, there are broader types of conflict of interest that should be avoided if possible:

5. HHS employees;
6. Recipients of NIOSH contracts or cooperative agreements (even if from elsewhere in NIOSH);
7. Reviewers with personal or professional conflicts of interest with the project staff, including recent collaborators, students, or teachers, or those who have had long-standing professional or personal differences;
8. Reviewers who might otherwise give the appearance of a conflict of interest or lack of objectivity. For example, reviewers who have strongly held professional or policy related position related to the proposed work should be avoided if their position is likely to affect their objectivity as a reviewer.

It may not be possible to meet criteria 5-8 above in every case. Ideally, the perfect reviewer would be someone from outside the government who is a leading expert in the field, has had no ties to NIOSH or the researcher, and is completely objective about the area of research in the proposal. Obviously, the perfect reviewer may not exist, especially in narrow fields of research, and inevitably there will be trade-offs made when judging the relative importance of conflicts of interest versus the other qualifications of the reviewer.

Most Mining Program research projects will require reviewers with at least some knowledge of mines, mining methods and equipment, and the mining environment. Reviewers must also be technical experts in their fields with knowledge of scientific research methodology. The number of persons in the U.S. who are very knowledgeable about both mining and scientific research is limited. As a result it is probable that many of the best external peer reviewers will be persons who have had prior interactions with NIOSH researchers and who have worked with NIOSH staff or have received NIOSH funding.

All reviewers are asked to disclose anything that might be perceived as a possible conflict of interest. As an additional aid in avoiding conflicts of interest, the Mining Program normally keeps the reviews blind, i.e. avoids revealing the identity of the reviewers to the staff whose project is being reviewed. The Mining Program does not normally pay persons doing written reviews of these documents, unless the review requires any on-site visits to the Mining Program Laboratories.

Review Criteria

Prior to being sent for external review, draft project proposals are reviewed internally by the author's section and branch chiefs, and the appropriate Laboratory Director, Deputy Director, and Associate Director for Science (if applicable). The proposal or protocol must provide sufficient detail to enable reviewers to determine the suitability of the study design and methods for accomplishing the proposed work. Proposals are returned if they need correction or do not meet minimum standards. Acceptable proposals are also sent to the Associate Director for Mining and Construction for approval prior to external review.

Proposals which pass internal review are sent to two or more external peer reviewers.

These reviewers are asked assess the overall impact that the project could have on the field taking into account, among other factors:

1. The significance of the goals of the proposed research, from a scientific or technical standpoint, and expected impact on injury reduction or health hazard exposure;
2. The adequacy of the approach and methodology proposed to carry out the research;
3. The innovativeness and originality of the proposed research;
4. The qualifications and experience of the principal investigator and proposed staff;
5. The scientific environment and reasonable availability of resources necessary to the research; and
6. The reasonableness of the proposed budget and duration in relation to the proposed research.

Reviewers are told that the primary usefulness of their review will be to provide constructive help in improving the research. To do so, they should provide comments on the strengths and weaknesses of the project plans and suggestions for how they might be improved. They are not asked to give any evaluation score or to make comparisons between the plan they are reviewing and any other research plans. The reviewers are asked to complete their reviews and provide the results within four to six weeks. Normally reviews of new projects are done by E-mail or regular mail. A sample letter to reviewers is attached as an appendix.

Response to Reviews

The reviews are requested by and returned to the appropriate Mining Program Division. The review comments are forwarded to project PI and their supervisors, after any identifiers of the reviewer have been removed. The project PI will provide to the OD, a written response to the review comments and revised research plans with any changes, which are made as a result of the review. The Mining Program Division maintains a file containing the written reviews, comments in response to the reviews, and the research plans and protocols. If the reviewer has asked for feedback on the results of the review, the Mining Program Division will provide a response to the reviewer. In any case, reviewers are sent a thank you note for their help by letter or E-mail.

Projects Exceeding Five Years Duration

Very few projects in the Mining Program would be expected to continue for more than five years. Any project, which has continued for four years, will be examined to determine if it should be completed in the fifth year or continued. If the work is to be continued, the project will be treated as a new project whether under the same or new title and CAN. New research plans will be prepared for such projects and evaluated by external peer review in the same manner as any other new research project.

Appendices

1. Sample letter to external peer reviewers
2. Research planning and evaluation flow chart

Related Documents

1. Mining Program research project proposal instructions
2. Project proposal form
3. Project budget form
4. Protocol checklist and guide (separate file); also at http://inside.niosh.cdc.gov/hsrb/pdfs/protocolchecklist.pdf
5. Hints for writing project proposals

Appendix

Sample Letter to Reviewer

Dear Dr. Smith:

Thank you for agreeing to review a proposal for a new research project at the NIOSH Pittsburgh Research Laboratory. NIOSH has adopted the practice of having all internal project proposals peer reviewed. The goal is to ensure that we use our limited intramural budget to fund high quality work that will improve mine safety and health. Of course, the success of this process depends upon the willingness of experts such as you to carefully review the proposals. We know that it is not easy to find time to take on these additional activities, and accordingly, we are delighted that you have agreed to participate as a technical reviewer.

The proposal for which we have requested your review is attached. The project title is, "Guidelines for Eliminating Hazardous Ground Conditions from Underground Stone Mines". The proposals for new internal mining projects have been developed in a format similar to that requested for applications to NIOSH's extramural research grant program. We are asking you to assist us in the evaluation of the proposals, using the criteria outlined below. The results of your evaluation will be released to the principal investigator, but your identity will not be disclosed unless you request it.

Please review and assess the overall impact that the project could have on the field taking into account, among other factors:

1. The significance of the goals of the proposed research, from a scientific or technical standpoint, and expected impact on injury reduction or health hazard exposure;
2. The adequacy of the approach and methodology proposed to carry out the research;
3. The innovativeness and originality of the proposed research;
4. The qualifications and experience of the principal investigator and proposed staff;
5. The scientific environment and reasonable availability of resources necessary to the research;
6. The reasonableness of the proposed budget and duration in relation to the proposed research.

The primary usefulness of the review will be to provide constructive help in improving the research. To do so, please provide comments on the strengths and weaknesses of the project plans and suggestions for how they might be improved. You do not need to give any evaluation score, or to make comparisons between this proposal and any others.

Please provide your completed review by May 31. If this is going to present a problem, notify me as soon as possible. Please return your review comments by either regular mail or E-mail to me:

Dr. John A. Breslin
Associate Director for Science
NIOSH Pittsburgh Research Laboratory
P.O. Box 18070
Pittsburgh, PA 15236
Phone: 412-386-6873
E-mail: ozb1@cdc.gov

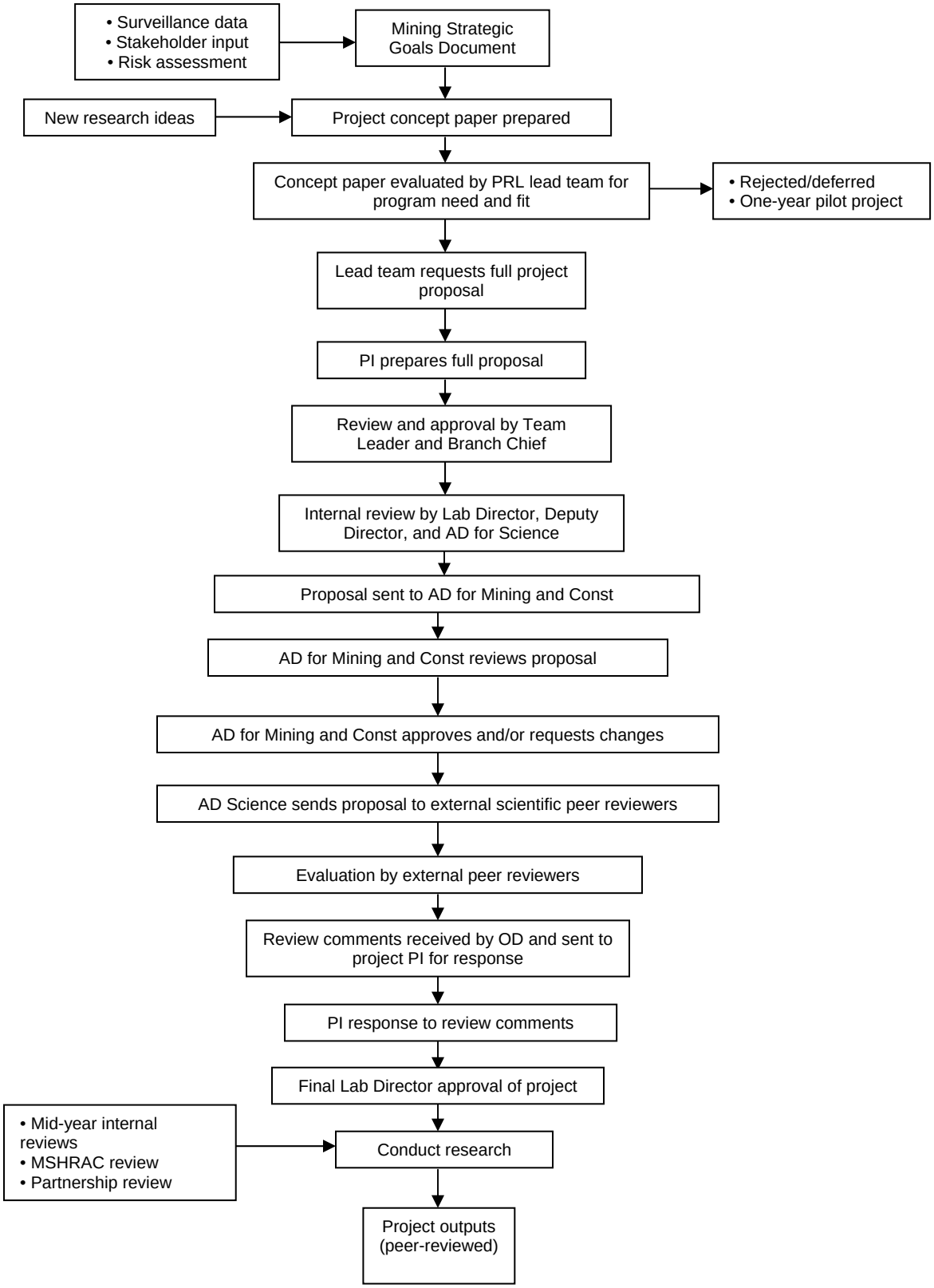
We are not aware of any conflict of interest that might interfere with your review of the proposal. However, if you think that there might be any appearance of a possible conflict of interest, please contact me to discuss the situation. It would be helpful if you could provide a brief CV or resume along with your review, which will help us to document the credentials of our external reviewers for our files.

Thank you again for your assistance in this review process. Contact me if you have any questions.

Sincerely yours,

John A. Breslin
Associate Director for Science
NIOSH Pittsburgh Research Laboratory

Research Planning and Evaluation Process



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FY2006 Project Concept Paper Outline (Approximately two pages)

1. Project Title: *(short descriptive phrase / sentence)*

2. Project Objective: *(1-2 sentences, precise statement)*

3. Problem Statement: *(One-paragraph description of the nature and magnitude of the problem to be addressed)*. The problem described should be that which can be affected by the project objective. The mining commodity (e.g., underground coal, surface metal) should be identified here. Reference any relevant information from the strategic planning reports. Surveillance data should be used if available. If not available, mention a few reasons why data are not available / cannot be used. Cited data should be specific to the problem - for example, a project to reduce surface drill dust should cite exposures to this dust source, not silicosis data for all mining. Mention any external organizations that have expressed specific interest in the problem.

4. Health and Safety Outcomes:
State the health and safety outcome(s) expected if the project is successful and the results implemented. The outcomes can be site-specific and the results of the research extrapolated to other similar work locations (e.g., all longwall mines). In the outcome estimates, be as quantitative as possible, e.g., numbers of injuries, fatalities, illnesses avoided per year. If applicable, mention any relevant outcomes outside of mining (other industries).

5. Project Description:
This is a critical part of the concept paper. It describes the approach and general methodology to be followed in achieving the project objective. It should briefly describe the tasks and major milestones. Identify any collaborators that will be involved in the project. Describe how project results will be communicated and implemented.

6. Personnel:
Identify critical skills/disciplines needed and FTE (optional - listing of proposed employees).

7. Discr. $ budget estimate for first year:
   a. Extramural (e.g. contracts, interagency agreements)
   b. Travel (domestic/foreign)
   c. Other discretionary funding - estimate the total and any major equipment over 5K.
   d. Total needed for first year

8. Duration of project; total discretionary funds, and FTE needed from start to completion:

Year #	Year					Total
	1	2	3	4	5	
FTE						
Discretionary $						

9. Proposer(s) (telephone no. and e-mail):

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NIOSH FY2006 Project Form – Research Proposal Information

Summary

TITLE OF PROJECT					
PROJ. OFFICER (Last, first, middle)				DEGREE(S)	
POSITION TITLE				MAILING ADDRESS (Street, city, state, zip code)	
DIVISION/BRANCH					
TELEPHONE (Area code, number, and extension)					
FAX				E-MAIL ADDRESS	
Will this projects utilize human subjects?				Will this project utilize vertebrate animals?	
YES:	NO:			YES:	NO:
				Species of animals to be used:	
				Approximate number of animals to be used:	

DATES OF PROPOSED PERIOD OF SUPPORT (MM/DD/YYYY)		NEW FUNDS REQUIRED (Do not include existing base funding)				
			PS&B	Other Intramural	Extramural	Total
From:		FY2006				
Through:		All Years				

NEW FTEs		% Project Category(s):	
CURRENT FTEs		% NORA Priority Area(s):	
TOTAL FTEs		% Special Interest Areas(s):	
		% GPRA Category(s):	

DESCRIPTION. State the project proposals broad, long term objectives and specific aims. Describe the occupational safety and health problem that will be addressed. Describe concisely the research design and methods for achieving these goals. Avoid summaries of past accomplishments and the use of the first person. This description is meant to serve as a succinct and accurate description of the proposed work when separated from the proposal. **DO NOT EXCEED TWO PAGES**

Additionally, it is important to specifically address the following items (be sure to also address in the Research Plan):
Need for research

- Existing burden of disease or injuries addressed by the research
- Customer input regarding need for the research

Impact of research

- What changes will the completed research make in the workplace? What effect will it have in the long term on reduction of risk factors, disease and injuries?
- What long term impact is the research likely to have in terms of reduced burden?

Translation of research

- How will the research results be translated into the workplace?
- Will the translation occur through NIOSH efforts or through efforts of partners?
- What are the barriers/challenges to use of the results in the workplace?

Outcome goals and performance measures

- List the long term outcome goals for the research
- List the performance measures for each goal. For each measure list performance targets for a successful program, and for a minimally effective program. (Targets may be quantitative or qualitative, but should be measurable.)
- List annual accomplishments that can be tracked

(place project description here)

PERFORMANCE SITE(S) (organization, city, state)

KEY PERSONNEL

NAME	ORGANIZATION	ROLE ON PROJECT

BIOGRAPHICAL SKETCH. Provide the following information for the key personnel in the order listed above. Include a copy of this section (including Research and Professional Experience) for each person.

NAME	**POSITION TITLE**

EDUCATION/TRAINING (Begin with baccalaureate or other initial professional education, such as nursing, and include postdoctoral training.)			
INSTITUTION AND LOCATION	**DEGREE (If applicable)**	**YEAR(s)**	**FIELD OF STUDY**

RESEARCH AND PROFESSIONAL EXPERIENCE: Concluding with present position, list, in chronological order, previous employment, experience, and honors. List, in chronological order, the titles, all authors, and complete reference to all publications during the past three years and to representative earlier publication pertinent to this proposal. If the list of publications in the last three years exceeds two pages, select the most pertinent publications. **DO NOT EXCEED TWO PAGES.**

Research Proposal, Personnel Plan, and Budget

RESOURCES

FACILITIES: Specify the facilities to be used for the conduct of the proposed research. Indicate the performance sites and describe capacities, pertinent capabilities, relative proximity, and extent of availability to the project. Under "other" identify support services such as machine shop, electronics shop, and specify the extent to which they will be available to the project. Use continuation pages if necessary.

Laboratory: (Provide room numbers where the work will be performed)

Field: (Identify workplaces or other sites to be used.)

Animal: (Provide room numbers where the work will be performed. Provide requests for special care and handling of the animals or for special equipment needed in the animal facilities.)

Other:

Major equipment: List the most important equipment items already available for this project, noting the location and pertinent capabilities of each.

The Research Plan: Include a) Specific Aims; b) Background and Significance; c) Preliminary Studies/Progress Report; d) Research Design and Methods (see instructions).

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e.) Literature Cited

f.) Consultants

g.) Mission Relevance

h.) Project Description

i.) Short Project Summary

j.) Involvement of Stakeholders

k.) Technology Transfer

l.) Marketing/Dissemination Plan

DETAILED PERSONNEL PLAN

Name and Degree	Role on Project	FY2006	FY2007	FY2008	FY2009	FY2010
Onboard:						
1						
2						
3						
4						
Onboard Subtotals:						
New Hires						
1						
2						
New Hires Subtotal:						
Totals						

PROJECT BUDGET SPREADSHEET

Complete *ProjectBudget.xls* and attach as an appendix to this form.

NIOSH FY2005 Project Form – Research Proposal Information Summary

TITLE OF PROJECT	
Guidelines for Eliminating Hazardous Ground Conditions from Underground Stone Mines	
PROJ. OFFICER (Last, first, middle)	**DEGREE(S)**
Esterhuizen, Gabriel S.	PhD, M.Eng., BSc(Eng) (Mining Engineering)
POSITION TITLE	**MAILING ADDRESS (Street, city, state, zip code)**
Senior Service Fellow	NIOSH Pittsburgh Research Laboratory P.O. Box 18070 626 Cochrans Mill Road, Building 143, Room 209 Pittsburgh, PA 15236
DIVISION/BRANCH	
Rock Safety Engineering	
TELEPHONE (Area code, number, and extension)	
412-386-5207	
FAX	**E-MAIL ADDRESS**
412-386-6718	eee5@cdc.gov

Will this project utilize human subjects?				Will this project utilize vertebrate animals?			
YES:		**NO:**	X	**YES**:		**NO:**	X
				Species of animals to be used:			
				Approximate number of animals to be used:			

DATES OF PROPOSED PERIOD OF SUPPORT (MM/DD/YYYY)		NEW FUNDS REQUIRED (Do not include existing base funding)				
			PS&B	Other Intramural	Extramural	Total
From:	04/01/2005	**FY2005**				
Through:	09/30/2008	**All Years**				

NEW FTEs	3.2	**% Project Category(s):**	100% Research
CURRENT FTEs	15.6	**% NORA Priority Area(s):**	0
TOTAL FTEs	18.8	**% Special Interest Areas(s):**	100% Mining
		% GPRA Category(s):	100% Research

DESCRIPTION.

Fall of ground accidents have been the largest single cause of fatalities in underground stone mines in the decade 1994 through 2003, while the fall of ground injury rates have remained essentially unchanged since 1995. The stability of the roof and ribs in underground stone mines can be improved by tailoring the excavation layout to the rock conditions. An engineered approach to stone mine design is needed which considers both the geotechnical properties of the surrounding rock and the imposed loads.

The room and pillar method is used in the majority of underground stone mines. The dimensions of the pillars and the roof spans in these mines are largely based on past experience without consideration of the geotechnical parameters that affect stability. A result is that large roof falls can occur unexpectedly and pillars are designed with questionable width-to-height ratios. In addition, anecdotal evidence seems to indicate that fluctuations in mine air temperature and humidity affect the mine stability. Guidelines are needed that will allow mine designers and operators to proactively design stable excavations to reduce the hazard of uncontrolled rock falls.

The objective of this project is to develop design guidelines for maximum roof spans and minimum pillar dimensions in underground stone mines. The effect of temperature and humidity on excavation stability will also be assessed and incorporated into the design guidelines.

The project has been subdivided into eight tasks to be carried out over a period of four years:

- Task1 - Geotechnical Data and Mine Characterization: Geotechnical and mining parameters will be collected from thirty underground stone mining operations in the Eastern and Midwestern States.
- Task 2: Back Analysis of Pillar Performance – Surveyed pillars will be evaluated in terms of loading and geotechnical characteristics.
- Task 3: Evaluate Pillar Strength at Low Width-to-height Ratios – Existing pillar design techniques and numerical models will be evaluated to establish factors important to pillar strength at low width to height ratios.
- Task 4: Analyze data and develop pillar design guidelines – All the collected data will be evaluated and guidelines will be developed for pillar design and layout, with a focus on pillars with low width-to-height ratios.
- Task 5 - Monitor and evaluate temperature and humidity effects: Monitoring of temperature and humidity changes and associated roof and rib stability issues will be conducted at three mine sites.
- Task 6 - Analyze roof span stability in stone mines: Collected field data, existing roof span design methods and numerical models will be utilized to identify appropriate criteria for designing stable roof spans.

- Task 7 - Case studies of roof span stability: Specific case study sites will be studied by field measurements and monitoring of roof behavior to identify failure and stability mechanics.
- Task 8 - Develop guidelines for selecting maximum roof span dimensions.

The outcome of the project will result in improved techniques for underground stone mine design, the elimination of potentially hazardous ground conditions and improved safety of the mine workers.

PERFORMANCE SITE(S) (organization, city, state)

1) Pittsburgh Research Laboratory's Bruceton and Lake Lynn sites; PA.

2) Collaboration with various commercial stone mines throughout the U.S. and with MSHA is anticipated and most essential to the successful completion of this project.

KEY PERSONNEL

NAME	ORGANIZATION	ROLE ON PROJECT
Gabriel S. Esterhuizen	NIOSH	Principal Investigator – Mining/geotechnical specialist (Senior Service Fellow)
Dennis R. Dolinar	NIOSH	Project Engineer – Mining/geotechnical specialist (Mining Engineer)
R. Güner Gürtunca	NIOSH	Project Consultant (Acting Laboratory Director)
Anthony T. Iannacchione	NIOSH	Project Engineer - Mining/geotechnical specialist (Acting Team Leader Geotechnical Engineering)
Leonard J. Prosser	NIOSH	Project Geologist (Research Physical Scientist)
Stephen C. Tadolini	NIOSH	Overall project direction and performance (Branch Chief Rock Safety Engineering)

BIOGRAPHICAL SKETCH:

NAME	POSITION TITLE		
Gabriel S. Esterhuizen	Senior Service Fellow		
EDUCATION/TRAINING (Begin with baccalaureate or other initial professional education, such as nursing, and include postdoctoral training.)			
INSTITUTION AND LOCATION	**DEGREE (If applicable)**	**YEAR(s)**	**FIELD OF STUDY**
University of Pretoria, South Africa	B.Sc. Eng.	1974	Mining Engineering
University of Pretoria, South Africa	M.Eng.	1991	Rock Engineering
University of Pretoria, South Africa	Ph.D.	1997	Rock Engineering

RESEARCH AND PROFESSIONAL EXPERIENCE:

1975 - 1980: Gold Fields of South Africa, Careltonville, South Africa.

Mining Engineer in Training, Rock Mechanics Engineer, Senior Rock Mechanics Engineer, Chief Rock Mechanics Engineer. After initial training period responsible for on-site rock engineering services to various deep gold mines with seismicity and high stress issues. Activities included support design, mine layout design, mine sequencing and quality monitoring. Ultimately responsible for Rock Mechanics Department serving two large underground gold mines.

1980 – 1982: Steffen Robertson & Kirsten Consulting Engineers, Johannesburg, South Africa.

Senior Mining Engineer. Rock Engineering consulting to a wide variety of mining and civil projects. Assignments included mine design for feasibility studies, stability of operating mines, hard rock room and pillar design, deep and high stress mine layout design, open pit stability and coal mine stability, groundwater and geohydrological studies.

1983 – 1999: University of Pretoria, Pretoria, South Africa.

Lecturer, Senior Lecturer, Associate Professor, Department of Mining Engineering. Responsible for undergraduate and graduate teaching in rock engineering. Research activities included issues such as coal mine pillar and barrier pillar design, gold mine design to mitigate seismicity, roof stability in deep gold mines. Conducted part-time consulting practice to gold, diamond, coal and base metal mines. Involvement as specialist in the International Caving Study Consortium, Brisbane, Australia.

1999-2003: SRK Consulting Inc., Denver, Colorado, USA.

Principal Mining Engineer. Consulting in rock engineering mainly to international clients in Australia, Africa, South America, Canada, Indonesia and Europe. Assignments included due diligence reviews for banking institutions, mine layout design for feasibility and operating mines and long term stability issues related to mine closure for both underground and surface mines.

2003-Present: NIOSH, Pittsburgh, PA, USA.

Senior Service Fellow. Involved in various projects including roof stability in stone mines, realistic numerical modeling of coal mine workings, groundwater and gas migration around coal workings, ground reaction curve analysis for coal mines and seismic analysis of fracturing around stone mine workings.

Awards and Honors:

The 1999 Salamon Award of the South African National Institute for Rock Engineering.

Relevant Publications:

Esterhuizen GS & AT Iannacchione, Investigation of pillar-roof contact failure in Northern Appalachian stone mine workings, Proc. 23rd International Conference on Ground Control in Mining, Morgantown, WV, pp. 320-326, 2004.

Esterhuizen GS, Jointing effects on pillar strength, Proc. 19th International Conference on Ground Control in Mining, Morgantown, WV, pp. 286-290, 2000.

Esterhuizen GS, Variability considerations in hard rock pillar design. Proc. Rock Engineering Problems Related to Hard Rock Mining at Shallow to Intermediate Depth, SANGORM, Rustenburg, South Africa, pp. 48-54, 1993

Esterhuizen GS, Investigations into the effects of discontinuities on the strength of coal pillars, J S Afr Inst Min Metall., v97, March/April 1997, pp 57 - 61 , 1997.

Page CH, Haines A & Esterhuizen GS, Design criteria for a room and pillar fluorspar mine, Proc 5th Int Congress on rock mechanics, Melbourne, Australia, pp D61 – D65, 1983.

Esterhuizen GS, Rock engineering evaluation of jointing in South African coal seams and its potential effect on coal pillar strength, in Mechanics of Jointed and Faulted Rock, Rossmanith (ed) Balkema, Rotterdam, pp 807 – 812, 1995.

Esterhuizen GS & Akermann KA, Stochastic keyblock analysis for stope support design, Int J Rock Mech & Min Sci, V 35 No 4 /5, p 397, 1998.

Esterhuizen GS & Streuders SB, Rockfall hazard evaluation using probabilistic keyblock analysis. J S Afr Inst Min Metall., v98 March/April 1998, pp 59 - 63 , 1998.

Esterhuizen GS, An improved method for the assessment of deep mine layouts using elastic models, 1st Southern African Rock Engineering Symposium, Johannesburg, pp 197 – 204, 1997.

BIOGRAPHICAL SKETCH.

NAME		**POSITION TITLE**	
Dolinar, Dennis,Roger		Mining Engineer	
EDUCATION/TRAINING (Begin with baccalaureate or other initial professional education, such as nursing, and include postdoctoral training.)			
INSTITUTION AND LOCATION	**DEGREE (If applicable)**	**YEAR(s)**	**FIELD OF STUDY**
University of Minnesota, Minneapolis, MN	B S Mining Engineering	1973	Mining Engineering
Colorado School of Mines		1973-1974	Grad. courses in Rock Mechanics
West Virginia University	M S Mining Engineering	2004	Ground Control

RESEARCH AND PROFESSIONAL EXPERIENCE

1973 to 1980 U. S. Bureau of Mines, Denver Research Center

Mining engineer working on several project involved with ground control research. That included geothechnical and laboratory investigations for mine structural design. This research involved determination of in situ stress, determination of in situ and laboratory physical properties, and monitoring of instrumentation at field sites

1980 to 1996 U. S. Bureau of Mines, Denver Research Center

Principal investigator on ground control projects ground control research in both coal and metal non metal mines. These projects included Support of Large Underground Openings, Convergence Rates applied to Instability of Openings in Massive Evaporite Deposits, Energy Release induced by Caving in retreat Mining, Pillar reinforcement Techniques in Longwall Entries and Thrust Bolting, Ground Control Technology.

1996 to present National Institute for Occupational Safety and Health (NIOSH) Pittsburgh Research Laboratory

Evaluated the design and performance of roof support systems in underground coal mines resulting in the development of a database on primary roof support performance from 40 coal mines. Participated in the design and installation of several instrumented underground field sites to evaluate mine structure design and roof support. Conducted and completed a field evaluation and analysis of the innovative mining system "advance and relieve mining" a mining method used to reduce the affects of horizontal stress.

Presently, principal investigator on the project "Prevent Injuries from Fall of Ground in Underground Coal Mines.". The major responsibilities include the planning and conducting of the project research and the technical supervision of project personnel.

Relevant Publications

Dolinar D,[2003]. Variation of Horizontal Stresses and Strains in Mines in Bedded Deposits in the Eastern and Midwestern United States. 19th Conference on Ground Control in Mining August 5-7, 2003, Morgantown, WV pp 178-185.

Dolinar D, Marshall T. Barczak T. Mucho, T [2003]. Stability of Underground Openings Adjacent to the sink hole at the NIOSH Lake Lynn Research Laboratory. SME Preprint 03-154, 7 pp.

Iannacchione T, Dolinar D, Mucho, T [2002]. High Stress Mining Under Shallow Overburden in Underground U. S. Stone mines. Proceedings of 1st International Seminar on Deep and High Stress Miing, Nov 6-8, Perth Australia.

Dolinar D, Mark C Molinda G[2001]. "Design of Primary Roof Support Systems in US Coal Mines Based on Analysis of Roof Fall Rates. 4th International Symposium on Roof Bolting in Mining, Aachen, Germany, June 6 and 7 2001 pp235-252.

Dolinar D, Mucho T, Oyler D, Pablic J [2000]. "Advance and Relieve" Mining, A Method to Mitigate the Affects of High Horizontal Stress on the Mine Roof. Presented at SME annual meeting Feb 26-28 2001, SME Preprint 01-113.

Dolinar D, Martin L [2000]. Cable Support in Longwall Gateroads. In: Proceedings of New Technology in Coal Mine Roof Support. Pittsburgh, PA. NIOSH IC 9453, pp 165-192.

Mark C, Dolinar D, Mucho T [2000]. Summary of Field Measurements of Roof Bolt Performance In: Proceedings of New Technology in Coal Mine Roof Support. Pittsburgh, PA. NIOSH IC 9453, pp 81-98.

Molinda G, Mark C, Dolinar D [2000]. Assessing Coal Mine Roof Stability Through Roof Fall Analysis In: Proceedings of New Technology in Coal Mine Roof Support. Pittsburgh, PA. NIOSH IC 9453, pp.

Dolinar, D. R., Mucho, T., Oyler, D. C. and J. Pablic. Utilizing the "Advance and Relieve Method to Reduce Horizontal Stress affects on the Mine Roof, A Case Study. 19th Conference on Ground Control in Mining August 7-9, 2000, Morgantown, WV.

Dolinar, D. R. and L. Martin. Cable Support in Longwall Gateroads. In New Technology for Coal Mine Roof Support. NIOSH Special Publication, 2000.

Dolinar, D. R., Oyler, D. C. and C. S. Compton. Analysis of Extensometer Data from a Room Widening Experiment Designed to Induce a Roof Fall. In Proceedings 16th Conference on Ground Control In Mining, August 5-7, 1997, Morgantown, WV, pp 289-295.

BIOGRAPHICAL SKETCH

NAME	POSITION TITLE		
Stephen C. Tadolini	Acting Branch Chief , Rock Safety Engineering Branch		
EDUCATION/TRAINING (Begin with baccalaureate or other initial professional education, such as nursing, and include postdoctoral training.)			
INSTITUTE AND LOCATION	DEGREE (If applicable)	YEAR(s)	FIELD OF STUDY
West Virginia University, Morgantown, WV	Ph.D.	2003	Mining Engineering
University of Colorado, Denver, CO	M.S.	1988	Civil and Geotechnical Engineering, Rock Mechanics
University of Colorado, Denver, CO	B.S.	1979	Civil and Environmental Engineering

RESEARCH AND PROFESSIONAL EXPERIENCES:

Employment and Experience:
2002- Present: Currently Acting Branch Chief, Rock Safety Engineering Branch, National Institute for Occupational Safety and Health (NIOSH), Pittsburgh, PA. Responsible for management of multi-disciplinary research team conducting safety and health research in the areas of geotechnical engineering, rock mechanics, and ground control.

1999 - 2002: Vice President of Engineering and Research, Excel Mining Systems, Inc., Cadiz, OH.
Responsible for new product development in the areas of underground metal/non-metal and coal ground control products. Conduct mine stability analysis and make cost-effective ground control recommendations to increase safety and enhance stability. Co-ordinate Company engineering and research program and direct technical field efforts and reporting.

1996 - 1999: Manager of Technical Services, Excel Mining Systems (Division of ANI) with manufacturing and engineering design and support in Australia, United States, Poland, Chili, and United Kingdom.
Served as the Team Leader of an International research team with the task of addressing ground control issues in the U.S., Australia, Poland, United Kingdom, and Chili. The findings of the team were submitted to senior management as research proposals, were selected on merit, and conducted for execution into ground control product innovations.

1995 - 1996: Vice President, Technical Services, Rocky Mountain Bolt Co., Denver, CO.
Broad engineering, consulting, and management responsibilities, in the area of ground control and underground mine design.

1986 - 1995: Principal Investigator, U.S. Bureau of Mines, Denver Research Center, Denver. CO.
Management responsibilities in the area of ground control, rock mechanics, support system design and selection, and new product development. Received 37 Special Achievement Awards and 4 Quality Step Increases.

1980 - 1986: Mining engineer, U.S. Bureau of Mines, Denver Research Center, Denver. CO.
Mining research in the areas of rock mechanics, mine design, and ground control, including drilling and instrumentation installation and data interpretation.

1979 - 1980: Geotechnical project engineer, Chen & Associates, Consulting Geotechnical Engineers, Denver, CO.
Performed on-site and laboratory analysis of soil and rock mechanics behaviors.

Society Memberships:

Member of Society of Mining, Metallurgy, and Exploration Engineers (1980)
Member of International Society of Rock Mechanics (1990)
Member of Colorado Mining Association (1982)
Member of American Rock Mechanics Association (2004)

Professional Activities:

1998 - 2005 Organizing Committee of International Ground Control Conference, WVU
2003-2005 Publication Committee of SME
1996 - 2002 ASTM Committee Member on ASTM-432, Standard Specifications for Roof and Rock Bolt Accessories.
1998 - 2002 American Mining Congress, Special Committee on Cable Supports.

Selected Publications:

Tadolini, S. C. and T. M. Barczak. Design Parameters of Roof Support Systems for Pre-Driven Longwall Recovery Rooms. SME Annual Meeting, Denver, CO, February 23-25, 2004. SME Preprint 05-54. Submitted for Peer-Review for SME Transactions.

Barczak, T. M. and S. C. Tadolini. Inflatable Hydraulic Bladders: An Innovation in Roof Support Technology. The 23rd International Conference on Ground Control in Mining, Morgantown, WV, August 3-5, 2004. pp. 286-294.

Barczak, T. M. and S. C. Tadolini. Standing Support Alternatives for Western Longwalls. SME Annual Meeting, SLC, UT, February 28-March 2, 2005.

Tadolini, S. C., Barczak, T. M., and Y. Zhang. The Effect of Standing Support Stiffness on Primary and Secondary Bolting Systems. The 22nd International Conference on Ground Control in Mining, Morgantown, WV, August 5-7, 2003.

Tadolini, S. C., Y. Zhang, and S. S. Peng. The Use of Pre-Driven Longwall Recovery Rooms Under Weak Roof Conditions - Design, Implementation, and Evaluation. Paper in Proceedings of the 21st International Conference on Ground Control in Mining, Morgantown, WV. August 6-8, 2002, pp. 1-10.

Tadolini, S. C. and H. S. Mitri. Field and Numerical Analysis of Resin-Grouted Cable Bolts Used for Coal Mine Longwall Roof Support. Paper in Proceedings of the 5th North American Rock Mechanics Symposium, Toronto, Canada. NARMS-TAC 2002, Hammah et al. (eds) ISBN 0 7727 6708 4, University of Toronto, July 7-10, 2002. pp 841-849.

Tadolini, S. C. and D. R. Dolinar. Enhanced Surface Control for Roof and Rib Support. Paper in Proceedings of the 20th International Conference on Ground Control in Mining, Morgantown, WV. August 7-9, 2000, pp.173-179.

Tadolini, S. C., P. W. Kraus, and A. Worbois. High Capacity Tensioned Cable Bolts for Tailgate Support. Paper in Proceedings of the 19th International Conference on Ground Control in Mining, Morgantown, WV. August 8-10, 2000, pp.59-66.

Tadolini, S. C., J. L. Gallagher, and J. M. Goris. Resin-grouted Cable Supports for Coal Mine Ground Control. The Canadian Mining and Metallurgical Bulletin, Volume 92, No. 1028, March 1999, 135-139 pp.

Tadolini, S. C. and G. Hendon. The Effects of Reduced Annulus in Roof Bolting Performance. Paper in Proceedings of the 17th International Conference on Ground Control in Mining, Morgantown, WV. August 4-6, 1998, pp. 231-236.

Tadolini, S. C., McDonnell, J. P. and K. F. Hollberg. Recent Developments in Cable Support Technology. SME Annual Meeting & Exhibit, Orlando, FL, March 9-11, 1998. SME Pre-Print 98-26.

Rico, G. H., R. Orea, R., Tadolini, S. C., and R. Mendoza L. Implementation and Evaluation of Roof Bolting in MICARE Mine II. Paper in Proceedings of the 16th International Conference on Ground Control in Mining, Morgantown, WV. August 5-7, 1997, pp. 139-148.

Tadolini, S. C. Roof Support Selection Criteria. Proceedings of Safety Seminar for Underground Stone Mines. Evansville, IN, December 10, 1997. pp. 12-14.

Dolinar, D. R., and S. C. Tadolini. High Horizontal Movements in Longwall Gate Roads Controlled by Cable Support Systems. Paper in Proceedings of the 15th International Conference on Ground Control in Mining, Colorado School of Mines August 13-15, 1996, pp. 497-509.

Tadolini, S. C., J. L. Gallagher, and J. M. Goris. Resin-Grouted Cable Support for Coal Mine Ground Control. 97th Annual General Meeting of the CIM, Halifax, Nova Scotia, May 14-18, 1995.

BIOGRAPHICAL SKETCH

NAME	POSITION TITLE		
Anthony Iannacchione	Acting Team Leader , Geotechnical Section, Rock Safety Engineering Branch		
EDUCATION/TRAINING (Begin with baccalaureate or other initial professional education, such as nursing, and include postdoctoral training.)			
INSTITUTE AND LOCATION	DEGREE (If applicable)	YEAR(s)	FIELD OF STUDY
University of Pittsburgh, Pittsburgh, PA	Ph.D.	1997	Civil Engineering
University of Pittsburgh, Pittsburgh, PA	M.S.	1990	Civil Engineering
University of Pittsburgh, Pittsburgh, PA	M.S.	1977	Geology
California University of Pennsylvania, California, PA	B.S.	1975	Geology

RESEARCH AND PROFESSIONAL EXPERIENCES:

Employment and Experience:
From: November 2004 to Present: Acting Team Leader, Geotechnical Section, Rock Safety Engineering Branch, Pittsburgh Research Laboratory (PRL), National Institute for Occupational Safety and Health (NIOSH), Centers for Disease Control and Prevention (CDC), Pittsburgh, PA. Responsible for management of multi-disciplinary research team conducting safety and health research in the areas of geotechnical engineering.

From: March 2002 to November 2004: Senior Scientist, Disaster Prevention and Response Branch, PRL, NIOSH, CDC. Lead scientist in the following topic areas within the Ground Control programmatic research area: 1) increasing miner awareness to strata instabilities by promoting the use of various geomechanical instrumentation, including stress measurements, deformation monitoring, and/or microseismic networks; and 2) reducing miner exposure to unstable ground by advancing the fundamental understanding of rock failure processes principally through the application of state-of-the-art numerical and geologic models.

From October 1998 to March 2002: Deputy Director, PRL, NIOSH, CDC. The Deputy Director assisted the Director with planning, developing, evaluating and managing the programs of the laboratory. Provided leadership for the prevention of work-related illness and injury of miners through the management of three Branches and one Activity: 1) Disaster Prevention and Response Branch, 2) Health Branch, 3) Mining Injury and Prevention Branch, and 4) Surveillance, Statistics, and Research Support Activity. The Pittsburgh Research Laboratory has a staff of over 200 FTEs, with an annual budget of approximately 18 million dollars. The work force is composed of various occupations and groups of professional, technical, and administrative staff. Dr. Iannacchione was

involved in program planning, resource allocation, awards and promotions, hiring, disciplinary actions, stakeholder interactions, and budget formulation and approval.

From August 1998 to September 1998: Acting Director, PRL, NIOSH, CDC. See above for a list of duties.

From May 1998 to August 1998: Acting Deputy Director, PRL, NIOSH, CDC. See above for a list of duties.

From October 1997 to April 1998: Acting Team Leader, Rock Mechanics Group, PRL, NIOSH, CDC. Directed a staff of 12 engaged in research to lower falls of ground injuries associated with mining by transferring existing technology and developing engineering design tools which emphasize safety. Frequently acted for the Branch Chief of the Disaster Prevention and Response Branch (~90 people).

From January 1999 to October 1997: Supervisory Civil Engineer: Rock Mechanics Group, Pittsburgh Research Center (PRC) under NIOSH, the U.S. Department of Energy (DOE), and the U.S. Bureau of Mines (USBM). Similar duties to those stated above for the Active Team Leader position. Frequently acted for the Research Supervisor of the Ground and Methane Control Group (45 people). One acting period lasted for 4 month from April 2 to July 2, 1995.

From June 1984 to January 1991: Supervisory Geologist, Geologic Studies Group, PRC, USBM. Supervised a team of approximately 14 geologist, engineers, and technicians. This team was tasked to investigate the geologic factors responsible for hazards ground conditions in underground coal mines and the fundamental factors responsible for coal mine bumps.

From June 1975 to June 1984: Geologist, Geologic Studies Group, PRC, USBM. Conducted research into the generation, retention, and liberation of methane gas in geologic formations associated with active mining districts. This knowledge was used to develop mine specific methane control programs. The work in the Arkoma Basin of Oklahoma and Arkansas was used to develop strategies for commercial extraction of the methane gas. The work in domal salt mines was used as the scientific rationale for the development and implementation of MSHA's gassy mine standards for nonmetal underground mines.

Society Memberships:

1. American Society of Civil Engineers (1990 – present)
2. Society of Mining Engineers (1998-present)
3. Pittsburgh Geological Society (2002-present)
4. American Rock Mechanics Association (2004)
5. Professional Engineer, PE-045672-E, Commonwealth of Pennsylvania, 1996-present

6. Professional Geologist, PG-000050-G, Commonwealth of Pennsylvania, 1994-present

Professional Activities:

- Leadership of the Pittsburgh Section, American Society of Civil Engineers (2003-05), serving as Vice-President, President and now Past-President. The Pittsburgh Section contains approximately 1,500 members. The role of the Pittsburgh Section President is to uphold the section's Constitution and ByLaws, keep the section organized, preside over meetings, recognize peoples efforts, correspond with Society Officials/other-organizations/individuals, participate in the District 4 Council, help defuse problems, and most of all, provide leadership through an articulated vision and a clear set of goals.
- Participated in the Society of Mining Engineers: 1) performed a technical review or the paper entitled "Performance of Coal Mine Pillars Under Varying Roof and Floor Conditions", 2) Chair of Geomechanics Session at the 2003 SME Annual Meeting, and 3) member of the SME Senior Project Award Committee.
- Member of the organizing committee for the 2005 Rock Mechanics Symposium, Anchorage, Alaska, June, 2005. Responsible for the organizing the plenary panel discussion and the session on Geophysical Methods.

Selected Publications:

<u>First author over the last 3 years</u>

"Characterising Roof Fall Signatures from Underground Mines" by A.T. Iannacchione, M.Chapman, and L.Burke, (11 pages) approved for publication by the organizing committee of the 6th International Symposium on Rockburst and Seismicity in Mines. Scheduled for publication and presentation on March 11, 2005, Perth, Australia.

"Relationship of Roof Movement and Strata Induced Microseismic Emissions to Roof Falls", by A.T. Iannacchione, P.R. Coyle, L.J. Prosser, T.E. Marshall, and J. Litsenberger, <u>Mining Engineering</u>, December, 2004, pp. 53-60 also published as SME PrePrint #04-58, SME Annual Meeting, Denver, CO, Feb. 23-25 2004.

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Part B: Research Proposal, Personnel Plan, and Budget

THE RESEARCH PLAN

a) Specific Aims

Objective 1: Develop guidelines for minimum pillar width-to-height ratios in underground stone mines

Objective 2: Develop guidelines for maximum roof span dimensions in underground stone mines

Objective 3: Determine the effect of changes in temperature and humidity on roof and rib stability in underground stone mines

b) Background and Significance

Ground fall accidents have accounted for 45% of all fatalities in underground stone mines over the past decade. Accident statistics from the Mine Safety and Health Administration (MSHA, 2005) database indicate that the fall of ground injury rate (per 200,000 hrs worked) in underground stone mines during 2003 was 0.433 compared to 1.51 for underground coal mines and 1.34 for all underground mining in the US. The trend in the fall of ground injury rate has been decreasing over the past several decades, but has remained essentially unchanged since 1995, as shown in Figure 1. The ground fall hazard in stone mines is exacerbated by:

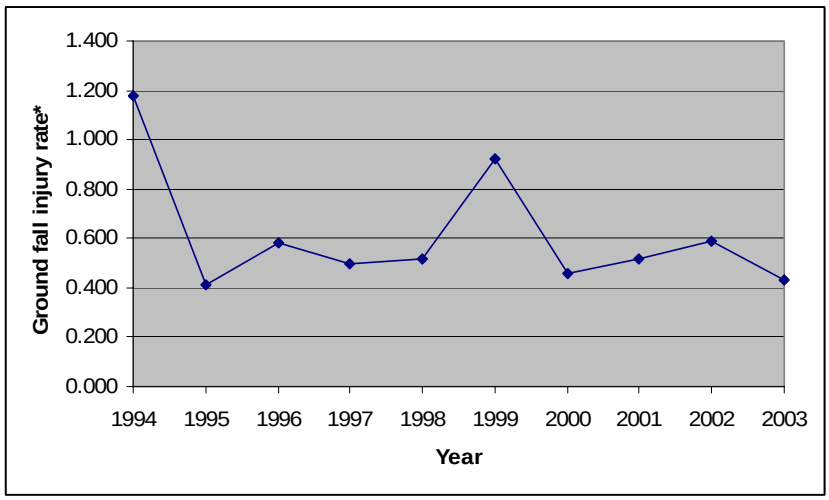

Figure 1: Ground fall injury rate in underground stone mines 1994 to 2003

- The large opening dimensions which make it difficult to identify unstable roof.
- Rock falls can be large and can have devastating effects owing to the great fall distance.
- The large dimensions make it difficult to access the roof for remedial action.
- Small rocks can have serious consequences if they fall from a great height.

Many underground stone mines use the room-and-pillar method of mining in which stable pillars are required to support the overburden and stable roof spans are required to provide access to the working face. A conflict exists between production requirements and safety because larger openings are required for increased productivity but the stability of the roof decreases with increasing dimensions. A further conflict exists between the need to extract a high proportion of the underground reserves and the stability of the pillars to support the overburden. As the pillars become smaller their strength is reduced but the load increases, potentially overloading the pillars.

The stability of the roof and the support pillars depends on the quality of the rock mass as well as the imposed loads from the overburden and near surface tectonic stresses. Variations exist in rock mass properties, overburden loads and tectonic stresses that require the mine layout and support systems to be adjusted to maintain safe working conditions. It is therefore necessary to quantify the rock mass quality, the overburden loading and tectonic stresses to design stable mine excavations.

Problem Area 1: Pillars with low width-to-height ratios

The strength of a pillar depends on the strength of the rock that forms the pillar as well as the width-to-height ratio. A reduction in the width-to-height ratio causes a reduction in the overall strength of the pillar. In stone mines the following issues have been identified regarding pillars with low width-to-height ratios:

- Pillars are often developed to an initial height of about 25 ft but this can be followed by benching of the floor, which can increase the height to 60 ft or more. The slender pillars in the benched areas will be weaker than in the original development and can fail when their strength decreases owing to the reduction in width-to-height ratio.
- Pillars that were initially stable during development can become unstable during benching. NIOSH researchers have observed that benching operations were abandoned in several underground stone mines owing to the deterioration of rock conditions in the benched area.
- Large scale collapse of the overburden can occur if the failure of one pillar overloads the adjacent pillars, setting off a chain-reaction. The likelihood of a chain-reaction of failures is enhanced if the pillars are slender.
- Pillars with reduced width-to-height ratios are sensitive to the weakening effect of through-

Figure 2: Pillar with a low width-to-height ratio in a stone mine

going joints or slips. In stone mines the rock mass can be generally very good, but the presence of a single slip or fault can initiate unexpected stability problems, especially in slender pillars

Empirical pillar strength equations have been developed for coal and base metal mines. These equations are not applicable outside their empirical basis and should not be used for the design of stone mines. They also do not adequately address strength at low width to height ratios often found in stone mines, such as the pillar shown in Figure 2. At present stone mine pillar dimensions are determined largely from past practices or the trail-and-error approach. Consequently stone mines use pillars with questionable width to height ratios. A methodology for designing pillars in stone mines, with an emphasis on pillars at low width-to-height ratios, is clearly needed.

Problem Area 2: Maximum Roof Span Dimensions

Stone mine operators have a desire to maximize roof spans for production purposes. Owing to the bedded nature of limestone formations, the immediate roof is likely to consist of one or more rock beams that are parallel to the roof. The stability of these beams depends on the rock characteristics and loading of the beam by overburden or tectonic stresses. Typical roof spans in stone mines are 43 ft, and spans of up to 60 ft are used. As the roof span increases, the stability of the rock beams can decrease for the following reasons:

- Increased deflection can result in buckling or tensile failure of the rock beams.
- Bending stresses in the rock beams increase and can result in failure of the intact rock in tension or shear.
- The likelihood of intersecting unfavorable joints or slips increases.

Figure 3: Failure of the immediate roof beam in a stone mine

An example of failure of the immediate roof beam is shown in Figure 3. Similar to pillar design, roof span dimensions are determined largely from previous experience or by a trial-and-error approach. Methods to account for site specific ground and stress conditions do not exist. Methods developed for metal and coal mines are sometimes used, but do not adequately address the bedded nature of limestone rocks.

Problem Area 3: Changes in Temperature, Humidity, and Air Flow

A particular concern in underground stone mines is that the ground fall frequency during August and September is nearly twice that of December and January. Reasons typically given for the higher number of ground falls in the summer months are:

- Production rates are also higher in the summer months. This would result in a higher rate of exposure of new roof, with an increase in the likelihood of exposing unstable roof.
- During the summer months the air temperature and humidity increases. The presence of moisture sensitive layers in the roof strata and along rock joints can induce instability.
- Air flow directions can change, causing entries that were in fresh intake air to be exposed to saturated return air. Moisture sensitivity of the rocks can result in instabilities under the changed conditions.

No published or reliable data exist to determine the validity of these explanations. A limited amount of work has been done to evaluate the effect of mine climate changes on weak coal mine roof and sensitivity of weak rocks to moisture changes. These results do not address the conditions in underground limestone mines.

c) Preliminary Studies / Progress Report

Previous and current NIOSH projects related to stone mine stability:

Stability in stone mines has been targeted for research by NIOSH since 1996. Roof beam stability was investigated by field monitoring of deflection, showing that accelerated rates of deflection occur prior to roof falls (Prosser et al., 2003; Marshall et al. 2000). The effectiveness of different types of rock bolts was investigated through a detailed program of field monitoring and analysis. The findings were published (Iannacchione et al. 1997) and recommendations made regarding beam stability issues and roof bolt selection. A roof deflection monitoring system, called the RMSS, was developed and its used in operating mines was promoted by site visits to mines and through industry seminars. Guidelines for stone mine layout design were produced in which the issues associated with pillar design (Iannacchione, 1999) and layout in high stress conditions, (Iannacchione et al. 2003) were addressed. The potential hazard of pillars with low width-to-height ratios was clearly identified in these studies. In addition, the existence of large roof spans, many of which are unsupported, was recognized.

A current NIOSH project titled “Fundamental studies of factors responsible for roof falls” has investigated micro seismic emissions associated with roof falls in stone mines (Iannacchione, 2003) and evaluated the causes of unique roof failures in stone mines (Esterhuizen & Iannacchione, 2004). The project will continue into the foreseeable future, focusing on precursory micro seismic activity prior to large roof falls.

Previous and on-going NIOSH projects into stone mine stability have identified the potential hazards associated with slender pillars and excessive roof spans in underground stone mines. Guidelines were developed for avoiding potentially problematic ground conditions when designing room and pillar layouts. Issues such as roofbolt selection and

micro seismic pre-cursors to failure have been investigated. However, these projects have not developed an explicit design methodology for determining safe roof spans and pillar dimensions for given rock mass conditions.

The following sections present a summary of the current state of knowledge in the three problem areas identified for this new project:

Pillars Strength

Dimensions of Pillars in Stone Mines:

A survey of 70 underground stone mines was conducted by NIOSH researchers during the late 1990's (Iannacchione, 1999). The room and pillar dimensions and other pertinent data were collected. The survey indicated that the average width-to-height ratio in underground stone mines was 1.77 during development and fell to 0.93 in benched areas. In the benched areas, 69% of the cases had width-to-height ratios of less than 1.0. Figure 4 summarizes the data.

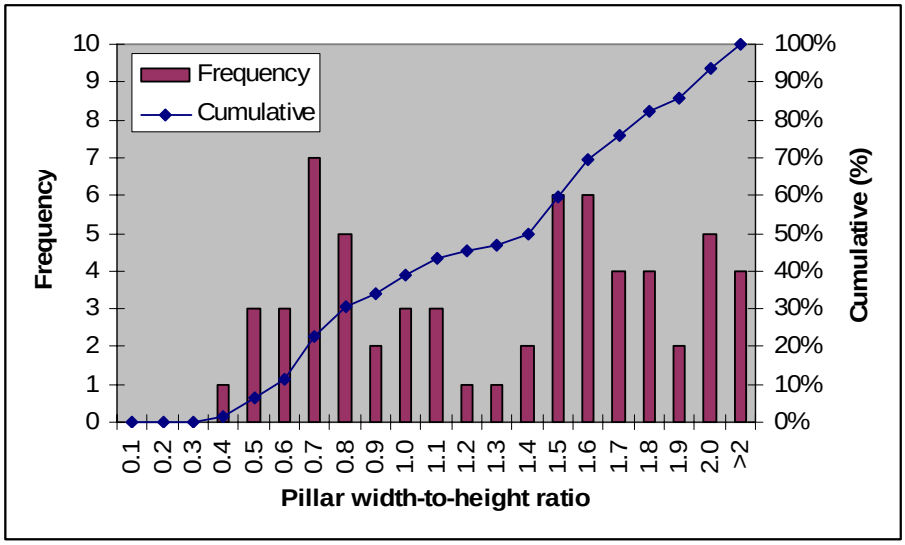

Figure 4: Width-to-height ratio distribution of underground stone mine pillars

Pillar Failure in Stone Mines:

Pillars in underground stone mines have been generally stable and provide adequate support to the overburden. Failure of pillars is rare and only two instances of widespread failure of pillar systems are on record. The fist case was the catastrophic failure of pillars in a limestone mine, in which an area of approximately 1000 ft x 2000 ft collapsed suddenly at a depth of cover of less than 200 ft, (Ropchan & Zipf, 1996). The area was mined with highly irregular pillar dimensions. Owing to the absence of details on the

mine mining geometry and geotechnical parameters, it was not possible to investigate this case in greater detail.

A second instance of a large scale collapse in Kansas was investigated by Zipf & Schmuck, (1996). In this case the pillars were square, 25 ft wide by 17 ft high and were located under depths of cover of 100-200 ft. An area of approximately 4 acres collapsed over a weekend. The report concludes that the collapse was caused by a "wide area roof fall" and not pillar failure. Punching of the pillars into weak floor and roof rocks is thought to have caused the fall. This case highlights the importance of considering both roof and floor competence in pillar system design.

During the NIOSH survey of stone mine workings in the late 1990's, a total of four instances of localized pillars failure were observed. Fortunately, none of these cases resulted in the large scale collapse of the overburden (Iannacchione, 1999). An evaluation of the pillar stress at failure of these four cases indicated that the pillar strength was highly variable. The width-to-height ratios were less than 1.25 in all four cases, highlighting the sensitivity of slender pillars to local rock mass conditions.

Guidelines for pillar layout design have been published by NIOSH (Iannacchione, 1999) in which it was noted that pillars with width to height ratios of less than 1.25 can fail if they are subject to overburden loads of greater than 200m or extraction ratios in excess of 0.83.

Pillar design methods:

Pillar strength has been widely researched for several decades. Most of the research has been directed towards coal mine pillars and some of it has transferred to hard rock mining. In broad terms it has been found that pillar strength is positively related to the strength of the rock forming the pillar and inversely related to the slenderness of the pillar. Slender pillars are weaker than squat pillars. Pillar design methodologies can be divided into three types (modified after Potvin, 1985):

- Heuristic method, in which an educated guess of required pillar dimensions is made based on "what worked before might work again". This is the least sophisticated method and does not consider the strength or loading conditions of pillars. Provided the rock mass and loading conditions remain similar, this approach can be successful. It appears that many room and pillar layouts in stone mines are designed using a heuristic approach.
- Empirical design, which relies on experiment or experience. The difference from heuristic methods is that case histories are studied and strength relationships derived. The relationships can then be used to design pillars in similar conditions as the experiments or case histories. Examples are the Mark-Bieniawski equation for coal pillars, developed in the United States (Mark 1999), the Salamon-Munro equation developed for South African coal mines (Salamon & Munro, 1967) and the Hedley & Grant (1972) equation developed for uranium mines in Canada. Empirical methods have found wide acceptance in coal and hard rock mining practice world-wide.

- Analytical methods which are based on a mathematical description of the mechanical behavior of rock. Methods proposed by Wilson (1972) and Barron (1992) are well known examples. These methods, while providing insight into pillar mechanics, have not found acceptance in practice, most likely owing to the requirement for input parameters that are difficult or impossible to obtain.
- Numerical modeling, in which advanced numerical techniques are used to simulate pillar loading and rock mass response. These methods have been used in coal mining (Gale, 1999) and metal mines (Lunder, 1994) where pillar geometry is highly irregular and loading conditions are difficult to obtain. Modern modeling techniques allow sensitivity to specific conditions, such as through going joints or weak bands, to be evaluated (Iannacchione, 1999). Numerical models play an increasing role in site specific pillar design.

Pillar design methods developed for coal and metal mines are not directly applicable to stone mines, especially for the low width-to-height ratio pillars found in stone mines. Most empirical databases of pillar failure contain few, if any cases in which the width-to-height ratio is less than 1.0, rendering the equations inaccurate in this range.

Stability issues with pillars at low width to height ratios

Pillars with low width to height ratios are sensitive to the effect of through-going discontinuities. The results of numerical models showed that the strength of pillars with a width-to-height ratio of 1.2 can drop by about 50% if through-going joints at 45° are introduced (Iannacchione, 1999). This is part of the problem facing benching operations. The development pillars may be initially be stable, but once benching is carried out, the strength is reduced significantly and the pillars can yield. Figure 5 shows development and benched pillars, the increased height of the benched pillars will result in a significant reduction in strength. This phenomenon can explain several instances where mines have had to abandon benching operations because the rock conditions had become unstable.

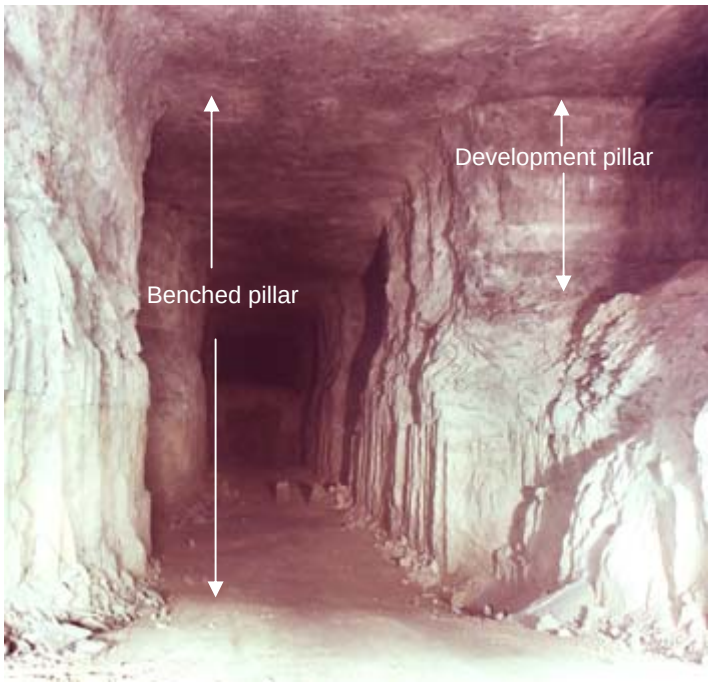

Figure 5: Illustration of development and benched pillars

A further problem with slender pillars is that they are more likely to fail in a catastrophic manner. The problem of cascading pillar failure has been addressed extensively in the

literature, especially in relation to coal mine pillars, (Salamon 1970, Zipf, 1992, Galvin, 1992). The sudden collapse of the Coalbrook Colliery in 1960 in South Africa, with a loss of 437 lives was attributed to this type of failure, in which a single pillar fails, it overloads the adjacent pillars, which also fail, and set off a chain reaction of failures. The issue at stake is the rapid loss of strength of slender pillars once they start to fail. A squat pillar on the other hand loses it strength much more gradually and is less likely to fail catastrophically. In coal mine workings, catastrophic failures have occurred with pillar width to height ratios of between 1.0 and 2.8. The existence of large numbers of pillars in stone mines with width-to-height ratios of less than 1.0 is a concern that will be addressed by this research project.

Catastrophic failure is also dependent on the stiffness of the overburden which acts as the loading system that drives the pillars to failure, (Salamon, 1970). As the lateral extent of a mining panel increases, the loading system becomes less stiff and the likelihood of catastrophic failure is increased. In stone mines, where the width of mining panels can be several times the depth of cover, the loading system will therefore be "soft", increasing the potential for catastrophic failure.

Roof Span Design in Bedded Rock

Roof span dimensions and support in stone mines

The limestone rock mass in US stone mines can be very competent allowing relatively large roof spans to remain stable. In the US underground stone mines the average roof span is 43 ft and spans of up to 60 ft were recorded during the NIOSH survey of stone mine workings in the late 1990's. The distribution of roof spans is presented in Figure 6. Roof spans of 35 ft to 50 ft account for 69% of all roof spans observed. Of the mines

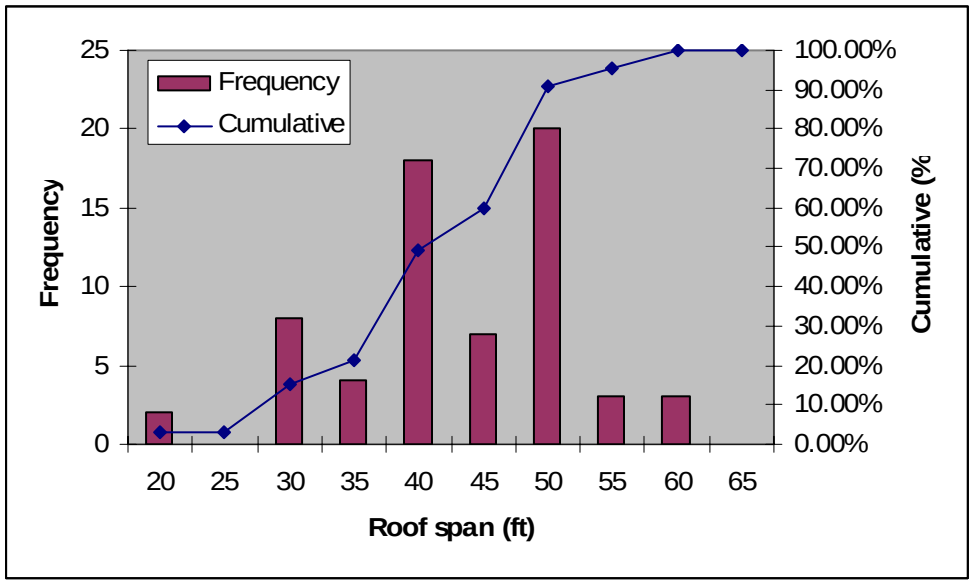

Figure 6: Distribution of roof spans in underground stone mines

surveyed, only 24% used regular bolting to support the roof while 21% did not use any support. The remaining 55% used spot bolting.

The immediate roof in underground stone mine workings usually consists of rock beams formed by the horizontal layering of the limestone. These beams vary in thickness and competence, depending on the rock strength and the bedding and joint frequency in the limestone formation. Stability of the roof is usually determined by the stability of the first beam in the roof. Stone mine operators often select specific horizon in the limestone formation, so that a strong beam of adequate thickness forms the immediate roof.

Roof failures in stone mines

High horizontal stresses have been identified as a cause of roof beam failure in several US stone mines (Iannacchione et al., 1997). High stress conditions have been observed in stone mines in western Pennsylvania, eastern Kentucky, West Virginia and southwestern Virginia. The high horizontal stresses are caused by tectonic loading of the Mid-North American Plate (Zoback, 1992) and have been measured in many of the area's coal mines (Mark & Mucho, 1994). Figure 7 shows a typical large roof failure caused by excessive horizontal stresses in a limestone mine. The stresses can cause failure of the intact rock forming a beam, mobilize shear along pre-existing joints and cause buckling of the beam in compression.

In lower stress conditions, roof beam failure can occur as a result of bucking under gravity loading, or loss of integrity owing to inclined joints. Simple plug failure in the absence of external stresses can also occur, which can result in subsidence and sinkhole formation.

Stone mine roof span design should therefore consider the characteristics of the immediate roof rocks, their stability under gravity loading and the effect of horizontal stress.

Roof Span Design

Techniques for designing stable roof spans in underground mining have followed a similar path as that of pillar design, relying much on empirical relationships developed from a study of stable and unstable cases. Analytical methods have also enjoyed recent attention, with the expansion of classical beam theory to the special case of rock

Figure 7: Roof fall caused by excessive horizontal stress in a limestone mine

beams. Each of these approached are discussed below.

Empirical Methods of Roof Span Design

A widely accepted approach to determine stable roof spans is the application of empirical relationships between roof spans and rock mass classification. The well known Rock Mass Rating (RMR) system (Bieniawski, 1989) relates the RMR to stable roof spans and stand-up time. Similarly, the Q-System of rock mass classification (Barton et al., 1974) relates the rock mass quality "Q" to excavation span and support requirements. These relationships were largely developed from civil engineering case histories, and are not directly applicable to mining applications. A further problem with the RMR and Q-systems of rock classification is that they are poorly suited to classifying bedded rocks. This has resulted, for example, in the development of the Coal Mine Roof Rating (CMRR) by Molinda & Mark (1994) which was specifically designed for classifying bedded rocks in US coal mines.

In hard rock mining, Laubscher (1990) developed a modified version of RMR called the Mining Rock Mass Rating (MRMR) in which stable and caving case histories were used to develop a relationship between MRMR and excavation dimensions. The chart is based on non-entry mining conditions, meaning personnel do not enter into the openings. A stable configuration for non-entry mining is unlikely to be satisfactory for entry mining methods such as room and pillar mining where a small rock fall from a great height can cause serious injuries to personnel.

The Matthews stability chart (Matthews et al., 1980) and several modifications (Potvin, 1988, Stewart and Forsyth, 1995) are based on the Q-system of rock classification. The chart was developed using Canadian open stoping case studies in metal mines, which are also non-entry excavations. The method modifies the Q-rating of a rock mass to account for stress, orientation and failure mode. The attraction of this approach is that an adjustment can be made to account for bedded strata parallel to the roof. Since the design chart has been based on metal mining case studies, it is not likely to be directly applicable to stone mines. In addition, the higher requirements for stability in entry mining, versus non-entry mining, are not addressed. Nevertheless, the method of accounting for roof bedding appears to be well suited to modification for stone mining applications.

The empirical approach is likely to be equally valid for stone mines. The approach used for the Matthews stability chart appears to be suitable for modification to make it applicable for stone mines.

Analytical Methods of Roof Span Design

Elastic beam theory can be used to evaluate the stability of rock beams in the roof of stone mine excavations. Beam deflection and the development of tensile and shear stresses as well as the potential for beam buckling can be calculated (Jaeger & Cook, 1979). However, the theory assumes elastic behavior and the absence of defects in the beam. In practice, rock beams typically contain joints and other defects which are not included in the simple elastic equations. A more robust approach has resulted from the recognition that a cracked beam maintains stability through a compressive arch that forms

within the beam, called a “voussoir arch”. Beer & Meek (1982) presented an updated version of the voussoir arch model. The beam fails realistically when the arch either “snaps-through”, fails by crushing the abutments or simply drops out under shear. The model was recently re-visited and improved (Diederichs & Kaiser, 1999) who found that it provides similar results as the Matthews stability chart, except that now lamination thickness can be explicitly accounted for. This appears to be a promising approach for predicting stone mine roof stability.

Temperature and Humidity effects on Roof Stability

The effects of temperature and humidity changes on roof stability has been researched extensively in coal mines (Statenham & Radcliffe, 1978; Pappas, Bauer & Mark. 2000), for example a doubling of the rate of roof falls during the summer months has been reported in a Northern Appalachian coal mine (Mark et al., 2004).The weatherability of rocks has been recognized as a significant factor in coal mine roof stability (Unrug & Pagett, 2003).

The limestone rocks in underground stone mines are not as susceptible to weathering as the some of the weaker coal measure rocks. Slake durability tests on Ohio limestone rocks have shown high resistance to weathering (Bawden & McCreath, 1979). Tests on non-limestone roof rocks from roof falls an underground limestone mine in central Kentucky (Unrug, 1997) showed a moderate degree of weatherability. The presence of these weaker rock types as interbeds in limestone or in the immediate roof of a limestone formation can affect roof stability if they are weakened by exposure to moisture in the mine air. Measurement of roof deflection and rockbolt loading showed a direct correlation between mine air temperature and roof response (Dolinar & Mucho).

The temperature and humidity in underground mines fluctuates with the seasons. In the summer months the moist outside air is cooled as it enters the mine and can cool below the dew-point. The excess moisture will condense onto rock surface and in cracks within the rock. In the cold dry winter months, moisture is extracted by the low humidity mine air. These fluctuations in moisture content can lead to deterioration of weaker water sensitive rock types.

d) Research Design and Methodology

The research project will address the need for methodologies to determine:

- the minimum pillar width-to-height ratio;
- maximum roof span dimensions, and
- the effect of temperature and humidity on roof and rib stability in underground stone mines.

A combined empirical and analytical approach will be followed, in which rock mass conditions, successful and unsuccessful mine designs, laboratory testing, field monitoring and numerical modeling will be used. The project tasks include field surveys and field data collection at operating stone mines, monitoring of temperature and humidity, stress measurements and displacement monitoring, analysis of past failures as well as stable layouts, laboratory testing at PRL, data analysis and development of relationships between important rock mass properties and excavation stability in stone mines. These relationships will be presented as design charts which will act as guidelines for the maximum roof spans and minimum pillar widths in underground stone mines. The basis for the design charts is expected to be rock classification, using one of the established classification methods, with additional modification parameters tailored for roof span and pillar design.

The approach that will be followed for pillar design is expected to be similar to the method developed by Ryder & Ozbay, (1990), in which pillar strength is determined by applying a series of strength correction factors to the basic rock material strength. Correction factors for “shape effect”, “width-to-height ratio effect”, “foundation damage” and “creep” can be incorporated into the design. Additional factors such as bedding strength and joint orientation will be considered. Geotechnical characterization of the different limestone mining areas, assessment of excavation performance, back analysis of stable and failed cases and numerical modeling will be employed to identify the important factors and develop relationships to be included in the pillar design methodology.

The development of a design chart for maximum roof spans will follow a similar approach, most likely developing a design chart similar to the Matthews Stability Chart in which a basic rock classification is modified by a number of factors to account for roof stability. Factors that are likely to be considered are bedding spacing and horizontal stress. The field data collection and rock mass characterization efforts together with numerical modeling will be used to identify the important parameters and develop the relationships in the design chart.

The investigation of temperature and humidity effects on excavation stability will be based largely on field monitoring and laboratory testing. Relationships will be developed between the observed roof and rib behavior, rock properties and the humidity/temperature variations. Depending on the outcome, a humidity/temperature factor can be included in the roof span design methodology.

The project will run for four years with eight specific tasks:

Task 1: Geotechnical Data and Mine Characterization
The geotechnical setting of the underground stone mines needs to be characterized since this will form the basic input to the roof span and pillar design methodologies. Site visits will be made to selected mines in the various stone mining districts in the Eastern and Midwestern states. The site visits will include quarries where underground mining has been unsuccessful owing to poor rock conditions. These cases are expected to provide bounding limits to roof and pillar stability. A total of 30 mines will be visited over a two year period. Based on currently available data, approximately 22 mine operations have pillar width to height ratios of less than 1.0. These mines are potential cases of pillar instability. Poor roof conditions are expected to be found at almost every mine operation, providing approximately 30 cases of poor roof conditions for the database. Care will be taken to identify "abnormal" rock conditions that may result in specific cases of instability at the different mine operations. A field data collection sheet will initially be developed and tested at the Lake Lynn Laboratories. The following data will be collected:

- **Geological characteristics:** The regional geology of each mine site will be reviewed from published literature and local data available at the mine site. The objective will be to identify any regional characteristics such as folding or faulting that may affect the mine stability. The succession of the various rock formations will also be determined from the literature. The immediate roof and floor lithology will also be determined from inspection and available records.
- **Field mapping and rock classification**: During each site visit, rock mass classification will be carried out, ideally at three different locations in each mine. Mapping of major joint orientations and frequencies as well as bedding characteristics will be carried out. A dataset will be collected that allows any of the major classification methods to be applied.
- **Mine layout parameters**: During the site visits, mine layout parameters such as room and pillar dimensions, benching height, heading orientation and depth of cover will be collected. Site specific measurements will be made at each location where rock classification is conducted**.**
- **Excavation performance assessment**: At each rock classification site a visual assessment of the local rock conditions and excavation performance will be made. Categories for quantifying the rock conditions will be developed which will include stress effects, blasting and rock defects. In addition, an assessment of the overall roof and rib stability in the mine will be made.
- **Failure mode assessment:** Where roof or rib failures are observed an assessment of the type of failure and likely causes will be made. A list of typical failure modes and causes will be developed so that each observed failure can be categorized.
- **Field monitoring**: Field monitoring activities will be conducted to investigate specific stability issues encountered during the field data collection activities. Potential sites for detailed monitoring or measurements will be identified. Monitoring activities will depend on the specific aspect that requires investigation and can include stress measurements using the maxi-frac system, stress change

monitoring using vibrating wire strain cells to assess pillar stability and displacement monitoring using extensometers or roof-floor convergence meters to assess system stability. An allowance has been made in the budget for measurements to be carried out at two different sites.

- **Laboratory testing of rock properties:** Rock samples or drill core, if available, will be collected at the mines to determine the strength of the limestone and surrounding rocks. Where possible, samples of the immediate roof rocks will be obtained. Testing of rock strength and mechanical properties will be carried out at the PRL laboratories. The weathering characteristics will be tested using the slake durability test or other appropriate testing methods.

The major outcome expected from the task is a quantitative assessment of the geotechnical characteristics of the limestone formations in the Eastern and Midwestern stone mines as well as an evaluation of the performance of the room and pillar designs in the various geotechnical settings. These data will allow an assessment to be made of the important factors that affect roof and pillar stability. A peer-reviewed document describing the geotechnical characteristics and pillar and roof performance in underground stone mines will be prepared.

Task 2: Back analysis of pillar performance

The development of an empirically based pillar design chart requires that numerous cases of stable and unstable pillars should be evaluated. The field data collected during Task 1 will form the basis for the back analyses. The analyses described below will be carried out during the first two years of the project, providing input to the development of a pillar design chart.

- **Analysis of failed pillar systems:** Although pillar failures are rare in stone mines, some instances of unstable pillars were recorded during the NIOSH survey of stone mines in the late 1990's. Four cases of isolated unstable pillars were recorded. In addition two cases of large scale collapse of workings have been reported in the literature. Geotechnical and other pertinent data on each of these cases will be collected through site visits, as part of Task 1,

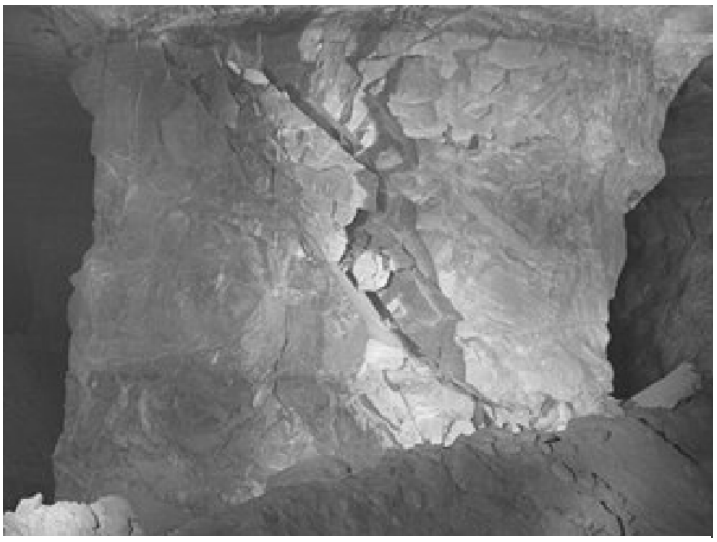

Figure 8: Failed pillar showing through-going fracture

or from literature reviews. An analysis of likely pillar loads and pillar strength will be conducted. An example of a failed pillar is shown in Figure 8.

- **Analysis of unsuccessful benching operations:** NIOSH researchers have observed that benching operations often result in poor rock conditions forcing the mines to abandon benched areas. Site visits to a selection of these areas will be made to characterize the rock mass and obtain site specific mining data as part of Task 1. Analyses will be carried out to evaluate the effect of benching on stress distributions in the benched pillars and the surrounding pillars.
- **Analysis of stable pillars:** Both failed and stable cases are required to develop a pillar strength relationship. Analysis of slender pillars that have not failed will provide important data on their strength characteristics. The field and geotechnical data collected as part of Task 1 will be used to carry out simple analyses based on tributary area theory.

The outcome of this task will form the empirical basis for developing a pillar design chart. A document on the performance of stone mine pillars in various geotechnical settings and critical factors affecting their strength will be prepared for publication.

Task 3: Evaluate pillar strength at low width-to-height ratios

A pillar design methodology for stone mines must be particularly accurate at low width to height ratios. Many stone mine operations are located at a shallow depth of cover and slender pillars can be used. The lack of large numbers of failed stone mine pillars will make it difficult to assess the lower limit of their strength from case histories. It will be necessary to supplement the field studies with numerical models and experience from other types of mining to enhance our understanding of pillar strength at low width-to-height ratios. The task will comprise of the following activities:

- **Review of existing pillar design methods and relevance to low width-to-height ratio pillars**: Pillar strength equations have been developed from large numbers of case histories in hard rock metal mines. These case histories and the developed equations will be reviewed and evaluated for their relevance to stone mine pillar design. Particular attention will be paid to their validity and robustness in the lower width-to-height ratio ranges (<1.25). A pillar strength equation will be selected or modified for application to stone mine pillars.
- **Numerical analysis of low width to height ratio pillars**: Numerical models will be used to assess the strength of slender pillars under various loading and geotechnical conditions. The effect of through-going structures, foundation materials, contact properties and rock mass variability will be considered. The results will be compared to output of the empirical pillar strength equations and used to assist in selecting or developing an appropriate equation.
- **Reliability analysis of a system of pillars with a low width to height ratio**: Based on the outcome of the numerical models and review of pillar strength equations, a reliability analysis will be carried out to assess the risks associated with low width-to-height ratio pillars. The output will be used to assist in identifying the necessary safety factor for pillars at low width-to-height ratios.

The major outcome of this task will be an improved understanding of the factors affecting pillar strength at low width to height ratios and will provide needed input to the development of a pillar design methodology. The findings will be presented in a peer reviewed publication.

Task 4: Analyze data and develop pillar design guidelines
The results of tasks 1 through 3 will be collated and evaluated to develop a pillar design methodology and a design chart. It is expected that the method will be based on an initial rock classification followed by the application of adjustment factors for the important parameters that affect pillar strength in stone mines. The focus will be to quantify pillar strength and performance at low width-to-height ratios. The activities under this task include:

- **Develop rock classification adjustments for pillar design:** Based on a review of all the collected case studies, the numerical models and evaluation of pillar strength equations, a hierarchical arrangement of factors affecting the strength of pillars will be made. Appropriate relationships between each important parameter and pillar strength will be established from field data, numerical models and existing pillar strength equations. For example, the effect of joint dip might be based on a relationship developed from numerical model results. Factors such as immediate roof and floor stability are also likely to be included.
- **Develop pillar design methodology and layout guidelines:** The rock mass strength modification**s** and empirical pillar performance data will be used to develop a relationship between geotechnical characteristics and pillar strength. Statistical techniques, such as minimization can be used to define appropriate parameters for the pillar design equations. It is likely that a pillar strength chart showing strength for different geotechnical settings will be developed. The procedures for developing input for the pillar design chart will be described and a design methodology developed. The methodology will also address situations in which adequate data are not available for the design, typically by recommending the user to assume conservative inputs. The layout guidelines will be based on observations made during the site visits and will incorporate guidelines related to excavation orientation and pillar patterns from the literature. Validation of the developed method will be carried out by testing the method at selected mine sites and comparing the "predicted" pillar dimensions to performance of actual pillars. A document will be prepared that describes the pillar design methodology and includes layout guidelines. The document will be circulated for peer review and discussion with MSHA and other stakeholders.

The task will produce pillar design guidelines for the specification of pillar width-to-height ratios in stone mine workings. The focus will be on pillars with low width-to-height ratios and, depending on the outcome, may specify a lower limit to the width-to-height ratio for pillar design. This outcome is expected to have a significant impact on the risk of instability in shallow stone mine workings. A peer reviewed report for publication

in major mining/rock engineering journal will be prepared. The results will in addition be presented at industry conferences and seminars.

Task 5: Monitor and evaluate temperature and humidity effects
This task will provide specific measurements on mine environment variables including production and ground fall locations documenting a comprehensive characterization of these variables and unknowns at two to three mine sites over a period of three years. The task will require an on-going low level of activity over a period of three years, while field monitoring continues. During the fourth year, the findings will be summarized and, depending on the results, appropriate guidelines for identifying hazardous conditions related to temperature and humidity fluctuations will be developed. The plan includes 3 principal activities:

- **Field instrumentation at selected mine sites:** Underground Mine Site Identification, Instrument Package Installation, and Data Collection and Assessment. Full cooperation from the mine operator and mine worker is required for successful instrumentation installation, maintenance, and data collection. A presentation and explanation to the mine workforce of the intended work will preface the installation stage, as needed. Location, budget, and mine conditions will be evaluated during the selection process. Installation will include sag monitors, convergence stations, temperature, and humidity instruments. Two or possibly three mine sites will be monitored for at least 12 months each.
- **Laboratory testing of weatherability:** The weatherability of the limestone and surrounding rocks at the selected mine sites will be tested at the PRL rock mechanics laboratory. Slake durability tests or other appropriate tests will be used to quantify the sensitivity of the mine rocks to the presence of moisture.
- **Analysis of data and development of relationships:** Field and laboratory test results will be evaluated and correlations made with observed excavation stability. The findings will be reported at interim stages at industry seminars with a final report being prepared and published in the fourth year of the project.

The outcome of this task will be a clarification of the issues related to temperature and humidity effects on stability in stone mines. A publication on the results of this study together with any appropriate guidelines will be prepared for publication at industry forums.

Task 6: Analyze roof span stability in stone mines
The factors affecting roof span stability and associated failure mechanics in stone mines will be evaluated based on the data collected during Task 1. Geotechnical conditions and failure modes will be categorized for further analysis and inclusion into the proposed design methodology. The original premise of relating roof spans to rock mass properties will be reviewed in the light of the collected field data. Published empirical and analytical techniques for the prediction of stable spans in underground mines will be tested against the data to determine which approach is the most likely to replicate the experience in

stone mines. Numerical models of the various scenarios will be evaluated to improve understanding of roof failure mechanics. The activities under this Task are as follows:

- **Review of roof span design methods and test applicability to stone mine design:** The existing roof span design methods will be tested against the field data to identify the most appropriate approach for developing a roof stability chart for stone mines. The premise of relating roof spans to rock mass data will be reviewed. Methods that will be tested include the voussouir arch approach, simple elastic beam methods and rock classification methods.
- **Evaluate field data to identify causes of roof instability**: The field data collected as part of Task 1 will be categorized according to the assessed failure mechanism and the geotechnical characteristics. Conditions leading to certain types of failure will be identified and where possible, relationships between stable spans and specific geotechnical conditions identified. This will form the basis for developing a roof span stability chart.
- **Numerical analysis to evaluate beam stability and failure mechanisms:** Numerical models of the different roof categories will be evaluated to improve understanding of the likely failure mechanisms. For example, the effect of weak bands overlying a strong roof beam, the effect of thin beams overlying thicker beams, the effect of high horizontal stress on beam deflection will be evaluated. The results will assist in developing relationships between the different geotechnical categories and roof span stability.

The task will produce a categorization of causes of roof instability in stone mines, an improved understanding of the mechanisms involved in the failures and an assessment of the applicability of existing roof span design methods. Specific issues for further field monitoring and data collection will be identified. The results will form part of the input to develop a design approach for stone mines. A document summarizing the outcomes will be prepared for publication at an appropriate forum.

Task 7: Case studies of roof span stability

A number of field sites visited during the data collection stage will be identified for detailed case study analysis. Sites that are likely to be evaluated may include areas in which the failure mechanisms are not clear or to clarify the roof behavior in a specific geographic area. More detailed data on the rock mass properties, field stresses and mining parameters will be collected for analysis. If appropriate, field monitoring will be conducted of roof behavior and associated rock mass response. Allowance has been made in the budget for two field monitoring sites, including the measurement of field stresses and roof deflections. The activities under this task are as follows:

- **Collect data for case studies**: Sites for detailed case studies will be identified and arrangements made with mine operators for site access and conducting measurements. More extensive rock classification and rock strength testing will be done to fully quantify the geotechnical conditions. Mine records will be

inspected to obtain data on mining methods, mining sequences and blasting practices. Records of roof falls and their effect on mine operations and safety will be collected. The data will form the basis for a comprehensive evaluation of roof stability at the mine site.

- **Conduct field measurements**: The observational data at the case study sites will be supplemented by field measurements. A program of field measurements will be designed appropriate for the local conditions and specific parameters identified for investigation. The types of measurements could include: in-situ stresses determination using the maxi-frac system, roof beam deflection measurements using extensometers or roof-floor closure meters, rock bolt load measurements and damage mapping in the excavations.
- **Analyze case studies:** The field data will be evaluated and analyzed. Numerical models of the case study sites will be developed to assess potential failure mechanics and to calibrate the models.

The task will provide well documented case studies in which roof stability and failure mechanisms are quantified. The improved understanding provided by these case studies will be used to validate the design procedures. The case study results will be written up in one or more documents that will be published in industry forums and in the technical literature.

Task 8: Develop guidelines for selecting maximum roof span dimensions
The final task of the project will be to collate the results of the investigations into roof stability and develop a roof span design methodology. The methodology will have the objective to account for local geotechnical conditions in roof span selection. The methodology is therefore expected to include a basic rock mass classification with adjustment factors for specific geotechnical conditions. The task will be carried out as follows:

- **Establish relationships between geotechnical parameters and roof stability:** Based on the field surveys and case study sites, the important factors affecting roof stability will be identified using statistical analysis. The results of numerical and analytical models will be incorporated into the evaluation. Relationships will be developed to rate the relative importance of factors such as beam thickness, joint frequency and horizontal stress on roof stability. The results will guide the selection of factors for inclusion into the design methodology.
- **Develop roof span design charts and guidelines for mine layout:** A roof span design chart will be developed that allows local geotechnical parameters to be included in the design. This will be accomplished by incorporating the important factors that affect span stability into a classification scheme. Adjustments for the effect of mining parameters such as bolting, blasting practice and excavation orientation are likely to be included. Validation of the developed method will be carried out by testing the method at selected mine sites and comparing the "predicted" roof spans to performance of actual spans. Depending on the outcome of this research, the potential for specifying an upper limit to roof spans in

underground stone mines will be investigated. A guideline document will be prepared which will incorporate the developed design method as well as established excavation design principles. The document will be submitted for expert review and input by MSHA and other stakeholders.

The major output of this task will be the document presenting the guidelines for roof span design in underground stone mines. The results will be published through industry seminars and peer reviewed publication.

PROJECT SCHEDULE

FY 2005

Task 1 - Geotechnical Data and Mine Characterization
- Collect geotechnical and mining related data at fifteen mines
- Conduct laboratory tests of rock properties

Task 2 – Back Analysis of Pillar Performance
- Evaluate two cases of unsuccessful pillar systems

Task 3 – Evaluate pillar strength at low width-to-height ratios
- Review existing pillar design methods and their relevance to low width to height ratios
- Start numerical analysis of pillars with low width to height ratios

Task 5 – Monitoring of temperature and humidity effects
- Develop program and install instrumentation at first mine site
- Monitor mine climate changes and roof/rib stability

FY 2006

Task 1 - Geotechnical Data and Mine Characterization
- Collect geotechnical and mining related data at fifteen additional mines
- Conduct laboratory tests of rock properties
- Conduct field stress measurements at two sites

Task 2 – Back Analysis of Pillar Performance
- Evaluate two additional cases of unsuccessful pillar systems
- Evaluate two cases of unsuccessful benching operations
- Evaluate stable pillar layouts

Task 3 – Evaluate pillar strength at low width-to-height ratios
- Numerical analysis of pillars with low width to height ratios
- Reliability analysis of pillar systems with low width-to-height ratios

Task 5 – Monitoring of temperature and humidity effects
- Develop program and install instrumentation at second mine site
- Monitor mine climate changes and roof/rib stability

Task 6 – Analyze roof span stability in stone mines
- Review of roof span design methods and test applicability to stone mine design

Task 7 – Case studies of roof span stability

- Identify and collect data at a case study site
- Conduct field measurements at a case study site

FY 2007

Task 4 – Analyze data and develop pillar design guidelines

- Develop rock classification adjustments for pillar design
- Develop pillar design methodology and layout guidelines
- Validation of methodology

Task 5 – Monitoring of temperature and humidity effects

- Develop program and install instrumentation at third mine site
- Monitor mine climate changes and roof/rib stability

Task 6 – Analyze roof span stability in stone mines

- Review premise of relating rock mass conditions to roof span stability.
- Numerical analysis of roof span stability and failure mechanisms
- Evaluate field data and identify causes of roof instability

Task 7 – Case studies of roof span stability

- Identify and collect data at second case study site
- Conduct field measurements at case study sites

FY 2008

Task 5 – Monitoring of temperature and humidity effects

- Evaluate data and prepare final report and guidelines

Task 8 – Develop guidelines for selecting maximum roof span dimensions

- Establish relationships between geotechnical parameters and roof stability
- Develop roof span design charts and guidelines for mine layout
- Validation of methodology

RESOURCES

Laboratory:

Pittsburgh Research Laboratory

- Rock Mechanics Testing Facility – Rock strength and mechanical properties testing
- Rock Engineering Software – Analysis of roof and pillar failure mechanics
- Rock Mechanics Instrumentation – Instruments for measuring and recording in-situ stresses, rock displacement, temperature and humidity.

Lake Lynn Laboratory

- Access to underground mine for testing of data collection techniques and monitoring systems

Mine Sites:
Commercial Mines

- Underground mine sites in eastern and mid-western US for data collection
- Mine sites for underground monitoring and measurements, to be identified during first year of project

Clinical: none

Animal: none

Other: none

Major equipment: none

e.) Literature Cited

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f.) External Consultants - none

g.) Mission Relevance

Fall of ground accidents have been the largest cause of fatalities in underground stone mines over the past decade. Injury rates from ground falls in underground stone mines are higher than other underground mines, highlighting the need for methods of improving roof and rib stability. This project has the objective to eliminate hazardous ground conditions from underground stone mines, which directly addresses our mission to “Eliminate occupational diseases, injuries and fatalities from the mining workplace through a focused program of research and prevention”.

h.) Short Project Summary

The objective of this project is to develop design guidelines for maximum roof spans and minimum pillar dimensions in underground stone mines. The effect of temperature and humidity on excavation stability will also be assessed and incorporated into the design guidelines. The project will provide assistance to mine designers and operators in selecting excavation dimension based on an engineered approach, rather than trial and error methods.

Geotechnical and mining parameters will be collected from thirty underground stone mining operations in the Eastern and Midwestern States. The field data will be supplemented by measurements and monitoring at selected case study sites. Numerical model analyses and evaluation of existing pillar and roof span design techniques will be conducted to develop relationships between geotechnical parameters and stability. Monitoring of temperature and humidity changes and associated roof and rib stability issues will be conducted at three mine sites.

The results will be evaluated and guidelines for pillars and roof span design developed allowing local geotechnical parameters as well as mining inputs to be included in the design process. The outcome will be better engineered underground mines and the elimination of some of the potentially hazardous ground conditions found in underground stone mines.

DETAILED PERSONNEL PLAN

Name and Degree	Role on Project	FY2005	FY2006	FY2007	FY2008
Onboard:		%	%	%	%
R Güner Gürtunca PhD (Mining Engineering)	Project Consultant (Acting Director, NIOSH Pittsburgh Laboratory)	10	10	10	10
Stephen C Tadolini PhD (Mining Engineering)	Controls overall project direction and performance (Acting Branch Chief)	10	10	10	10
Anthony T Iannacchione PhD (Civil Engineering)	Geotechnical and mining engineering, project design and evaluation of outputs (Acting Team Leader Geotechnical Engineering)	20	20	20	20
Gabriel S Esterhuizen PhD (Mining Engineering)	Principal investigator (Senior Service Fellow)	80	80	80	80
Dennis R Dolinar MS (Mining Engineering)	Mining and geotechnical project design, field studies, data analysis and development of outputs (Mining Engineer)	50	50	50	50
Leonard J Prosser BS Geology	Conducts studies of temperature and humidity effects and coordinates r2p activities (Physical Scientist)	70	70	70	70
John L Ellenberger MS Geology	Data analysis, numerical modeling (Research Geophysicist)	50	50	50	50
David C Oyler BS (Mechnical Engineering)	Field instrumentation design, implementation and analysis. (Mechanical Engineer)	20	40	40	20
David L Dwyer	Rock testing, instrumentation (Engineering Technician)	50	50	50	50
Craig S Compton	Field instrumentation specialist (Engineering Technician)	0	40	40	0
Onboard Subtotals:		3.60	4.20	4.20	3.60
New Hires					
Numerical modeler	Develop and run numerical models and analyze outputs	80	80	80	80
New Hires Subtotal:		0.80	0.80	0.80	0.80
Totals		**4.4**	**5.0**	**5.0**	**4.4**

PROJECT BUDGET SPREADSHEET

Project Budget Guidelines for Eliminating Hazardous Ground Conditions from Underground Stone Mines

			2005			2006			2007			2008		
Travel	Meeting/Purpose	Personnel	Registration	otel+perdiem	subtotal	Registration	otel+perdiem	subtotal	Registration	otel+perdiem	subtotal	Registration	otel+perdiem	subtotal
	Temperature & Humidity Monitoring													
		Prosser		475			475			475			475	
		Compton		475			475			475			475	
	Convergence monitoring													
		Prosser		475			475			475			475	
		Compton		475			1,300			1,300			475	
	Mine data collection/monitoring													
		Iannacchione		1,300			1,300			650			520	
		Esterhuizen		2,600			2,600			1,300			520	
		Prosser		2,600			2,600			1,300			520	
		Dolinar		2,600			2,600			1,300			520	
		Oyler		500			2,600			2,600			520	
		Compton		650			2,600			2,600			520	
	Ground Control Conf.													
		Esterhuizen	320	200		320	200		320	200		320	200	
		Prosser	320			320			320			320		
		Ellenberger	320			320			320			320		
	Stone Safety Seminar													
		Iannacchione		275			275			275			275	
		Prosser		275			275			275			275	
		Dwyer		275			275			275			275	
		Compton		275			275			275			275	
		Esterhuizen		275			275			275			275	
	Rock Mechanics Symposium													
		Esterhuizen	400	1,600		400	1,600		400	1,600		400	1,600	
					16,685			21,560			17,010			9,555
Software Purchase/Upgrades														
	Purchase Examine3D			1,500										
	Training PFC			5,000										
	Upgrade FLAC Software			3,800			3,800			3,800			3,800	
					10,300			3,800			3,800			3,800
Supplies	Type													
	Field supplies/connectors/tools			1,500			1,500			1,500			100	
	Batteries/film			100			100			100			50	
	Cablng			500			1,000			1,000				
	Lab testing supplies			500			1,500			500			100	
					2,600			4,100			3,100			250
Equipment														
	Roof sag equipment			2,500			2,500			2,500				
	Stainless wire			400			400			400				
	Extensometers/borehole monitoring			1,500			1,500			1,500				
	Dataloggers			5,000			5,000			2,000				
	Stress Measuring Equipment			8,000			5,000			6,000				
	Compass/Measuring equipment			2,000			2,000			1,000				
	Logging equipment/camera/lights			2,000			1,000			500				
					21,400			17,400			13,900			0
Seminars (r2p)														
	Stone Safety Seminar			800			800			800			800	
	Lake Lynn Live			500			500			500			500	
					1,300			1,300			1,300			1,300
Total					52,285			48,160			39,110			14,905

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NIOSH FY2006 Project Form – Research Proposal Information

Summary

TITLE OF PROJECT	
Dust Control Technology for Black Lung Hot Spots	
PROJ. OFFICER (Last, first, middle)	**DEGREE(S)**
Pollock, Douglas Edward	B.S. Mechanical Engineering Technology, Licensed Professional Engineer – Commonwealth of Pennsylvania
POSITION TITLE	**MAILING ADDRESS (Street, city, state, zip code)**
Mechanical Engineer	P.O. Box 18070 626 Cochrans Mill Road Pittsburgh, PA 15236
DIVISION/BRANCH	
Respiratory Hazards Control Branch/ Dust Control	
TELEPHONE (Area code, number, and extension)	
(412) 386-6863	
FAX	**E-MAIL ADDRESS**
(412) 386-4917	depollock@cdc.gov

Will this project utilize human subjects?				Will this project utilize vertebrate animals?			
YES:		**NO:**	X	**YES:**		**NO:**	X
				Species of animals to be used:			N/A
				Approximate number of animals to be used:			N/A

DATES OF PROPOSED PERIOD OF SUPPORT (MM/DD/YYYY)		NEW FUNDS REQUIRED (Do not include existing base funding)				
			PS&B	Other Intramural	Extramural	Total
From:	10/1/2005	**FY2006**		$28,000		
Through:	09/30/2009	**All Years**		$98,000		

NEW FTEs	0.0	**% Project Category(s):**	100% Research
CURRENT FTEs	1.8	**% NORA Priority Area(s):**	100% Control Technology and PPE
TOTAL FTEs	1.8	**% Special Interest Areas(s):**	100% Mining
		% GPRA Category(s):	80% Research, 20% Evaluation, Intervention, and Recommendations

DESCRIPTION

Coal Workers' Pneumoconiosis (CWP) is a disabling and potentially fatal lung disease that results from excessive exposure to respirable coal dust. A chest x-ray program is administered by NIOSH that monitors the prevalence of CWP in the mining workforce. Since 1970, underground coal miners have had the opportunity to participate in this program on a voluntary basis. X-ray results from this program indicate that there are large regional differences in the prevalence of CWP, with the highest prevalence for bituminous coal mining found in the southern Appalachian region (SAR). The SAR is comprised of the coalfields of eastern Kentucky, southern West Virginia, and western Virginia. The counties of southern West Virginia have CWP rates at least five times higher than those observed in western and mid-western states.

The exact cause of these elevated CWP levels in the SAR has not been established but several factors may be contributing. Higher-rank coals are mined in a portion of this region, and the mining of high rank coals is known to lead to higher CWP rates. A high fraction of the mines in the region are on reduced standards because of silica and the miners may be exposed to an excessive amount of silica dust. Overexposure to silica dust can lead to silicosis, another disabling and potentially fatal lung disease. From chest x-rays, it is has not been established that silicosis can be distinguished from CWP. Another possible contributor to the high CWP prevalence is the high portion of small mines, fewer than 50 employees, found in the region. These small mines may lack the knowledge, resources, and resolve to adequately control dust.

The objectives of this project are to identify the types and effectiveness of the dust controls currently being used by mines in the SAR (with emphasis on small mines), develop dust controls targeted for the unique conditions found in these mines, and to provide educational materials to promote and facilitate implementation of these controls.

The project has been subdivided into five tasks to be carried out over a period of four years:

- Task 1 – Survey the conditions at the mines: Utilize Mine Safety and Health Administration (MSHA) inspector and mine operator compliance sampling data (e.g., average dust concentration, reduced dust standards, number of samples exceeding the dust standard) to identify mines of interest. In addition, RHCB personnel will periodically interact with personnel from DRDS in Morgantown to gather information of cases of rapidly progressing CWP for mines located within the SAR. The MSHA district offices will then be visited to gather data from dust/ventilation plans and inspector reports on selected mines. The types of controls and the level of controls will be established. Information such as type of equipment, ventilation quantities, water usage, and mining height (including rock cutting) will be gathered.

- Task 2 – Identify effective control technologies: Utilize compliance sampling data to identify six of the "cleanest" mines and six of the "dustiest" mines. Data

from these mines will be compared to highlight the differences in the dust controls employed. Subsequent mine visits will be completed to document the effectiveness of current controls and to uncover good/poor practices which are not evident from inspection reports.

- Task 3 – Develop appropriate dust controls: Utilizing information from Task 2, develop dust controls targeted to reduce overexposures in these mines, many of which may be small mines working in low coal seam. Past dust control research has typically emphasized medium-to-high seams. Perform laboratory work at the Respiratory Hazards Control Branch full-scale dust and ventilation galleries to study interactions between water sprays, dust scrubbers, and face ventilation in low coal applications.

- Task 4 – Implement control technologies: Conduct field evaluation of new dust controls developed in the laboratory that have been targeted for these mines. This will involve the use of gravimetric samplers placed on equipment, operators, and in the intakes and returns to properly evaluate the effectiveness of the controls. Personal Data RAMS (PDR) will also be used to gather real-time dust concentrations. Several personal dust monitors (PDM) may be employed during these field evaluations to supplement the data collected with gravimetric samplers.

- Task 5 – Develop the appropriate training materials: Update the Guidelines for Dust Control in Small Underground Coal Mines which was published by the Bureau of Mines in 1987. The updated handbook will also be made available on the NIOSH website. Develop control technology training modules that are targeted for presentation at annual refresher training classes, which are required by MSHA for all miners.

OUTCOME: Successful completion of this research program will reduce the respirable dust exposure of workers in the SAR and will ultimately lead to reduction in lung disease in this high-risk region.

PERFORMANCE SITE(S) (organization, city, state)

1) NIOSH Pittsburgh Research Laboratory, Bruceton, PA

2) Mines throughout the southern Appalachian region, which includes eastern Kentucky, southern West Virginia, and western Virginia

3) MSHA – headquarters office in Arlington, VA and district offices

KEY PERSONNEL

NAME	ORGANIZATION	ROLE ON PROJECT
Douglas E. Pollock	NIOSH	Principal Investigator (Mechanical Engineer)
Gerrit Goodman	NIOSH	Co-investigator (Mining Engineer)
Timothy Beck	NIOSH	Co-investigator (Mining Engineer)
Randy Reed	NIOSH	Co-investigator (Mining Engineer)
Jerry Joy	NIOSH	Co-investigator (Industrial Hygienist)

BIOGRAPHICAL SKETCH:

NAME	POSITION TITLE		
Douglas E. Pollock, P.E.	Mechanical Engineer		
EDUCATION/TRAINING (Begin with baccalaureate or other initial professional education, such as nursing, and include postdoctoral training.)			
INSTITUTION AND LOCATION	**DEGREE (If applicable)**	**YEAR(s)**	**FIELD OF STUDY**
University of Pittsburgh at Johnstown Johnstown, PA 15907	B.S.	1986	Mechanical Engineer

RESEARCH AND PROFESSIONAL EXPERIENCE:

Commonwealth of Pennsylvania, Licensed Professional Engineer PE-043822-E 1993
Association of Energy Engineers Certified Energy Manager 1999

1986 to 1987
Booz Allen & Hamilton Inc.

Security Clearance: Secret

Engineer/Consultant - Provided ship systems engineering support to the TRIDENT submarine acquisition program in the Naval Sea System Command (NAVSEA).

1987 to 1989
U.S. Army Depot System Command

Security Clearance: Secret

General Engineer - Provided engineering support to the Headquarters, U.S. Army Depot System Command (DESCOM) Facilities Engineering Branch. Participated in several Joint Chiefs of Staff (JCS) operations as the DESCOM facilities engineer. Acted as the DESCOM Energy Officer responsible for goal setting, reduction ideas, and energy monitoring of 16 Army depots located throughout the United States.

1989 to 1990
Letterkenny Army Depot
Operations and Maintenance Division

General Engineer - Provided engineering support to the Operations and Maintenance Division of Letterkenny Army Depot.

1990 to 2002
Pittsburgh Research Laboratory/ Administrative Service Branch/ Facilities Engineering

General Engineer - Provided facilities engineering support to the Pittsburgh Research Laboratory of the National Institute for Occupational Safety and Health.

2002 to Present
Pittsburgh Research Laboratory/ Respiratory Hazards Control Branch/ Dust Control

Mechanical Engineer - Provides research engineering support to the Dust Control Section of the Pittsburgh Research Laboratory's RHCB Branch. Responsible for project apparatus design, conducting research tests, and collection and analysis of data.

Honors:

Outstanding Performance: 2001, 2003
Excellent Performance: 1995, 2000, 2002, 2004

Publications:

Cecala, AB, JA Zimmer, JF Colinet, RJ Timko, GJ Chekan, and DE Pollock. Control Technology Using Ventilation to Reduce Respirable Dust Exposures at U.S. Metal/Nonmetal Mining Operations. To be published at 8th International Mine Ventilation 2005 Congress. Brisbane, Queensland, Australia, July 2005.

Cecala, AB, AD O'Brien, DE Pollock, JA Zimmer, JL Howell, and LJ McWilliams. Reducing Respirable Dust Exposure of Workers Using An Improved Clothes Cleaning Process. Journal of Occupational and Environmental Hygiene. Journal review – to be published 2005. (Peer Reviewed)

Organiscak, JA, DE Pollock. Development of a Lower Pressure Water-Powered Spot Scrubber for Mining Applications. 2005 SME Annual Meeting and Exhibit. Salt Lake City, Utah, March , 2005

Pollock, DE, AB Cecala, AD O'Brien, JA Zimmer, JL Howell. A New Method to Clean Dust-Soiled Work Clothes. Rock Products, March, 2005.

Goodman, GVR, DE Pollock. Use of a Directional Spray System Design to Control Respirable Dust and Face Gas Concentrations Around a Continuous Mining Machine. Journal of Occupational and Environmental Hygiene, December, 2004, pp.806-815.

Goodman, GVR, DE Pollock, and TW Beck. A Comparison of a Directional Spray System and a Flooded-Bed Scrubber for Controlling Respirable Dust Exposures and Face Gas Concentrations. Proceedings of the Tenth US/North American Mine Ventilation Symposium, Anchorage, Alaska, May, 2004. pp. 241-248.

BIOGRAPHICAL SKETCH:

NAME	POSITION TITLE
Gerrit V.R. Goodman	Mining Engineer

EDUCATION/TRAINING (Begin with baccalaureate or other initial professional education, such as nursing, and include postdoctoral training.)			
INSTITUTION AND LOCATION	**DEGREE (If applicable)**	**YEAR(s)**	**FIELD OF STUDY**
Penn State University	B.S.	1979	Mining Engineering
Virginia Tech	M.S.	1980	Mining Engineering
Virginia Tech	Ph.D.	1987	Mining Engineering

RESEARCH AND PROFESSIONAL EXPERIENCE:

Employment

Consolidation Coal Company	6/75-8/77	Cooperative employment working in underground coal mines during summers and falls
Virginia Tech	3/79-9/80	Graduate teaching assistant (classroom and laboratory teaching)
Consolidation Coal Company	9/80-9/82	Assistant mine engineer in charge of production and reclamation planning at two surface mining operations
Virginia Tech	10/82-5/87	Graduate teaching assistant (classroom and laboratory teaching)
U.S. Bureau of Mines/NIOSH, Respiratory Hazards Control Branch	5/87-present	Mining engineer involved in research to improve both face ventilation and dust control for continuous mining operations

Honors

1999 Stefanko Award – awarded by the Coal Division/SME for the paper "Variations in Dust Levels with Continuous Miner Position" which had been presented at the 1998 SME annual meeting.

Outstanding Performance: 1988, 2000, 2002, 2003, 2004

Excellent Performance: 1989, 1990, 1991, 1992, 1995, 1999, 2001

Publications

Goodman GVR and Pollock DE [2004]. Use of a Directional Spray System Design to Control Respirable Dust and Face Gas Concentrations Around a Continuous Mining Machine. J. Occup. Environmental Hygiene, 1(12):806-815.

Goodman GVR, Pollock DE, Beck TW [2004]. A Comparison of a Directional Spray System and a Flooded-bed Scrubber for Controlling Respirable Dust Exposures and Face Gas Concentrations. Proceedings, 10th US/North American Mine Ventilation Symp., Anchorage, AK, May.

Kissell FN, Goodman GVR [2003]. Continuous Miner and Roof Bolter Dust Control. In Handbook for Dust Control in Mining, Information Circular, No. 9465, DHHS (NIOSH) Publication No. 2003-147.

Goodman GVR, Organiscak JA [2003]. Assessment of Respirable Quartz Dust Exposures at Roof Bolters in Underground Coal Mining. Journal, South Afr. Mine Vent. Society, 56(2):50-54.

Goodman GVR, Organiscak [2002]. Evaluation of Methods for Controlling Silica Dust Exposures on Roof Bolters. Transactions, Society for Mining, Metallurgy, and Exploration, 312:133-137.

Goodman GVR, Listak JM, Organiscak JA [2001]. An Assessment of Occupational Silica Exposures on Continuous Mining Operations. Transactions, Society for Mining, Metallurgy, and Exploration, 310:63-68.

Goodman GVR, Taylor CD, Colinet JF, Thimons ED [2001]. Research by NIOSH for Controlling Respirable Dust and Methane Gas on Continuous Miner Faces. Proceedings, 7th International Mine Ventilation Congress, Krakow, Poland.

Goodman GVR, Organiscak JA [2001]. Laboratory Evaluation of a Canopy Air Curtain for Controlling Occupational Exposures of Roof Bolters. Proceedings, 7th International Mine Ventilation Congress, Krakow, Poland.

BIOGRAPHICAL SKETCH:

NAME	POSITION TITLE		
Timothy W. Beck	General Engineer		
EDUCATION/TRAINING (Begin with baccalaureate or other initial professional education, such as nursing, and include postdoctoral training.)			
INSTITUTION AND LOCATION	**DEGREE (If applicable)**	**YEAR(s)**	**FIELD OF STUDY**
University of Missouri - Rolla	BS	2000	Mining Engineering

RESEARCH AND PROFESSIONAL EXPERIENCE:

2000-2002: Mining Engineer, TXU Mining Company, Big Brown Mine, Fairfield, TX.

As part of TXU training program, rotated through different departments and worked as an Applications Engineer and Operations Engineer. In these positions, worked on multiple projects related to improving operations at the mine. In last year of employment, worked as an Operations Foreman and supervised a 30-person production crew.

2003-present: General Engineer, NIOSH-PRL, Pittsburgh, PA.

Conducting laboratory and mine site testing to evaluate dust control technologies for use in underground coal mines.

Publications

Goodman GVR, Pollock DE, Beck TW [2004]. "A comparison of a directional spray system and a flooded-bed scrubber for controlling respirable dust exposures and face gas concentrations." Proceedings, 10th US/North American Mine Vent. Symp., May 17-19, Anchorage, AK, pp. 241-248.

BIOGRAPHICAL SKETCH:

NAME	POSITION TITLE		
Wm. Randolph Reed	Mining Engineer		
EDUCATION/TRAINING (Begin with baccalaureate or other initial professional education, such as nursing, and include postdoctoral training.)			
INSTITUTION AND LOCATION	**DEGREE (If applicable)**	**YEAR(s)**	**FIELD OF STUDY**
University of Missouri-Rolla Rolla, Missouri	B.S.	1988	Mining Engineering
Wingate University Wingate, North Carolina	M.B.A.	1998	Business
Virginia Polytechnic Institute & State Univ. Blacksburg, Virginia	Ph.D.	2003	Mining Engineering

RESEARCH AND PROFESSIONAL EXPERIENCE:

Employment

1988-1990	Rand Mining Company	- Mining Engineer
1990-1997	Costain Minerals, Ltd.	- Sr. Project /Mine Engineer
1998	Concord Engineering & Surveying	- Project Manager
1999-2000	Virginia Tech	- Research Assist./ Instructor
2003- present	CDC/NIOSH/PRL/RHCB	- Mining Engineer

Registered Professional Engineer

South Carolina (1994)	-#15904
North Carolina (1994)	-#20384
Georgia (1995)	-#21838
Pennsylvania (1997)	-#053201
Virginia (1998)	-#33289

Recent Publications

Reed, Wm. R., and Organiscak, J.A.; "The Evaluation of Dust Exposure to Truck Drivers Following the Lead Haul Truck." 2005 SME Annual Meeting, Salt Lake City, UT, Feb 28 - Mar 2, 2005, SME Preprint #05-10, (Littleton, CO: SME, 2005).

Reed, Wm. R. and Westman, E.C.; "A Visual Basic Model for Predicting the Dispersion of Dust from a Haul Truck." International Journal of Surface Mining, Reclamation, and Environment. (Accepted for publication 2005).

Organiscak, J.A.; Reed, Wm. R.; Page, S.J.; and Cecala, A.B.; "NIOSH Studies Show Practical Aspects of Controlling Surface Mine Dust." Longwall USA, June 7-9, 2005. (Accepted for Publication 2005).

Reed, Wm. R.; Organiscak, J.A.; and Page, S.; "New Approach Controls Dust at the Dust Collector Dump Point, NIOSH Finds a Simple, Cost-Effective Solution for Reducing Dust for Blasthole Drills." Coal Age, (June 2004) 20-22.

Reed, Wm. R.; Organiscak, J.A.; and Page, S.; "New Approach Controls Dust at the Dust Collector Dump Point, NIOSH Finds a Simple, Cost-Effective Solution for Reducing Dust for Blasthole Drills." Engineering & Mining Journal, (July 2004) 29-31.

Reed, Wm. R.; "Performance Evaluation of a Dust Dispersion Model for Haul Trucks." SME Transactions, Vol. 316, (2004) 163-170.

Organiscak, J.A. and Reed, W.R.; "Characteristics of Fugitive Dust Generated from Unpaved Mine Haulage Roads." International Journal of Surface Mining, Reclamation, and Environment, Vol. 18, No. 4 (2004), 236-252.

Reed, W. R.; "Significant Dust Dispersion Models for Mining Operations." NIOSH Information Circular. (Submitted for publication Sept. 2004).

Reed, Wm. R.; Westman, E.C.; and Haycocks, C.; "The Introduction of a Dynamic Component to the ISC3 Model in Predicting Dust Emissions from Surface Mining Operations." Application of Computers and Operations Research in the Mineral Industry, Proceedings of the 30th International Symposium. Ed. Bandopadhyay, S.; (Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc. 2002) 659-667.

BIOGRAPHICAL SKETCH:

NAME	POSITION TITLE		
Gerald J. Joy	Industrial Hygienist		
EDUCATION/TRAINING (Begin with baccalaureate or other initial professional education, such as nursing, and include postdoctoral training.)			
INSTITUTION AND LOCATION	**DEGREE (If applicable)**	**YEAR(s)**	**FIELD OF STUDY**
West Virginia University, Morgantown, WV	B.A.	1978	Chemistry
University of Pittsburgh, Pittsburgh, PA	M.S.	1979	Chemistry
University of Pittsburgh, Pittsburgh, PA	M.S. Hyg.	1982	Industrial Hygiene

RESEARCH AND PROFESSIONAL EXPERIENCE:

1983-1985 Senior Industrial Hygienist, New York State Department of Labor
1985-1987 Health and Safety Coordinator, IT Corporation
1987-1989 Emergency Response Technical Coordinator, IT Corporation
1989-1990 Health and Safety Manager, IT Corporation
1990-1994 Health and Safety Manager, ICF Kaiser Engineers, Inc.
1994-1999 Director, Industrial Hygiene, ICF Kaiser Engineers, Inc.
1999-2002 Health and Safety Director, Shaw Environmental & Infrastructure, Inc.
2003- now Industrial Hygienist, NIOSH/PRL/RHCB

1988 Certified Industrial Hygienist
1990 Certified Safety Professional

Publications

Joy, GJ and Middendorf P., Trends in Noise Exposure & Hearing Conservation in U.S. Coal Mines, Journal of Occupational and Environmental Hygiene., (2005)

Research Proposal, Personnel Plan, and Budget

RESOURCES

FACILITIES:

Laboratory: (Provide room numbers where the work will be performed)

PRL Building 151 full-scale continuous mining machine test gallery: continuous mining machine equipped with both flooded bed dust scrubber and spray fan systems (Figure 1). Sensors installed to give real-time outputs of water spray pressure and flow rate. Gallery roof can be adjusted to simulate different mining heights. The ventilation system in the test gallery is designed to allow a large range of air volume flow adjustment along with various curtain setback configurations.

Figure 1. Continuous Miner Dust Gallery

Field: (Identify workplaces or other sites to be used.)

Various small mines located throughout the southern Appalachian region. Coordination and assistance from MSHA field districts will be critical for this project's success. MSHA field district offices will be visited to view the mine inspector reports and compliance data in order to target small mines for future field surveys.

Animal: (Provide room numbers where the work will be performed. Provide requests for special care and handling of the animals or for special equipment needed in the animal facilities.)

N/A

Other:

N/A

Major equipment: List the most important equipment items already available for this project, noting the location and pertinent capabilities of each.

PRL Building 151 full scale continuous miner test facility, Real-time aerosol monitors (RAM) with data logging capabilities, Building 144 environmentally controlled weighing laboratory for analysis of gravimetric filters.

The Research Plan:

a) Specific Aims

The intent of this project is to investigate the high prevalence of CWP in the southern Appalachian region and to develop dust control technologies and methods to reduce elevated exposures. The project will address these issues by completing the following:

- Determine the possible causes of the high CWP in the hotspot areas by identifying significant characteristics of the mines in these areas. Investigate compliance data and inspector reports of MSHA district offices in these areas in order to determine similarities/differences in control practices, equipment types, operating conditions, etc.

- Perform on-site dust surveys to quantify dust levels, control technologies utilized, and operating practices. Identify six of the cleanest and six of the dustiest mines of the SAR and contrast their methods of dust control. Define successful controls and areas of additional need.

- Develop new dust control technology/methods for application in the targeted mines, which will likely consist of small and/or low seam mines. Optimize existing controls and/or develop new control technologies through laboratory testing and field evaluation.

- Develop an aggressive technology transfer effort to reach target mines by: completing an update of the Dust Control for Small Mines handbook, presenting research results in peer-reviewed journals, trade journals, and at mining

conferences, holding workshops in the SAR, and developing a training module that can be incorporated into annual refresher training.

b) Background and Significance

If the national effort to reduce coal workers' pneumoconiosis (CWP) is to be truly comprehensive, it is necessary to monitor the progress that is being made to eradicate it. This monitoring has been conducted through the National Coal Workers' X-ray Surveillance Program, which is administered by NIOSH. In this program, underground coal miners are offered a free chest radiograph at first employment and every 5 years thereafter while employed. These radiographs are then used to determine whether the miner is suffering from coal workers' pneumoconiosis (CWP), and successive radiographs may be used to chart the progress of the disease.

Data from the latest round of x-rays in this surveillance program was combined with x-rays from the Miners Choice Program [CDC, 2003], a special program sponsored by MSHA. Results showed that the prevalence of CWP among miners participating in these programs continues to decline, but that new cases are occurring among miners who have worked exclusively under current dust exposure limits. There were two other significant findings in this report that are especially relevant to this proposal.

The first finding was a wide variation in CWP prevalence from state-to-state. This state-to-state variation may be seen by dividing the major coal mining states into highest and lowest- prevalence groups (Table 1):

Table 1. Major coal-producing states, divided by prevalence of CWP

State	**Prevalence of CWP[1]**
Maryland	9.60%
Virginia	8.60%
West Virginia	7.60%
Tennessee	4.90%
Kentucky	3.50%
Pennsylvania	1.80%
Ohio	1.70%
Colorado	1.50%
Illinois	1.10%
Utah	0.50%

1[1] Based upon small opacity profusion greater than or equal to ILO category 1/0.

The second finding was an equally large difference between miners who work at small mines and those who work at large mines. Across the U.S., in small mines with less than 50 employees, the CWP prevalence was 5.6%, and in large mines with 50 or more employees, the prevalence was 2.0%. These state-to-state variations and small-to-large

mine variations are not entirely separate issues because the states with higher CWP appear to have a higher proportion of small mines.

These two findings are critically important to the development of new control technology and the thrust of technology transfer. If the prevalence of CWP is to be reduced below current levels, the most success will be found by targeting the unique mining conditions leading to the higher prevalence values. Simply put, to succeed we must go to where most of the black lung is.

c) Preliminary Studies/Progress Report.

In collecting additional prevalence information for this proposal, we have also found that the X-ray surveillance program data shows, in addition to state-to-state differences, large county-to-county differences within some states. For example, CWP prevalence is much higher in eastern Kentucky than in western Kentucky, and much higher in southern West Virginia than in northern West Virginia. Others in NIOSH and MSHA have come to similar conclusions. For example, a high proportion of miners experiencing a rapid progression of CWP were found in the so-called Southern Appalachian Region (SAR) a geographic cluster consisting of the southern Appalachian counties of eastern Kentucky, southern West Virginia, and western Virginia [Antao, 2005]. These counties also had high prevalence rates, with the highest prevalence counties shown in Table 2. By comparison, the average prevalence rate across the U.S. is 3.2%.

Table 2. CWP geographic cluster [Antao, 2005]

County, State	**Prevalence of CWP[1]**	**No. of miners evaluated[2]**
Randolph, WV	0.176	8
Grant, WV	0.143	7
Raleigh, WV	0.109	51
Dickenson, VA	0.103	31
Tazewell, VA	0.099	26
Buchanan, VA	0.086	122
Preston, WV	0.08	16
Pike, KY	0.068	73
Wise, VA	0.06	63
Floyd, KY	0.059	6
Upshur, WV	0.053	13
Martin, KY	0.05	10

[1] Only prevalence data is shown here. Miners with small opacity profusion greater than or equal to ILO category 1/0 divided by the estimated average number of miners employed by county.
[2] In some counties the prevalence values might be questioned because of the small number of miners evaluated. However, the overall trend is unmistakable.

The notion that there is a significant clustering of CWP in the U.S. is not an entirely new one. The Work-Related Lung Disease Surveillance Report [NIOSH, 2002] lists U.S. counties with the highest mortality rates for CWP deaths between 1985 and 1999. Two

high rank coal regions stand out. Counties in the southern Appalachian region (23%) and the Pennsylvania anthracite region (31%) account for over half of all fatalities reported nationwide. Anthracite mining has seen a significant decline and should not result in the degree of CWP that has been observed in the past, leaving the SAR as the most problematic region.

Possible causes of CWP variability. If CWP is to be reduced through control technology research, through technology transfer, and through implementation of these technologies, then it is important to have knowledge of the circumstances that lead to geographic clustering. Three possible causes of CWP clustering stand out: first are geographic differences in the rank of coal being mined; second are geographic differences in the amount of silica associated with the coal being mined; and third is the difficulty associated with application of dust controls in small mines. We will discuss each of these in turn.

Effect of coal rank The rank of a coal seam is a measure of the degree to which the coalification process (the transition from plant matter to coal with progressively higher carbon content) has proceeded, with higher rank coals exhibiting higher carbon content. It has been known for many years that miners who work in seams of higher rank coal are more susceptible to CWP. This relationship has been found to exist in the United States [McBride et al., 1963][Morgan, 1968][Dessauer, 1972], Great Britain [Jacobsen et al., 1971][Bennett et al., 1979], and Germany [Reisner and Robock, 1977].

Elevated rank can be used to explain part of the geographic clustering. A rank contour map of West Virginia,[1] shown as Figure 2, indicates higher rank coals, also known as low- medium-volatile bituminous coals in the counties of southern West Virginia, which includes the counties shown in Table 2.

[1] Source: West Virginia Geological Survey (www.wvgs.wvnet.edu/www/datastat/te/Photos/Rankmap.gif)

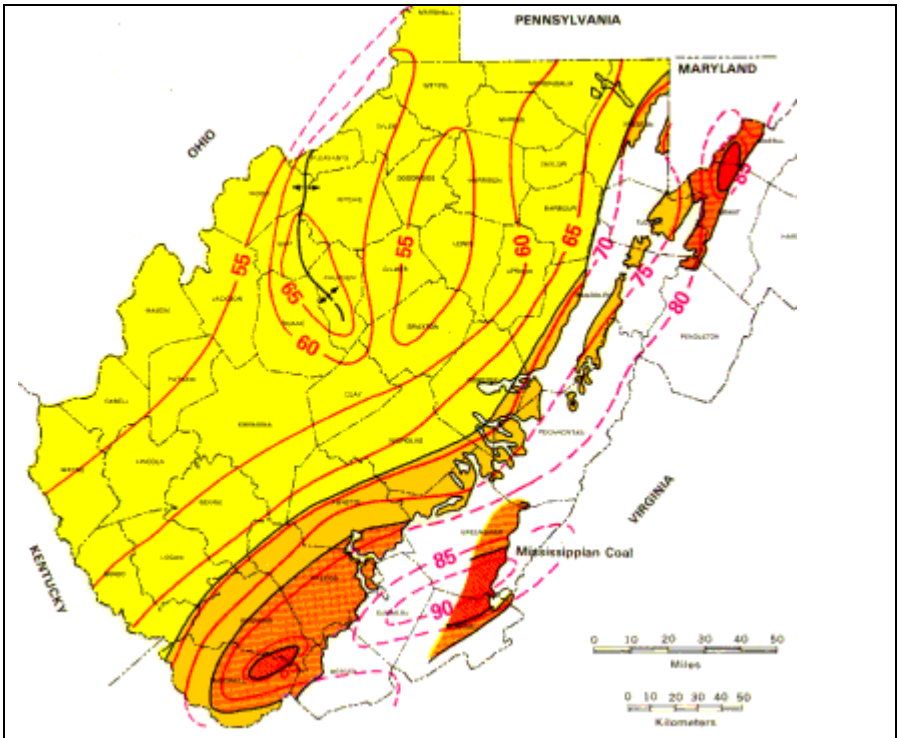

Figure 2. Rank Contour Map of West Virginia. Values shown represent percentage of fixed carbon (dry, ash-free)

Coal production from the state of Virginia originates in the counties in the western part of the state (Figure 3). These counties are adjacent to southern West Virginia, and the rank of the coals is similar.[2]

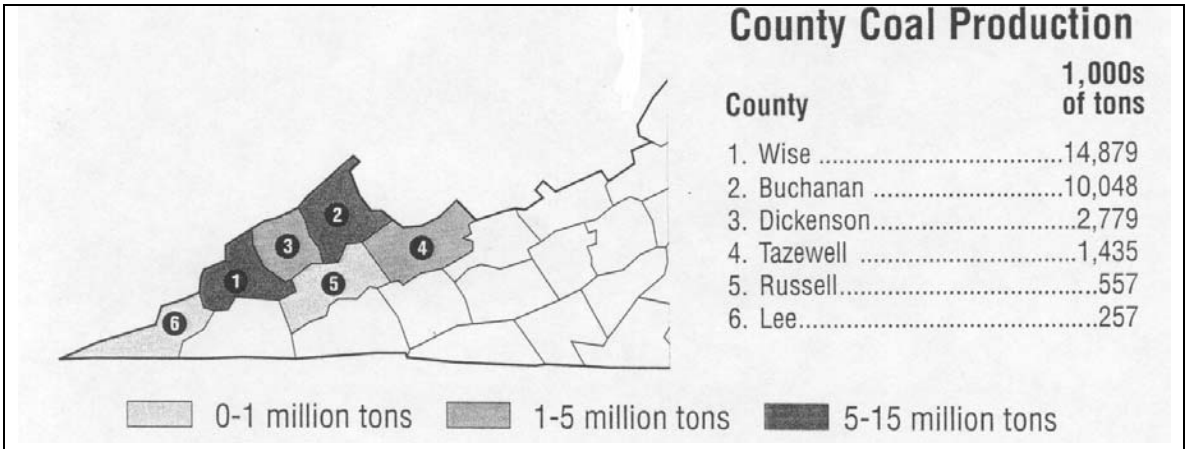

Figure 3. Coal producing counties of Western Virginia

For Kentucky, however, the coals in the eastern counties adjacent to southern West Virginia have a slightly lower rank than the coals of southern West Virginia. For

[2] Source: Virginia Dept. of Mines, Minerals, and Energy (www.energy.vt.edu/vept/coal/coal_rank.asp)

example, coals in the Big Sandy district of eastern Kentucky (the eastern tip of Figure 4) have an average fixed carbon value of 62% [Keystone, 2004][3], which may in part explain the lower CWP prevalence for Kentucky counties shown in Table 2.

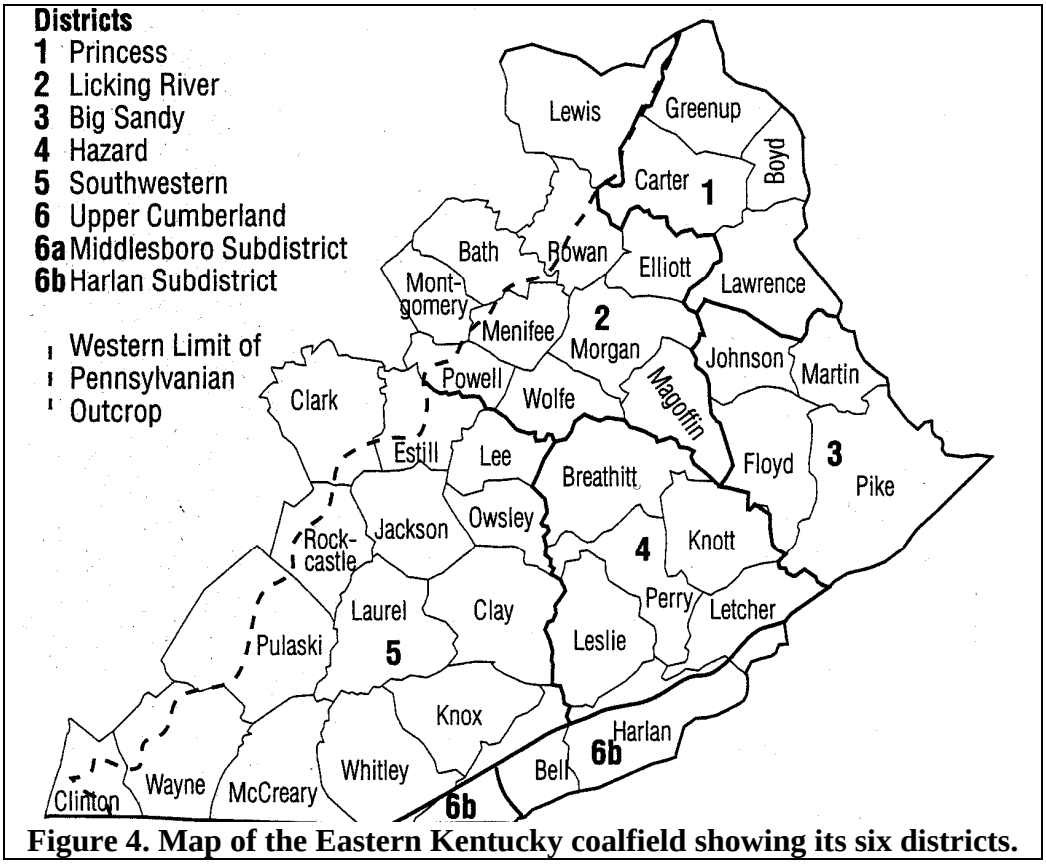

Figure 4. Map of the Eastern Kentucky coalfield showing its six districts.

While this proposal discusses coal rank as a possible contributor to CWP hotspots, RHCB does not intend to include this item for further investigation in this proposal. RHCB will focus on the mines in the SAR from a dust control and operations standpoint. However, RHCB personnel have had discussions with personnel from NIOSH's Division of Respiratory Disease Studies (DRDS) concerning the CWP hotspot problem. DRDS has expressed an interest in working jointly with RHCB and will focus upon the coal characteristics and epidemiological aspects of the CWP hotspot issue. Consequently, RHCB personnel plan to cooperate with DRDS in collecting and evaluating information concerning the relationship(s) between CWP and coal characteristics in the SAR.

Silicosis and the reduced standard Silicosis is an irreversible and progressive lung deterioration arising from the inhalation of respirable crystalline silica. This disease may be chronic, complicated, accelerated, or acute depending upon the length and intensity of the exposure. Miners with silicosis have an increased risk of lung cancer and other pulmonary disorders such as tuberculosis. Silica exposure may be a factor in the rapid development of progressive massive fibrosis (PMF). The Federal Coal Mine Health and

[3] Keystone gives rank values for raw coal. The authors corrected these values to put them on a dry, ash-free basis in order to facilitate a direct comparison with Figure 3.

Safety Act limits the amount of worker exposure to respirable silica dust by reducing the dust standard to 10 ÷ % silica when silica contents exceed 5% by weight. Compliance with a reduced standard maintains silica dust levels at or below 100ug/m³.

Effect of silica As a cause of coal workers' pneumoconiosis, the role of silica is usually seen as minor when compared to the mass of respirable dust that has been inhaled. For example, Hurley et al. [1982] conducted radiological assessments of 2600 British coal miners and reported that there was no evidence that the silica concentrations experienced (average 5% of mixed dust) affected the probability of developing coal workers' simple pneumoconiosis.

Nevertheless, a case-control study of men with unusually rapid progression of pneumoconiosis [Jacobsen and MacLaren, 1982] suggested that higher silica exposures were associated with a more aggressive form of the disease, and perhaps influenced the risks of developing PMF. More recently, Buchanan et al. [2003] have re-examined data collected during the Pneumoconiosis Field Research (PFR) program at one Scottish colliery where adverse geological conditions in the last decade before its closure in 1981 meant that sandstone roof and floor was machine cut along with the coal seam. The miners were exposed to higher silica exposures and subsequently showed more rapid progression of silicotic abnormalities on their chest X-rays than was typical of the others.

Statistical analysis for this mine showed that the risk of contracting silicosis was more closely related to the sum of the times spent in occupational groupings weighted by the square of silica concentration than the usually accepted model where risks from coal mine dust are simply related to cumulative exposure. This new analysis predicted that only twelve months exposure to 2 mg/m^3 silica was associated with a 73% risk of category 2/1 or greater silicosis. However, for lower silica concentrations in other mines, conventional cumulative exposures did appear to describe risks adequately (in that silica is a relatively unimportant determinant of risk from coal mine dust).

The counties of the SAR where Antao noted a rapid progression of CWP are also noted for their high silica levels, according to MSHA information regarding mines on reduced dust standards because of high silica levels. For example, in 2004, 35% of the 527 working sections (MMU) in the three MSHA districts comprising the SAR were on reduced dust standards due to more than 5% silica in the coal dust. In the other seven MSHA districts comprising the rest of the United States, only 6% of 324 working sections were on reduced dust standards. Thus, 90% of coal mine working sections in the United States on reduced standards are located in the SAR [Lindahl, 2005].

It is also instructive to examine the SAR proportion of working sections with silica levels exceeding 10%, equivalent to a reduced standard of 1.0 mg/m^3 or less. Across the United States, there are 59 working sections in this category. Of these, 45, or 76%, are in the SAR.

Small mines The SAR is a mountainous region with erosional and folded features that provide significant relief. More than other parts of the U.S., it contains deeply incised stream valleys where stream cutting has exposed rock layers and coal seams at outcrop. These seams are mainly of Pennsylvanian Era, and are interbedded with siliclastic rock

layers. Figure 5 shows a generalized geologic north-south cross section through the Eastern Kentucky Coalfield. It illustrates the great extent to which stream cutting has exposed outcrops of Pennsylvanian Era, shown as Pbu coal seams.

Coal outcrops facilitate the development of small drift mines that require less investment because no vertical shafts are needed. Small, undercapitalized companies can open a mine, and the SAR region, particularly in Kentucky, is known for its numerous small mines. For example, [DOE, 2003] data for the Pikeville KY zip codes of 41501 and 41502 indicates 59 small mines employing 1265 individuals and 6 large mines employing 384 individuals.

A high proportion of the small mines are in thin seams (so-called "low coal") where the siliclastic roof rock must be cut to gain adequate height for haulage equipment such as conveyor belts. Such mines are expected to have higher silica levels.

Safety conditions have been more problematic in small mines. Mines employing fewer than 50 people are responsible for a disproportionate share of fatal accidents. For the last several years, the fatal injury incidence rate at small mines has been more than double the rate for larger mines [Lauriski, 2003]. The operators of small mines often lack such resources as full-time safety directors, which larger companies can afford.

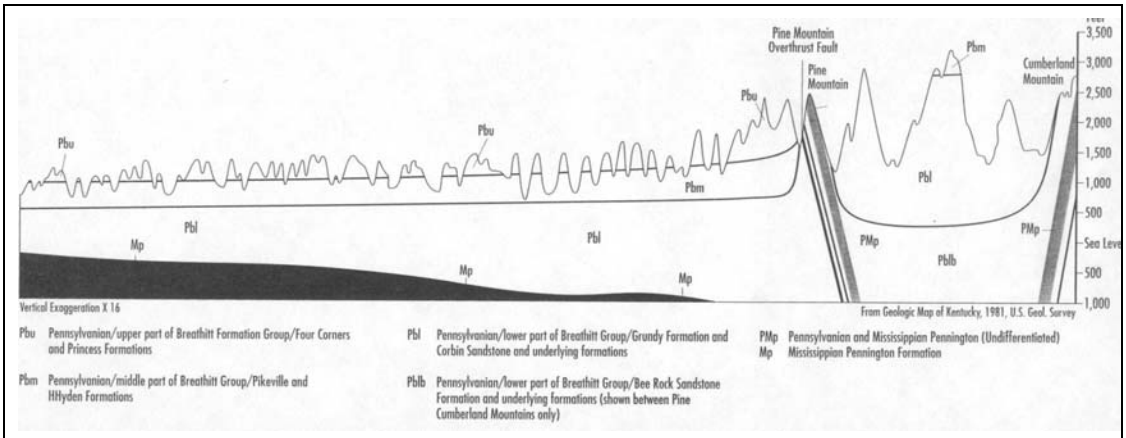

Figure 5. Generalized north-south cross section through the Eastern Kentucky Coalfield.

Impact of research and technology transfer: Given the elevated levels of CWP found in the SAR, control technology research and technology transfer of dust control information has the potential to have a highly positive impact on reducing the incidence of CWP in mines in the SAR. It is likely that all three factors – rank, silica, and mine size – will have some importance because they are all intertwined to some degree. The data collection and mine surveys proposed in the next section will be able to establish:

- the extent to which operators in the SAR are knowledgeable about dust controls
- whether SAR dust controls are up to national standards

- the degree to which extra roof cutting in low coal raises the silica level
- whether available control technology is meeting the unique needs of operators of low coal mines
- a contrast in the dust control practices of clean mines versus dusty mines – what are the clean mines doing that is different from the dusty mines. This technique has proven successful in past longwall mining research [Taylor et al, 1982] and [Jankowski et al, 1983].

d) Research Design and Methods

The ultimate goal of this research project is the development of improved dust control techniques and methods for mines located throughout the southern Appalachian region (SAR) thereby reducing worker exposure to elevated respirable dust levels. Findings may well also be applicable in varying degrees to other coal mining areas as well.

A summary of the work to be done is the following. The project will commence with an analysis of the MSHA compliance dust sampling data located in the TERA data base in order to do a preliminary evaluation of mines located in the SAR. Mines consistently maintaining compliance and mines exhibiting difficulty with maintaining compliance will be identified. Visits to the MSHA district offices will then be scheduled to examine dust control and ventilation plans and inspector reports. Discussions with MSHA health specialists will also provide information on control technologies and their use. Six of the cleanest mines and six of the dustiest mines will be identified. Mining conditions (rock thickness and coal thickness), equipment types, ventilation techniques and quantities, water usage and mining height will be compared and categorized in order to determine any relationships with measured dust levels. The data and observations will be compared to determine effective/ineffective methods for dust control. This approach was utilized in past longwall mining research with very favorable results [Taylor et al, 1982] and [Jankowski et al, 1983]. Subsequent field visits will be scheduled to each of these mines to conduct dust surveys during operation and to observe and possibly uncover conditions not obvious from the MSHA inspection reports. Dust controls in place will be evaluated in terms of their efficiencies in reducing worker exposures. Laboratory testing will then be conducted to improve dust controls including parameters such as air velocity, air flow quantity, water pressure, etc., while simulating mining conditions observed during the underground surveys. Return field visits will then be made to a number of the mines to implement and demonstrate the optimum dust controls from the laboratory testing in real world conditions. Technology transfer and training materials will be prepared to disseminate findings to the mining industry and regulatory personnel.

The following is a detailed description of the specific tasks to be completed:

1. <u>MSHA district office visits:</u> NIOSH will evaluate the compliance sampling data base to identify mines of particular interest based upon compliance history, level of silica, and mining conditions. MSHA field offices will be then be visited and

data gathered on approved dust-control plans for each of the selected underground small mines. MSHA dust samples will be utilized as well as operator samples. Current and historic samples will be examined. The current samples will be useful to relate measured dust levels during compliance sampling to existing control technologies and operating procedures. Current overexposures must be addressed in an effort to prevent the development of future cases of CWP. The investigators will also review the mine inspector reports and discuss operating practices for these mines with MSHA personnel. The production rate, mine equipment types, ventilation systems (both section and face), water pressures, spray systems and other unique characteristics to the mine will be noted. The inspector reports and compliance data will allow determination of the six dustiest and the six cleanest mines in the SAR. The data from these mines will then be compared in order to highlight the differences and identify factors that influence dust levels. Data and findings from the district office visits will routinely be shared with colleagues at DRDS. DRDS has data related to rapid progression of CWP for a number of mines in the SAR. This data will be used in the identification of the clean and dusty mines by cross referencing it with the compliance sampling data gathered by RHCB researchers Meetings with DRDS will be scheduled to discuss the selection of the mines for dust surveys.

2. Mine surveys: Mine surveys will be scheduled at the 12 mines selected to investigate and confirm findings from the district reports as well as to uncover conditions not obvious in the reports. The cleanest mine sites will be visited to observe their operations and to learn what they are doing correctly. Surveys may target the continuous miner, roof bolter, or both depending on the findings from the MSHA district reports. Each survey will typically consist of three to four consecutive days of testing and observation during production. Time studies will be conducted to track continuous miner cuts, shuttle car and roof bolter locations, and various other operations which may influence dust exposure readings. Curtain setback and configuration will be noted for each cut. Face ventilation measurements will be taken with a vane anemometer at the beginning of all cuts. Thermo MIE Personal Data RAMs will be utilized to record dust concentrations during the surveys. The PDR is a real-time aerosol monitor with logging capability. A typical sampling package will consist of a PDR and two MSA Elf sampling pumps (calibrated to 2 liters per minute) with pre-weighed 37-mm MSA filters and 10-mm nylon cyclones. Prior to each cut, the sampling packages are set in the intake and return and on or around the targeted machine(s). The sampling pumps are run for the duration of the cut or operation of the machine and placed on hold during the move to the next cut. The PDR monitors are left in logging mode since they have real-time capability. This procedure enables the researcher to analyze dust generation on a cut by cut basis. The PDR enables us to observe a real-time dust level reading at the instrument location which can be evaluated by using our time study notes. We are able to track what the machine/individual was doing during the point in time of high dust. The PDR provides a relative measure of dust levels and we use the two gravimetric samplers on the sampling rack to calculate a correction factor that is applied to the

PDR measurements. The MSA filters will be post weighed for dust concentration at PRL and then sent out to an independent laboratory for silica analysis. A personal dust monitor (PDM) will be placed on the miner and/or bolter operators to provide real-time tracking of their dust exposure throughout the shift. Various maintenance tasks such as bit replacement, bolter dust box cleaning, and spray maintenance will be observed and noted. Water spray types will be noted, water quantity will be measured, and water spray pressures will be measured at the spray nozzle.

These initial mine surveys will provide baseline information regarding relative effectiveness of dust controls currently in use and identify areas of additional need.

3. Evaluation of Dust Control Measures – Laboratory Evaluations: The continuous miner dust gallery will be utilized for this portion of the project to both optimize controls currently employed in the mines and to develop new and novel control approaches. By utilizing this unique laboratory set-up, test conditions are repeatable, easily verified and statistically sound. Laboratory testing will likely require that low coal operating conditions be simulated. The gallery is equipped with an adjustable roof which can be lowered to desired test conditions. To simulate the dust generated during mining operation, Keystone Mineral Black will be injected at the face at the cutting drum of the miner by using compressed air and a vibratory screw feeder. The rotation of the cutting drum will mix the dust with air ventilating the face. Dust feed into the gallery area will be adjusted by monitoring the concentration in the return and adjusting the feed rate to match levels encountered in the field. In addition to gravimetric samplers, real-time dust concentrations will be monitored at the left and right sides of the miner, the operator position, the standard and off-standard shuttle car positions, and in the return with MIE real-time aerosol monitors (RAM). The study will consist of simulation of the conditions encountered during the field surveys while varying such elements as curtain set-back distance, water spray pressure, spray locations, ventilation air flow, and scrubber or spray fan modifications. A matrix of tests will be developed to properly analyze the impact of the test variables. Improvements in dust control will be shown by the reduced dust concentration levels at the various monitoring points. In addition, new or novel control technologies, such as redirected scrubber exhaust, directional spray system designs, or redesigned scrubber applications, will be evaluated in the gallery in an effort to advance dust control technology for these mining operations.

4. Evaluation of Dust Control Measures – Field Evaluations: After new or improved control methods/equipment modifications have been tested at the NIOSH PRL continuous miner dust gallery, they will be applied at a number of SAR mine sites. A second round of dust surveys, identical to the original surveys, will be completed to evaluate reductions in respirable coal and silica dust levels resulting from the new control technologies. As with the initial field studies, it is critical to have the cooperation from the small mines as well as the MSHA district offices

for the success of this portion of the project. These control technology evaluations will be conducted similar to the initial field studies and consist of time studies, PDR measurements, and gravimetric dust sampling of the intake, return, and areas around the equipment. The PDM will again be utilized to gain a real-time dust exposure picture of the operator throughout the shift. Three to four consecutive days of testing will be conducted for each field evaluation. Data from the field evaluations will be analyzed to note any reductions in face area dust concentrations and the personal exposure of the operator. Detailed field reports will be written to present the findings, and a copy will be sent to each mine to provide guidance for reducing the dust exposure of their workers.

5. Publications, Presentations and Training Material Development: The findings of this project will be published in peer reviewed articles, trade publications, technology newsletters directed to the mining personnel, as well as presentations at SME and workshops which will be developed for the small mine operators. The Guidelines for Dust Control in Small Underground Coal Mines handbook will be updated to reflect the findings of this project. The updated handbook will be available in both hard copy and electronic format on the World Wide Web. Efforts will be undertaken to work with our training personnel to optimize ways to transfer the findings of this research to the mines in the SAR. Coordination with both NIOSH and MSHA training personnel will be utilized to develop and include a module for small mine dust control which would be presented during MSHA's annual refresher training courses.

Project Timeline:

CY 2005
Q4- Visit MSHA Arlington Office. Meeting to discuss project approach and district office visits.

CY 2006
Q1- MSHA District 4, Mt. Hope, WV office visit
Q2- MSHA District 5, Norton, VA office visit
Q3- MSHA District 6, Pikeville, KY and District 7, Barbourville, KY office visits
Q4- Dust survey at selected mine in MSHA District 4

CY 2007
Q1- Dust survey at selected mine in MSHA District 4, Attend conference
Q2- Dust survey at selected mines in MSHA District 5 and District 6, Laboratory testing
Q3- Dust surveys at selected mines in MSHA District 6 and District 7, Laboratory testing
Q4- Dust survey at selected mine in MSHA District 7, Laboratory testing,

CY 2008
Q1- Dust survey at selected mine in MSHA District 4, Laboratory testing, Attend conference
Q2- Dust surveys at selected mines in MSHA District 5 and District 6
Q3- Dust surveys at selected mines in MSHA District 6 and District 7
Q4- Dust survey at selected mine in MSHA District 4

CY 2009
Q1- Dust surveys at selected mines in MSHA District 6 and District 7
Q2- Workshops in Districts 4, 5, 6 and 7, Attend conference
Q3- Update Small Mines Handbook, Publish and present research findings

e) Literature Cited

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f) Consultants

None

g) Mission Relevance

A strategic goal of the PRL research program is to reduce the dust exposure of mine workers, with the ultimate goal of eliminating lung disease from mine workers. A review of x-ray surveillance data has illustrated an increased CWP prevalence in coal miners employed in the southern Appalachian region of the U.S. mining industry. It is suggested that rank of coal, elevated silica levels and high percentage of small mines may have a roll in this elevated risk. In small mines with less than 50 employees, the CWP prevalence was 5.6%, and in large mines, the prevalence was 2.0%. Consequently, a need for improved dust control in small underground coal mines is warranted to protect these workers at elevated risk. Research to develop new and/or improved technologies will be completed. Implementation by industry will be facilitated through: an update of a dust control handbook for small mines, publication in peer-reviewed and trade journals, the presentation of workshops in the SAR, and the development of a training module designed for incorporation into annual refresher training. Implementation of improved dust control will reduce worker dust exposure, thus lowering the prevalence of CWP in the future.

h) Project Description

This project will develop and evaluate control technologies to reduce coal and silica dust exposures for operators of roof bolting and continuous mining equipment in low coal mines. The project will commence with an investigation of the MSHA compliance data to identify the problem mines. MSHA districts will be visited to collect data specific to dust control technology and operating conditions at these mines. As a result of these preliminary investigations, mine surveys will be scheduled to collect data at the six dustiest and the six cleanest mines and to contrast the differences. The project will target areas such as ventilation techniques, spray types, equipment types, continuous miner and roof bolter operation. New dust control methods/techniques will be laboratory tested and verified in the field. Results from this work will be incorporated in an updated version of the Bureau of Mines handbook entitled “Guidelines for Dust Control in Small Underground Coal Mines” which was published in 1987. A training module will also be developed with the goal of adding this module to the annual refresher training required for coal miners.

i) Short Project Summary

This project will develop technologies to reduce exposures to respirable silica and coal dust for workers in small coal mines in the southern Appalachian region (SAR), where there exists a higher incidence of coal workers pneumoconiosis. MSHA compliance sampling data, inspector reports and dust control plans will be reviewed to characterize different mines. Field visits to the six dustiest and six cleanest mines will then be scheduled to contrast their dust control techniques and methods. Improved dust control technologies will be tested in the laboratory and then field tested in small mines. A handbook presenting dust controls for small mines will be published and a training module developed.

j) Involvement of Stakeholders

MSHA – Project Conception, Research Collaborator, Translator, Evaluator

Small Mine Operators – Research Collaborator

SME, Trade Magazines - Translator

k) Technology Transfer

N/A

l) Marketing/Dissemination Plan

The most important task of this project is to get the new dust control technology information out to the small mines where it can be implemented as soon as possible. In 1987, the Bureau of Mines published a small handbook entitled Guidelines for Dust Control in Small Underground Coal Mines by Ed Divers, Natesa Jayaraman, Steve Page, and Robert Jankowski. This handbook provided low cost dust control techniques to the small mines which were experiencing high dust concentrations. The handbook concentrated on continuous, auger, and conventional mining applications. This handbook was and still is a valuable tool to the small mine operator however, it is in need of some updating. With the assistance of NIOSH training personnel input, the handbook will be updated to include the improved dust control technology brought forth by this project and concentrate on the mining methods currently utilized in small mines today. The handbook will be available to the industry through the web and in hard copy form. Peer reviewed and trade magazine articles will be published as well as presentations given to disseminate the results to the small mines. A training module designed for inclusion in annual refresher training classes required by MSHA will be developed with coordination from NIOSH and MSHA training personnel. The module will relay the results of this project and the developed control measures to the coal miner as well as present the possible dust hazards in small underground coal mines.

DETAILED PERSONNEL PLAN

Name and Degree	Role on Project	FY2006	FY2007	FY2008	FY2009	FY2010
Onboard:						
1 Douglas E. Pollock, B.S.	P.I. – Mechanical engineer – data collection and analysis	70%	80%	80%	80%	
2 Gerrit Goodman, B.S., M.S., PhD	Mining engineer – dust and ventilation specialist, data collection and analysis	20%	20%	20%	20%	
3 Timothy Beck, B.S.	General Engineer – data collection and analysis	30%	30%	30%	20%	
4 Randy Reed, B.S., M.S., PhD	Mining Engineer-data collection and analysis	30%	20%	20%	20%	
5 Jerry Joy, B.A., M.S., M.S. Ind. Hyg.	Industrial Hygienist – data analysis	20%	20%	20%	20%	
6 Tom Mal	Technician-lab and field support	10%	30%	30%	20%	
Onboard Subtotals:		1.8	2.0	2.0	1.8	
New Hires						
1						
2						
New Hires Subtotal:						
Totals		1.8	2.0	2.0	1.8	

PROJECT BUDGET SPREADSHEET

Complete *ProjectBudget.xls* and attach as an appendix to this form.

Intramural Research Project Proposal Instructions

Introduction

These instructions should be used for completion of full research project proposals for new intramural projects in the NIOSH Mining Program. Proposals in this format will normally be evaluated by external peer reviewers to help ensure the quality of the research done in the Program. The format of the proposals is based on the R01 research grant application format used by NIH and CDC, and is similar to the format used for NIOSH NORA proposals.

Specific Instructions for Completing the Project Proposal Form

Please observe the page limitations. A summary of these limitations is given in the following chart:

Page Limitations and Content Requirements

Section	Page Limit	Content
Part A		
Description	2	See instructions on page 2 in *Project Form.doc*
Biographical Sketches	2 (per sketch)	1 sketch for each senior investigator
Part B		
Project Plan*	20	Text plus all figures, charts, tables and diagrams
Literature Cited*		Complete citations including titles and all authors.
Appendix*		• No more than 5 publications, including accepted or submitted manuscripts. • Photographs (include an electronic copy in the Research Plan) • Questionnaires • Other materials that cannot be provided in electronic format.
Personnel Plan		Listing for all project personnel
Budget Spreadsheet		*Project Budget.xls*

*Not required for cooperative agreement projects

The form is to be prepared and submitted in electronic format, with the exception of Appendix items. The form should be prepared using the standard CDC Word Processing Package (Word). Please use Times New Roman Font, 12 point Normal, for all text (except for the form on the first page which uses 10 point type). Use the supplied margins of 0.75" left, 0.5" right, 1" top, 1" bottom. Please convert all diagrams, charts and photographs to electronic format. Most diagrams and charts can be inserted into the Word document using cut-and-paste from other Windows programs. Please scan photographs and insert them into the electronic document.

Appendix items that cannot be converted to electronic format may be submitted as hard copies. Submit 5 copies of each item and attach a copy of page 1 of the project form as a cover sheet.

Summary

1. Summary Form

- **Headers.** Enter name of project officer and project ID# in header A. (To edit header A, select Header/Footer from the Insert menu, select Header A and click on the edit button.) The project ID# must follow the format DIVID FY NORA XXXX, i.e. DSR 06 NORA SN01.

- **Title of Project.** Do not exceed 56 characters, including the spaces between words and punctuation. Choose a title that is specifically descriptive, rather than general.

- **Project Officer (Names of project officer).** Name the one person responsible for the scientific and technical direction of the project.

- **Degree(s).** Indicate up to three academic and professional degrees or other credentials, such as licenses.

- **Position Title.** Provide the professional or academic title of the principal investigator/co-principal investigators. If more than one title, indicate the one most relevant to the proposed project, such as Branch Chief, Team Leader, Staff Scientist.

- **Mailing Address.** Provide complete information (including room number, building and street address) necessary for postal delivery.

- **Branch/Division.** Provide Branch and Division names, please do not use acronyms.

- **Telephone, FAX, E-mail Address.** Provide a daytime telephone number, a FAX number, and an e-mail address.

- **Human Subjects.** If activities involving human subjects are not planned at anytime during the proposed work, indicate “No.”

  If activities involving human subjects, whether or not exempt from Federal regulations for the protection of human subjects, are planned at any time during the proposed project period, either at NIOSH or at any other performance site or collaborating institution, check "Yes."

  If the planned activities involving human subjects are not exempt from Federal regulations, appropriate IRB approval is required and must be documented before any experimentation with human subjects can take place.

- **Vertebrate Animals.** If activities involving vertebrate animals are not planned at any time during the proposed project period, indicate "No."

  If activities involving vertebrate animals are planned at any time during the proposed project period, either at NIOSH or at any other performance site or collaborating institution, indicate "Yes.” An approved Institute Animal Care and Use Committee (IACUC) protocol is required and must be documented before any research using animals can be initiated.

- **Dates of Proposed Period of Support.** Identify start and end dates.

- **New Funds Required**. Provide an estimate of new funds being requested in FY2006 and an estimate of the total new funding for all years of the Project; do not include base

funding in this estimate. Extramural funding, for the summary page, should include only cooperative agreements. Research contracts should be listed under "Other Intramural."

- **FTEs**. Identify the number of new and current FTEs needed to carry out Program.

  Note: Refer to FY 2005 Project Planning Guidance for complete information concerning the next 4 entries.

- **% Project Category.** Assign weights to each of the following categories as they represent this project: Administration, Information, Research, Service, Surveillance or Training. Percentages should equal 100% and no attribution should be less than 10%.

- **% NORA Priority Area**. List NORA priority areas addressed in this Project and assign percentages to each area. No attribution should be less than 20%, total attribution may be less than 100%. To meet the NORA Quality Assurance Committee (QAC) criteria, 80% of the NORA research must be coded in a single NORA priority area.

- **% Special Interest Area.** Identify percentage of Project that applies to Special Interest Areas. Information entered in this section should be coordinated with the Program Analyst in your Division or Laboratory. NIOSH special Interest Areas include: Agriculture, Asthma, Cancer, Construction, Child Ag, Ergonomics, Energy, Firefighters, Genetics, Healthcare Workers, HIV, Latex, Mining, NORA 98, NORA 99, NORA 00, Service Sector, Silicosis, Small business, TB, Violence and transportation.

- **% GPRA.** Assign weights to the following GPRA Goals as they represent this project: 1) Research, 2) Surveillance, 3) Evaluation, Intervention and Recommendations, 4) Information, Training and Capacity, and 5) Other Administrative Costs. Percentages should equal 100%.

2. Description, Performance Sites, and Key Personnel

- **Description.** Note the instructions on the form page 2.

- **Performance Site(s).** Indicate where the work described in the Description will be conducted. If there is more than one performance site, list all the sites.

- **Key Personnel. Key personnel are defined as, and should be limited to, individuals who contribute in a substantive way to the scientific development or execution of the project.** Typically, these individuals have doctoral or other professional degrees, although individuals at the masters or baccalaureate level should be included if their involvement meets the definition of key personnel. External collaborators and partners should be included if they meet the definition of key personnel. Consultants should be included only when their level of involvement meets the definition. Individuals providing technical services are not considered key personnel and are not to be described here, but if they are NIOSH employees, they should be listed in the Detailed Personnel Plan. For each individual, provide: name, organization, and role on the project. Under role on the project, indicate how the individual will function with regard to the proposed project, for example, principal investigator, co-investigator, laboratory technician, etc. Use additional pages as necessary.

3. Biographical Sketch

- This section must contain the biographical sketches of all key personnel. Each biographical sketch is limited to two pages maximum.

Research Proposal, Personnel Plan, and Budget

1. Resources

- Provide requested information on facilities and major equipment required to conduct the proposed project.

2. Research Plan (not required for cooperative agreement projects)

The Research Plan should include sufficient information needed for evaluation of the project, independent of any other document. Be specific and informative, and avoid redundancies. The scientific peer review will focus primarily on this section.

- **Project Plan.** Organize Items a-d, to answer these questions: (1) What do you intend to do? (2) Why is the work important? (3) What has already been done? (4) How are you going to do the work? **Do not exceed 10 pages for Items a-d.** All tables, graphs, figures, diagrams, and charts must be included within the 10 page limit. Full-sized glossy photographs of material such as electron micrographs or gels may be included in an Appendix; however, a photocopy of each must also be included within the page limitations of the Research Plan.

  The total for items a-d may not exceed 10 pages, including all tables and figures; recommended number of pages for specific sub sections is listed.

  a. Specific Aims. List the broad, long-term objectives and what the specific work proposed is intended to accomplish. For research projects, state the hypotheses to be tested.

  b. Background and Significance. Briefly sketch the background leading to the present proposal, critically evaluate existing knowledge, and specifically identify the gaps which the project is intended to fill. State concisely the importance and occupational safety and health relevance of the research described in this proposal by relating the specific aims to the broad, long-term objectives.

  c. Preliminary Studies/Progress Report. Use this section to provide an account of the project officer's/program director's preliminary studies pertinent to the proposal and/or any other information that will help to establish the experience and competence of the investigator to pursue the proposed project. The complete references to appropriate publications and manuscripts **submitted or accepted** for publication may be listed, and are not part of the page limitations. Five collated sets of no more than 5 such items of background material may be submitted in the appendix.

  d. Design and Methods. Carefully describe the project design and the procedures to be used to accomplish the specific aims of the project. Include how the data will be collected, analyzed, and interpreted. Describe any new methodology and its advantage over existing methodologies. Discuss the potential difficulties and limitations of the proposed procedures and alternative approaches to achieve the

aims. As part of this section, provide a tentative sequence or time-table for the project. List annual accomplishments that can be tracked. Point out any procedures, situations, or materials that may be hazardous to personnel and the precautions to be exercised.

Note on Gender and Minority Inclusion for Research Involving Human Subjects.

The NIOSH policy is that women and members of minority groups and their subpopulations must be included in all NIOSH supported biomedical and behavioral research projects involving human subjects, unless a clear and compelling rationale shows that inclusion is inappropriate with respect to the health of the subjects or the purpose of the research. Exclusion under other circumstances may be made based on a compelling rationale and justification. Cost is not an acceptable reason for exclusion except when the study would duplicate data from other sources. Women of childbearing potential should not be routinely excluded from participation in clinical research. This policy applies to research subjects of all ages.

Address the inclusion of women and members of minority groups and their subpopulations in developing a research design appropriate to the scientific objectives of the study. Describe the composition of the proposed study population in terms of gender and racial/ethnic group, and provide a rationale for selection of such subjects. Include a description of proposed outreach programs for recruiting women and minorities as participants. Provide a compelling rationale and justification for requesting any exclusions noted above.

e. Literature Cited. List all references. Each reference must include the title, names of all authors, book or journal, volume number, page numbers, and year of publication. The reference should be limited to relevant and current literature. While there is no page limitation, it is important to be concise and to select only those literature references pertinent to the proposed research.

f. Consultants. Attach appropriate letters here from all individuals confirming their roles in the project.

Sections g-i are identical to items needed for the IRIS system, which will be used for NIOSH project and program planning. The length of sections g-i is not to exceed one and one half pages. It is not necessary to enter information into IRIS at this time.

g. Mission Relevance. This section should be brief (not to exceed 20 lines) but should describe the public health **impact** of the study. Describe the **need** for the project. Some elements that might be included in this section include:

- o A statement of the problem(s) being addressed.
- o Statistics that describe the number of people affected, extent of exposure, etc.
- o How the project relates to the NORA and Mining/Ag or Construction research priorities, other NIOSH research priorities, Healthy People 2010, and/or surveillance.
- o How the results might be used by a regulatory agency such as the OSHA, EPA, or MSHA.
- o How the project might be used to improve the health and safety of working men and women.

h. Project Description. (not to exceed 20 lines) Elements in the project might include:

- Hypotheses, goals, objectives and methodology
- Unique strength of project staff and partners (interdivisional + external).
- Results or public health accomplishments or products (publications, CRADA, Alerts, etc.), to be anticipated.
- Why project is being done as proposed, e.g., intramural, a support contract, extramural.
- Time frame for project.

i. Short Project Summary. (3-4 sentences, not to exceed 10 lines) Provide a short, succinct description of the project that can be understood by both technical and nontechnical audiences. A focused description of the project should be provided.

The following format should be used for each short summary:

- Select 3 keywords/phrases from the attachment in the latest version of the NIOSH Project Planning Guidance that best categorize your project
- Keywords/phrases should appear exactly as they appear in the attachment.
- A statement of purpose (no more than 1-2 sentences) should appear at the beginning of the abstract. Avoid beginning abstracts with statements that quote statistics, since there are many sources and methods for determining these numbers and it would be difficult to provide citations for every project.
- Provide a brief abstract of no more than 100-130 words (inclusive of the purpose statement) provide one or two sentences at the close of the abstract that addresses expected outcomes.

Sections j-l are items needed for the r2p component. Do not exceed two pages.

j. Involvement of Stakeholders. Stakeholders are internal and external partners, who are involved in the research, will use the research, or who will be impacted by the research findings.

- Characterize the role of each stakeholder in each project phase selecting from these potential roles:
  - Project conception - stakeholder was involved in the identification of the problem the project is addressing; helped to demonstrate need for project; or other pre-project role.
  - Planner - stakeholder was involved in the planning for the project.
  - Research collaborator - stakeholder is a research collaborator, either formally or informally.
  - Funding Source - stakeholder is providing funds (either direct or in-kind) for conducting the project.
  - Translator - stakeholder will translate research findings to end user. Examples of translators are regulatory agencies, unions, professional associations, trade magazines.
  - Evaluator - stakeholders who will assist in the evaluation of the project.

k. Technology Transfer. Identify if the work will likely result in a Cooperative Research and Development Agreement (CRADA), Employee Invention Report (EIR), or a Memorandum of Understanding (MOU) that will directly affect the problem addressed.

l. Marketing/ Dissemination. Each project should describe a preliminary plan for transmitting the knowledge or products to the end user. End users may be other researchers who will forward or expand the research concept, regulatory agencies who will use the findings in standard setting, translators who will interpret the findings for others, or workers and employers who will put the information to use. The

marketing plan should be developed to ensure the information is delivered through channels and in media appropriate to the target audience. The information or product must be relevant and practical.

Be sure to address the following:

- o A description of who will use the findings, technologies, or information;
- o How the findings, technologies, or information will be transmitted to the stakeholders;
- o Stakeholder involvement in the development of the marketing plan.

3. Detailed Personnel Plan

- **Name and Degrees.** Starting with the project officer, list the names and degrees of all employees who are involved with the project during the budget period.

- **Role on Project.** Identify the role of each individual listed on the project. Describe their specific functions.

- **Percent of Effort on Project.** For each FTE position, list the percent effort to be spent on this project.

4. Detailed Budget Plan

- **Complete the Excel form *ProjectBudget.xls* as follows:** New and existing funding should be broken out separately. On a separate page, provide detailed justification for all projected expenditures.

- **Personnel Salaries and Benefits** include onboard PS&B costs under contribution from current allocation.

  Use actual PS&B to project costs for each employee.

  Use 5% when projecting cost of living increases in out year projections.

- **Travel.** Itemize travel requests. Provide the purpose and destination of each trip and the number of individuals for whom funds are requested.

- **Contractual.** Enter estimate of contractual costs, excluding Research and Development Contracts (R&D Contracts), R&D Contractual information should be entered in the Extramural section of this form.

- **Supplies.** Estimate overall cost of supplies.

- **Other.** Itemize any other expenses by category and unit cost. These might include, patient travel, donor fees, publication costs, computer charges, rentals and leases, equipment maintenance, and service contracts. Justify costs on the next page where necessary.

- **Cooperative Agreement.** Provide cost.

- **Research and Development Contract.** Provide Cost

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Hints for Writing Project Proposals

Specific

The two page description at the beginning of the proposal should summarize the proposal so that a reviewer knows what to expect when reading the rest of it. It also should be helpful for any others who may not be reviewers, but need to understand and approve the general concept of the proposed research. This summary should not include information not explained in greater detail later in the proposal.

The heart of the project proposal is the first four sections of the research plan. These sections are: a) Specific Aims; b) Background and Significance; c) Preliminary Studies/Progress Report; d) Research Design and Methods

Some suggested lengths for these sections in single spaced pages are listed below. These lengths are very approximate, and should be modified depending on the expected audience of reviewers.

Specific aims – ½ page
Background and significance – 2 to 3 pages
Preliminary studies/progress report – 1 to 3 pages
Research design and methods – 5 to 10 pages

The specific aims should identify the research questions to be answered by the proposed research. Use hypotheses to be proven if these are non-trivial and it helps to clarify the aims. The specific aims are more detailed than the general objective of the project, and address research questions, not project outputs. These aims should not be preparation of outputs such as papers, reports, prototypes, etc.

The background and significance section should be detailed enough to convince a reviewer that the research addresses a significant problem. It should briefly explain the overall occupational health and safety problem, e.g. coal workers pneumoconiosis, miners hearing loss. It should more extensively discuss why this particular project is needed and the research questions to be resolved. It is important to clarify why this particular project is needed, as opposed to all the other possible projects that might be proposed to address the same overall health and safety problem. For example, it is not sufficient to explain that roof falls are a problem in mining. The proposal should also justify why the proposed approach to preventing roof falls is new and more promising than other possible approaches to the same problem. The relevant literature should be discussed to show what is already known about the technical problem, and the knowledge gap which still exists that can be filled by the proposed research. The background and significance section will be more important for competitive proposals written for NIOSH-wide solicitations like NORA. These proposals compete against other proposals in different problem and technical areas. The background section then must be more convincing as to why this particular mining health and safety problem is important. Proposals written for the Laboratory base program have already been determined by the Laboratory lead team to address a significant health and safety problem. They will be sent to external reviewers who are expert in the field and will usually know the significance of the problem.

The preliminary studies section should discuss work already done in this area by the authors. If this is a follow-up to another project which is ending, explain what was accomplished in the preceding project, and the research questions which remain to be answered by this proposed project. If this is an entirely new project for the authors, explain the preliminary work done before or during preparation of the proposal. Explain highlights found in the technical literature and discussions with others working in this field. Reviewers should believe that you have already done an extensive search of the relevant literature and contacted persons important for the success of the research before you submitted the proposal. Explain any contacts made such as with mines or other field sites and the degree to which others have agreed to help with the research. Do not make a literature search and initial contacts with key people part of your research project tasks. Most of this work should already have been done before the proposal was submitted.

The research design and methods section is the most important part and should be the most detailed section of any research proposal. This is the section of the proposals that the reviewers are expected

to read the most carefully and to comment on most extensively. This section should explain what you expect to do to answer the questions posed in your specific aims section. Normally this section will be broken into a number of tasks to be performed. Each task should be described and the sequence and duration of the tasks clarified in a table or Gantt chart. The design of experiments and statistical analysis to be used should be described. If necessary, seek the help of the staff of the Mining Program Division Surveillance & Research Support personnel for this part of the proposal. This section should also describe the research methods to be used. This should be in sufficient detail to convince a reviewer that you actually know how to do this research, and will not have to learn as you go along. On the other hand do not include any standard operating procedures, but mention that they are available and will be used when needed.

The summary material at the end of the proposal is for use in IRIS and for NIOSH R2P planning. Such sections may be copied from other parts of the proposal, if appropriate.

General

Use the spell check and grammar check features of the word processor. Don’t count on your supervisor or other internal reviewers to catch errors. Spelling errors can cause reviewers to assume that the author does not do careful work.

Take advantage of any opportunities to become involved with the NIOSH grant process or to be part of a contract RFP technical evaluation committee. It can be very revealing to see the effort that usually goes into the preparation of proposals for competitively funded government research.

PROJECT BUDGET ESTIMATE

DIVISION/LAB: ***PROJECT ID*** *DIV/LAB NXXX*

PROJECT TITLE:

PROJECT COST	***FY2006***	***FY2007***	***FY2008***	***FY2009***	***FY2010***	***TOTAL PROJECT***
CONTRIBUTION FROM CURRENT ALLOCATION:						
PERSONNEL SALARIES AND BENEFITS						
TRAVEL						
CONTRACTUAL (administrative, excluding R&D Contracts)						
SUPPLIES						
OTHER (ITEMIZE)						
INTRAMURAL SUBTOTAL						
CO-OPERATIVE AGREEMENT						
GRANT						
R&D CONTRACTS						
EXTRAMURAL SUBTOTAL						
TOTAL CONTRIBUTION FROM CURRENT ALLOC.						
NEW FUNDING REQUESTED:						
PERSONNEL SALARIES AND BENEFITS						
TRAVEL						
CONTRACTUAL (administrative, excluding R &D Contracts)						
SUPPLIES						
OTHER (ITEMIZE)						
INTRAMURAL SUBTOTAL						
CO-OPERATIVE AGREEMENT						
GRANT						
R&D CONTRACTS						
EXTRAMURAL SUBTOTAL						
TOTAL NEW FUNDING						
TOTAL INTRAMURAL PROJECT COST						
TOTAL EXTRAMURAL PROJECT COST						
GRAND TOTAL PROJECT COST						

Note: On separate page, provide detailed justification for all projected expenditures.

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DEVELOPING A PROTOCOL

Quality of science is often improved when study objectives and methods are clearly thought through and described. A written protocol facilitates high quality science and is an invaluable tool to investigators as they develop and conduct studies.

Regardless of the scientific discipline in which the study is undertaken, the same scientific method is used. Further, while the scientific content will differ across studies, the general elements of the study protocol will be similar.

The Excellence in Science committee has developed a general protocol checklist and companion guide to assist scientists in preparing protocols. The checklist is intended as an aid in suggesting a format for writing protocols and in identifying issues that scientists should consider as they design the study.

With many scientific disciplines represented by CDC scientists, the checklist was developed to have utility in conducting laboratory and basic science studies, epidemiologic studies, and behavioral and social science studies employing a variety of study designs. In using the checklist, investigators should select the items that apply to their types of studies. It is unlikely that any protocol would include every item on the checklist.

A number of studies are conducted at CDC that are not classified as research or do not involve humans as participants. To make the checklist applicable to the widest range of studies, the general protocol checklist does not contain requisite protocol items for review by an institutional review board. A separate addendum checklist for Protection of Human Research Participants is available.

GENERAL PROTOCOL CHECKLIST

This checklist is intended as an aid in suggesting a format for writing protocols and in identifying issues that scientists should consider as they design a study or surveillance system. When using the checklist, investigators should select the items that apply to their specific project. It is not expected that every item on the checklist is applicable to each protocol for a study or surveillance system.

Section	Item	☑
PROJECT OVERVIEW	Title	
	Protocol summary	
	Investigators/collaborators/funding sources	
INTRODUCTION	Literature review/current state of knowledge about project topic	
	Justification for study	
	Intended/potential use of study findings	
	Study design/locations	
	Objectives	
	Hypotheses or questions	
	General approach	
PROCEDURES/ METHODS DESIGN	How study design or surveillance system addresses hypotheses and meets objectives	
	Audience and stakeholder participation	
	Cost benefit/prevention effectiveness	
	Study time line	
	Expedited protocol review request	
PROCEDURES/ METHODS **STUDY POPULATION**	Description and source of study population and catchment area	
	Case definitions	
	Participant inclusion criteria	
	Participant exclusion criteria	
	Justification of exclusion of any sub-segment of the population	
	Estimated number of participants	
	Sampling, including sample size and statistical power	
	Enrollment	

Section	Item	☑
PROCEDURES/METHODS VARIABLES/INTERVENTIONS	Variables	
	Study instruments, including questionnaires, laboratory instruments and analytic tests	
	FDA Investigative New Devices (IND) information	
	Intervention or treatment	
	Outcomes and minimum meaningful differences	
	Training for all study personnel	
PROCEDURES/METHODS DATA HANDLING AND ANALYSIS	Data analysis plan, including statistical methodology and planned tables and figures	
	Data collection	
	Information management and analysis software	
	Data entry, editing and management, including handling data collection forms, different versions of data and data storage and disposition	
	Quality control/assurance	
	Handling results in the absence of a reference test	
	Measurement/estimation and adjustment for cross reactivity	
	Verifying independence of tests used to confirm results of new test being studied	
	Bias in data collection, measurement and analysis	
	Intermediate reviews and analyses	
	Limitations of study	
PROCEDURES/METHODS HANDLING OF UNEXPECTED OR ADVERSE EVENTS	Response to new or unexpected findings and to changes in the study environment	
	Identifying, managing and reporting adverse events	
	Emergency care	
PROCEDURES/METHODS DISSEMINATION, NOTIFICATION, AND REPORTING OF RESULTS	Notifying participants of their individual results	
	Notifying participants of study findings	
	Anticipated products or inventions resulting from the study and their use	
	Disseminating results to public	

Section	Item	☑
REFERENCES		
APPENDIX MATERIALS	Data collection forms	
	Proposed tables and figures	
	Other relevant documents	

GUIDE FOR GENERAL PROTOCOL CHECKLIST

PROJECT OVERVIEW

Title: Summarize the main idea under investigation. The title should be able to stand alone as an explanation of the study.

Protocol summary: Give a concise overview of the project. Describe the purpose of the study, including problem to be investigated and hypothesis(es) to be tested, the population, and the methods that will be used. Avoid the use of acronyms. Include the expected benefit of the study.

Investigators/collaborators/funding sources: Include the names and degrees of all investigators and their roles in the project. Note any conflict of interest for each investigator and acknowledge all funding sources.

INTRODUCTION

Literature review/current state of knowledge about project topic: Discuss relevant information about the subject of the project based on a review of the literature. In the Reference section, attach a bibliography of the sources used.

Justification for study: Explain the public health and scientific importance of the study. In the context of previous studies, describe the contribution this study will make.

Intended/potential use of study findings: Define the primary target audiences and discuss the expected applicability of study findings.

Study design/locations: Describe the study design and the locations where the study will be conducted.

Objectives: Clearly and concisely list the objectives that the project will address.

Hypotheses or questions: List the clear and focused question(s) that the study will answer. State the type of hypothesis(es) that will be explored or tested.

General approach: Describe whether the approach used will be descriptive, exploratory (hypothesis-generating), confirmatory (hypothesis testing), or developmental (focused on corrective action).

PROCEDURES/METHODS

DESIGN

How study design or surveillance system addresses hypotheses and meets objectives: Explain the appropriateness of the study design to the project and to the questions and objectives previously outlined. Distinguish between procedures that are experimental and those that involve routine care. Identify specific design attributes that characterize the study design (e.g., cross-sectional survey, case/control, cohort, focus group, chart review, etc.) or surveillance system (e.g., description of the system as active or passive, defining reported cases as individual versus aggregate and as laboratory confirmed or not).

Audience and stakeholder participation: Define the primary audiences for the project. Assess the major stakeholders and describe ways they can (and cannot) participate in the study. Explain the process by which those affected by the study can express their views, clarify their needs, and contribute to the project.

Cost benefit/prevention effectiveness: Describe how these measures will be addressed.

Study time line: Provide a calendar with estimated dates for implementing and completing key activities.

Expedited protocol review: If appropriate, describe the need for an expedited review of the protocol (e.g., because it is for an ongoing outbreak or emergency disaster).

STUDY POPULATION

***Description and source of study population and catchment area*:** Demographically and in terms of the specific public health conditions to be studied, define the population from which the participants, sample or surveillance subjects will be drawn and to what population inferences will be made.

Case definitions: Provide descriptions of illness, condition or health event which defines a study participant as having that condition.

Participant inclusion criteria: Describe conditions or characteristics applicable to the identification and selection of participants in the study and the conditions necessary for eligible persons to be included.

Participant exclusion criteria: Describe characteristics that would disqualify otherwise eligible participants from the project.

Justification of exclusion of any sub-segment of the population: If a sub-population as defined by gender, race/ethnicity, or age is excluded, provide reasons. In accordance with CDC's policy for inclusion of women and minorities in research, state how these populations are included in the sponsoring CIO's overall program of research if excluded in this particular study.

Estimated number of participants: State the estimated number of participants for the study. For a project establishing or using data from a surveillance system, this may include the expected number of reported cases per reporting period for epidemic and non-epidemic periods.

Sampling, including sample size and statistical power: Describe the sample (e.g., the sample will be one of convenience, a population-based representation or systematically chosen for some other purpose). State the sampling units and units of analysis. Estimate required sample sizes to answer questions and test statistical hypotheses (based on available information from pilot studies or previous reports). Include statistical power estimates. Explain the conditions under which sampling estimates would be revised. If group-level or aggregate information will be collected (e.g., from focus groups), explain how the groups will be comprised, or what procedures will be followed to create appropriate groups.

Enrollment: Describe the manner in which potential participants will be contacted, screened, and registered in the study. Describe procedures for tracking the number of persons who withdraw from the study. Explain the procedures for assigning participants to different groups.

VARIABLES/INTERVENTIONS

Variables: List and briefly describe the categories, topics, or domains of information to be explored and variables to be collected. Address consistency of definition of variables for data collected from multiple sources. Traditionally, for outbreak investigations, “time”, “place” and “person” would be collected to construct the epidemiologic curve. Explain how the variables will be utilized and the process by which variables will be defined.

Study instruments, including questionnaires, laboratory instruments, and analytic tests: Describe strategies to elicit information, including specific techniques and study and laboratory instruments, and explain how they will be used. Describe the attributes of those strategies/ instruments as demonstrated in other studies, including appropriateness, validity and reliability within the particular study populations, sensitivity and specificity of instruments, and how well they yield reproducible results.

FDA Investigative New Device (IND) information: If the study involves the use of an investigational new drug or investigation new device, provide IND number.

Intervention or treatment: Describe the types of interventions or treatments that will be tested in detail, including dosing, schedules of administration, etc.

Outcomes and minimum meaningful differences: List the possible results of exposure or intervention of interest in the study (i.e., the outcomes) and what clinical or epidemiologic differences in measurement of the outcomes are important to detect.

Training for all study personnel: Describe training, such as interviewer techniques, data collection and handling methods or informed consent, provided to study personnel.

DATA HANDLING AND ANALYSIS

Data analysis plan, including statistical methodology and planned tables and figures: Describe the sampling methods, information collection procedures, methods to maximize response rates, test procedures and relevant statistical quantities (e.g., variance, confidence intervals and power based on data from the study) in sufficient detail that the methods are reproducible. This includes calculation of relevant quantitative measures for tests and instruments, such as sensitivity and specificity. In outbreak investigations, it is common to employ an iterative process in the analysis (consisting of developing and testing hypotheses and planning and evaluating interventions) to identify the source of the outbreak and control it. For projects establishing or utilizing data from a surveillance system, this could include how and how often the surveillance system will be evaluated. Describe what tables and figures are planned to present study results.

Data collection: Describe data collection procedures, processes and documentation. For data emanating from a surveillance system, this would include frequency of reports.

Information management and analysis software: Provide the names of data entry, management and analysis software packages and computer programming languages to be used for the project.

Data entry, editing and management, include handling of data collection forms, different versions of data, and data storage and disposition: Describe the overall procedures for management the data collected. Include in the description the process for entering and editing data. Describe how study materials, including questionnaires, statistical analyses, unique reagents, annotated notebooks, computer programs and other computerized information, whether used for publication or not, will be maintained to allow ready, future access for analysis and review. Document operating procedures for managing and accessing different versions of data sets. State who the data belong to and any rights to and limitations to access for any primary and secondary data analyses and publications. Document procedures regarding confidentiality of the data, including how confidentiality will be preserved during transmission, use and storage of the data and the names of persons or positions responsible for technical and administrative stewardship responsibilities. Document what the final disposition of records, data, computer files, and specimens will be, including location for any relevant information to be stored. Records must be stored in compliance with CIO or Agency guidelines.

Quality control/assurance: Describe the steps that will ensure no unintended consequences that could affect the quality of the data. Those steps might include methods to capture all reported data exactly as received, assuring logical consistency among all parts of a record and ensuring that manipulation or transformation of the data (e.g from audio tape to transcribed text) produces no unintended changes. For outbreak investigations, this would include verifying diagnosis and confirming the outbreak. Describe procedures for ongoing data quality monitoring to assure that

information of appropriate depth, breadth, and specificity is collected and remains consistent within and among staff over time, and acceptable levels of such attributes as validity, reliability, reproducibility, sensitivity and specificity are achieved.

Handling results in the absence of a reference test: Describe how tests will be used and results interpreted in the absence of a referent test and/or consensus of multiple test results. Include how sensitivity and specificity are affected.

Measurement/estimation and adjustment for cross reactivity: Describe how cross reactivity will be measured, its potential effects on test results and how it will be accounted/adjusted for in the analysis.

Verifying independence of tests used to confirm results of new test being studied: Describe process to validate results and use of new test, including verification of independence of tests or adjustments made for non-independence.

Bias in data collection, measurement and analysis: Describe the kinds of bias that may occur in collecting the data or in the measurement or analysis phases, and the steps that will be taken to avoid, minimize and compensate for the bias. Include factors in the study population or in study personnel that could bias results, as well as the steps that will be taken to assure valid self-reporting or recording of observations. Include any randomization and blinding procedures that will be used to eliminate/minimize bias by investigators, other study staff or participants (e.g., in selection of participants, allocation to treatment groups, providing/receiving treatment).

Intermediate reviews and analyses: Describe the ways that progress will be tracked and the study will be evaluated prior to assessing final results.

Limitations of study: Explain factors that might reduce the applicability of study results.

HANDLING OF UNEXPECTED OR ADVERSE EVENTS

Response to new or unexpected findings and to changes in the study environment: Describe procedures for identifying and handling new or unexpected findings, and responding to changes in the study environment.

Identifying, managing, and reporting adverse events: Describe the types of adverse events that might be encountered and how study personnel will be trained to react. Describe methods that will be used to track adverse reactions and their potential impact on the study.

Emergency care: Explain the actions that would be taken in the event that an emergency develops during a study participant's involvement in the research.

DISSEMINATION, NOTIFICATION, AND REPORTING OF RESULTS

Notifying participants of their individual results: Describe the process used to notify

study participants of their results, including those of immediate importance. Include precipitating circumstances and whether or not counselors will be used.

Notifying participants of study findings: Explain whether the participant will be offered the option of receiving overall study findings and the form they will take.

Anticipated products or inventions resulting from the study and their use: List any products, including inventions, derived from the study, and how those will be used.

Disseminating results to public: Define effective communication channels and best formats for presenting information that will be used to disseminate project results to specific target audiences.

REFERENCES

List bibliographic references used to create and delimit all aspects of the study.

APPENDIX MATERIALS

Data collection forms: Include any forms or documents used to collect data or from which data are abstracted. Examples of these are questionnaires, medical records and other abstraction forms.

Tables and figures: Provide table shells and examples of figures for presentation of data and study results.

Other relevant documents: Include any other relevant supplementary materials.

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NIOSH Mining Program Briefing Book

Improving mine safety and health through research and education.

Appendix B - Project Evaluation

Approval Process for NIOSH Mining Presentations and Publications 937

Publications Processes Flowcharts

Conference Papers and Non-Peer Reviewed Publications 945

ICs and RIs 949

Novelty Items (Stickers, Bookmarkers, etc.) 953

Pamphlets and Flyers 955

Peer-Reviewed Publications 959

Software and Multimedia 963

Technology News 967

Video Products 971

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Approval Process for NIOSH Mining Presentations and Publications

The reputation and impact of the NIOSH Mining Program is largely determined by the timeliness, accuracy, and quality of the presentations and publications it produces and the venues in which these products are received. The purpose of this approval process is to ensure that NIOSH Mining publications and presentations contain accurate data, are of high quality and are presented and/or published in appropriate venues.

Obtaining Approval to Prepare

Authors must obtain permission to prepare any publication before work is initiated or an abstract submitted to any venue. To request permission to prepare, the author completes an electronic "Approval to Prepare" form. The author electronically forwards the form to his/her office automation assistant. The office automation assistant enters the request in the Research and Administrative database. The office automation assistant enters the database record number on the Approval to Prepare form and electronically forwards it to the section chief. The section chief approves the request and electronically forwards it to the program operations assistant (POA)/secretary. The POA/secretary electronically forwards the request to the branch chief. The branch chief approves the request and forwards it to Cindy Driscoll (PRL) or Nadine Hawley (SRL) and the POA/secretary. Once the OD approval is received, the author can submit an abstract to the conference or publisher for consideration, or begin writing the manuscript.

Non-Peer Reviewed Journal Articles, Conference Papers, RI's, and IC's

1. **Obtain approval to prepare** (as previously described).
2. **Author(s) writes the manuscript.**
3. **Author, in consultation with the Section Chief determines the number and type of reviewers.** At the very minimum, there must be one internal reviewer (PRL or SRL) and two external reviewers (external to PRL/SRL). If there might be an impact on current or proposed MSHA regulations, at least one reviewer must be from MSHA. In addition, appropriate NIOSH reviewers should be included if there is a possible impact on other NIOSH research projects within and outside PRL/SRL.
4. **The Section Chief shall review the paper to ensure that it is written clearly, and contains no technical errors.**
5. **The Branch/Activity Chief reviews the manuscript for agency policy issues and the appropriateness of the proposed reviewers.**
6. **Manuscript is sent out for review** using NIOSH Manuscript Review Form.
7. **Author reconciles reviewer comments** and writes letters to reviewers addressing their comments and thanking them for their input. The author prepares the *Final Manuscript Package* (Publication/Presentation Clearance Form CDC 0.576, the manuscript as sent for review, the review form(s) with comments, author replies to reviewer comments, and the final manuscript) and submits the package to the Section Chief for approval.
8. **The Section Chief reviews the *Final Manuscript Package* to ensure that all reviewer comments have been addressed.**
9. **The Branch/Activity Chief reviews the *Final Manuscript Package***, and forwards it to the Lab Director or designee for approval.
10. Upon Lab Director's approval, **the Author submits the manuscript** to the conference or non-peer reviewed journal for publication, or for IC's and RI's to Production and Distribution along with an account number for printing.
11. It is the responsibility of the principal author to obtain a copy of the final published version of his/her paper and forward it to the PRL/SRL Technical Editor and Lab Director along with the title page of the journal or proceedings, page numbers, and other necessary bibliographic information. A copy of the paper should also be forwarded to the Production and Distribution Center for conversion into pdf format and inclusion in NIOSHTIC-2. This procedure also applies to papers and articles published electronically or available on CD-ROM.

Peer-Reviewed Journal Article

1. **Obtain approval to prepare** (as previously described).
2. **Author(s) writes the manuscript.**
3. **Author prepares the *Manuscript for Approval Package*** (Publication/Presentation Clearance Form CDC 0.576 and the manuscript).
4. **The Section Chief determines if reviewers are needed**, and if so, identifies them. It is important to determine if reviews are needed at this stage of the approval process to avoid delay if reviews are determined to be needed at the Lab Director review step. Examples where reviews may be needed include: If the content is expected to have an impact on current or proposed MSHA regulations, MSHA must review the manuscript. In addition, appropriate NIOSH reviewers should be included if there is a possible impact on other NIOSH research projects within and outside of PRL/SRL. If the content contains a mathematical or statistical analysis, appropriate reviewers should be included.
5. **The Section Chief shall review the paper to assure that it is written clearly and contains no technical errors.**
6. **The Branch/Activity Chief reviews the manuscript for agency policy issues and appropriateness of reviewers**, if any. [If reviews are needed, the manuscript is sent for review. Reviews are returned to the author, who reconciles reviewer comments and writes letters to reviewers addressing their comments and thanking them for their input. The Section Chief reviews the revised manuscript, the review form(s) with comments, and author replies to reviewer comments, and ensures that all reviewer comments have been addressed. The Section Chief submits the package to the Branch/Activity Chief for approval]
7. **The Branch/Activity Chief forwards the manuscript** [if manuscript was sent for review, review form(s) with comments and Author replies to reviewer comments are included] **to the Lab Director or designee for approval.** Lab Director may send manuscript for review if it was not done in step 4 when needed, or if reviews are inadequate.
8. Upon obtaining the Lab Director's approval, **the Author submits the manuscript to the Journal**.
9. Journal reviews are returned to the Author, who reconciles reviewer comments.
10. **The Section Chief reviews changes made to the manuscript.**
11. **The Branch/Activity Chief reviews changes made to the manuscript.**
12. **Author submits the manuscript to the journal for publication.**
13. It is the responsibility of the principal author to obtain a copy of the final published version of his/her paper and forward it to the PRL/SRL Technical Editor and Lab Director along with the title page of the journal or proceedings, page numbers, and other necessary bibliographic information. A copy of the paper should also be forwarded to the Production and Distribution Center for conversion into pdf format and inclusion in NIOSHTIC-2. This procedure also applies to papers and articles published electronically or available on CD-ROM.

Technology News

1. **Obtain approval to prepare** (as previously described).
2. **Author writes the Technology News**.
3. **Author prepares the Technology News package** (Publication/Presentation Clearance form CDC 0.576, the manuscript, original figures, and an electronic version). An account number must be included for printing charges.
4. **The Section Chief shall review the Technology News to ensure that it is written clearly, and contains no technical errors.** The Section Chief determines if the content is expected to have an impact on MSHA, if so, MSHA reviewer(s) are identified. In addition, appropriate NIOSH reviewers should be included if there is a possible impact on other NIOSH research projects within and outside of PRL/SRL.
5. **The Branch/Activity Chief reviews the Technology News for agency policy issues and appropriateness of MSHA and NIOSH reviewers**, if any. [If reviews are needed, the manuscript is sent for review upon approval by the Branch/Activity Chief. Reviews are returned to the author, who reconciles reviewer comments and writes letters to reviewers addressing their comments and thanking them for their input. The Section Chief verifies that all reviewer comments have been addressed.]
6. **The Branch/Activity Chief forwards the Technology News to the Lab Director** or designee for approval.
7. Upon obtaining the Lab Director's approval, **Technology News is forwarded to Production and Distribution.**

Note: At some point prior to printing, the Tech News must undergo editorial review. After printing, the Technology News is distributed according to a master mailing list maintained in Pittsburgh.

Previously Approved Manuscript for Publication

1. **Author discusses intentions to publish with the Section Chief**, and submits a request for publication to the Section Chief via e-mail "Approval to Prepare" form. Author provides the Section Chief with a copy of the previously approved paper, its signed approval form, where the paper was previously presented and/or published, and a copy of the proposed paper and information about where it is to be published. **The Section Chief shall review the manuscript to ensure that it is written clearly, contains no technical errors, contains no new information, and to determine the appropriateness of it being republished** (see note below).

2. **The Branch/Activity Chief reviews the package** (proposed paper, information about where the proposed paper is to be published, the previously approved paper with its signed approval form and where the paper was previously presented and/or published).

3. **The request is then transmitted via e-mail to the Lab Director** or designee for approval.

4. Upon Lab Director's approval, **the Author can then commit to the publication** and it can be forwarded in the designated format to the conference or journal.

5. For previously approved manuscripts for publication, it is the responsibility of the principal author to obtain a copy of the final published version of his/her paper and forward it to the PRL/SRL Technical Editor along with the title page of the journal or proceedings, page numbers, and other necessary bibliographic information. This procedure also applies to papers published electronically or available on CD-ROM.

Note: Manuscripts previously published in refereed (peer-reviewed) journals should **NOT** be published a second time. If a manuscript has been previously approved for publication in a non-refereed journal or conference proceedings, it can be presented or published again in any forum following approval. However, only minor revisions can be made to the original manuscript. If a paper was previously approved for presentation **ONLY**, and the author plans to publish it, the paper must be treated as a new manuscript and follow the appropriate review procedures for a new manuscript.

Other Publications

There are other types of publications that are rarely used by PRL/SRL. These include Internal Reports, Criteria Documents, and Mining Health and Safety Updates. Contact the POA/secretary for more information as these needs arise.

Power Point Presentations

Background: Power Point (PP) has become the standard media for public presentation of the NIOSH Mining Program's research results. Presentations are easy to create and easier to distribute. PRL/SRL personnel often receive requests for copies of their presentations, which of course, can be easily e-mailed anywhere in the world and can be distributed by others. There are risks in sharing these presentations. One such risk is that portions of a given slide or presentation could be taken out of context or modified by others to change conclusions. Another risk is that when certain items, such as Excel charts, are imported into a PP slide, the entire underlying spreadsheet which may contain data not intended for release, is included in the PP presentation.

CDC has issued guidance concerning the availability of presentations that are attached in Appendix A. One of the most significant items in these guidelines is the warning that "CDC employees need to be aware that their materials are accessible to the public once they are presented in an open meeting in accordance with CDC Media Relations Guidelines and the Freedom of Information Act." This makes giving a presentation equal to publishing a paper in many ways. That is, the information is readily available and accessible by all, just like a publication in a trade journal. In the past, presentations, while important, were treated more as temporary media not having the permanence of a publication. This has now changed and presentations have a new permanence.

This approval process and guidelines serve to ensure that presentations are of high quality, contain accurate and reviewed data, that data is protected, and that unintentional consequences that can be associated with PP presentation distribution can be avoided.

Approval Process Steps:

1. The researcher discusses intent to present with their section chief. Included in the discussion are topic, location, audience, date, and costs. If the section chief agrees that the presentation is appropriate given the stage (progress) of the research, the audience, and that the project has funds, proceed to step 2.

2. **For a conference or formal meeting**, the researcher prepares an electronic "Approval to Prepare/Present" form along with an abstract and sends them through the Section Chief, to the Branch Chief for approval. Upon Branch Chief approval, the electronic "Approval to Prepare/Present" form along with an abstract are sent to the OD for approval. Upon OD approval, the Branch is notified to proceed with the presentation. The OD will let the Branch know at that time if they would like to see a dry-run of the presentation after it is prepared.

   For informal meetings (any meeting that includes non-PRL/SRL attendees), the Section Chief discusses the proposed presentation with the Branch Chief. If the subject matter is sensitive, or if data has not had peer-review, or if significant costs are involved, the Branch Chief discusses the proposed presentation with the OD. If the OD agrees with the presentation, the Branch is notified to proceed. The OD will let the Branch know at that time if they would like to see a dry-run of the presentation after it is prepared.

3. The researcher prepares the power point presentation.

4. The section chief shall review the presentation for technical accuracy, clarity and compliance with the following PP presentation guidelines, and verify that it doesn't contain any unreviewed or unapproved data or findings.

Guidelines Include:

- To prevent someone from easily modifying data (charts and tables) and to insure that hidden spreadsheets are not contained in a PP presentation, such data slides should contain only "objects", rather than charts or text. One technique to achieve this is to cut each chart, text box or graphic and "paste special" as a "picture". A second technique is to save the presentation in .jpg format. This creates a directory with a .jpg image for each slide in the presentation. Then open a new presentation and insert each .jpg image on a blank slide, creating a new presentation where each slide is an object that can't be modified and has no links to other data.
- The title slide should contain the NIOSH and CDC logos for presentations. The NIOSH and CDC logos should be contained in all slides that are distributed.
- The title slide would cite the published information and/or the forum where presented and a list of all co-investigators.
- CDC guidance – See Appendix A

5. The Branch/Activity Chief reviews the presentation for agency policy issues.

6. The OD reviews presentation if a review was requested during the approval process, or if the Branch requests the OD review. OD may also have others review the presentation.

7. Once all approvals have been given, the researcher gives the presentation.

Presentations can only be distributed to non-NIOSH persons as hard copies. Distribution of electronic versions of PP presentations to non-NIOSH personnel is <u>forbidden</u> without approval of the OD.

Appendix A:
ADDITIONAL GUIDANCE - POLICY ON SLIDES PRESENTED AT OPEN MEETINGS

When planning presentations, CDC employees need to be aware that their materials are accessible to the public once they are presented in an open meeting in accordance with CDC Media Relations Guidelines and the Freedom of Information Act.

Specific Considerations:

Presentation slides become public information at the time they are projected. This means that if anyone, including news media*, requests a copy of the slides, they must be made available as soon as possible.

When preparing presentations, it is important to consider the following:

Preliminary data should be identified as preliminary if further analyses are planned.

Personal identifying information should not be divulged unless permission is obtained from the individuals.

Proprietary information should not be used without permission.

Employees assigned to other organizations (e.g., state health departments) should ensure they get their supervisor's permission to present data that belongs to the non-CDC entity.

Information that might compromise any criminal investigation, CDC security or national security should not be projected. Often, it is necessary to clear certain information with other government agencies such as the FBI and the National Security Agency.

If the presenter anticipates seeking a patent of an invention, the patent application should be filed in the Patent and Trademark Office before the presentation is given.

While media access to slides has the potential for compromising the ability to publish the material later in a scientific journal, we are not aware of that happening and most journals will accept articles whose content has been previously presented at a scientific meeting if there have been no formal press releases or media briefings held. Remember the reporter has most likely already heard the oral presentation and taken notes on the slides and is checking for accuracy.

In any event, as federal employees, it is our obligation to disseminate high quality scientific information in a timely way to benefit public health regardless of its consequences for personal benefit.

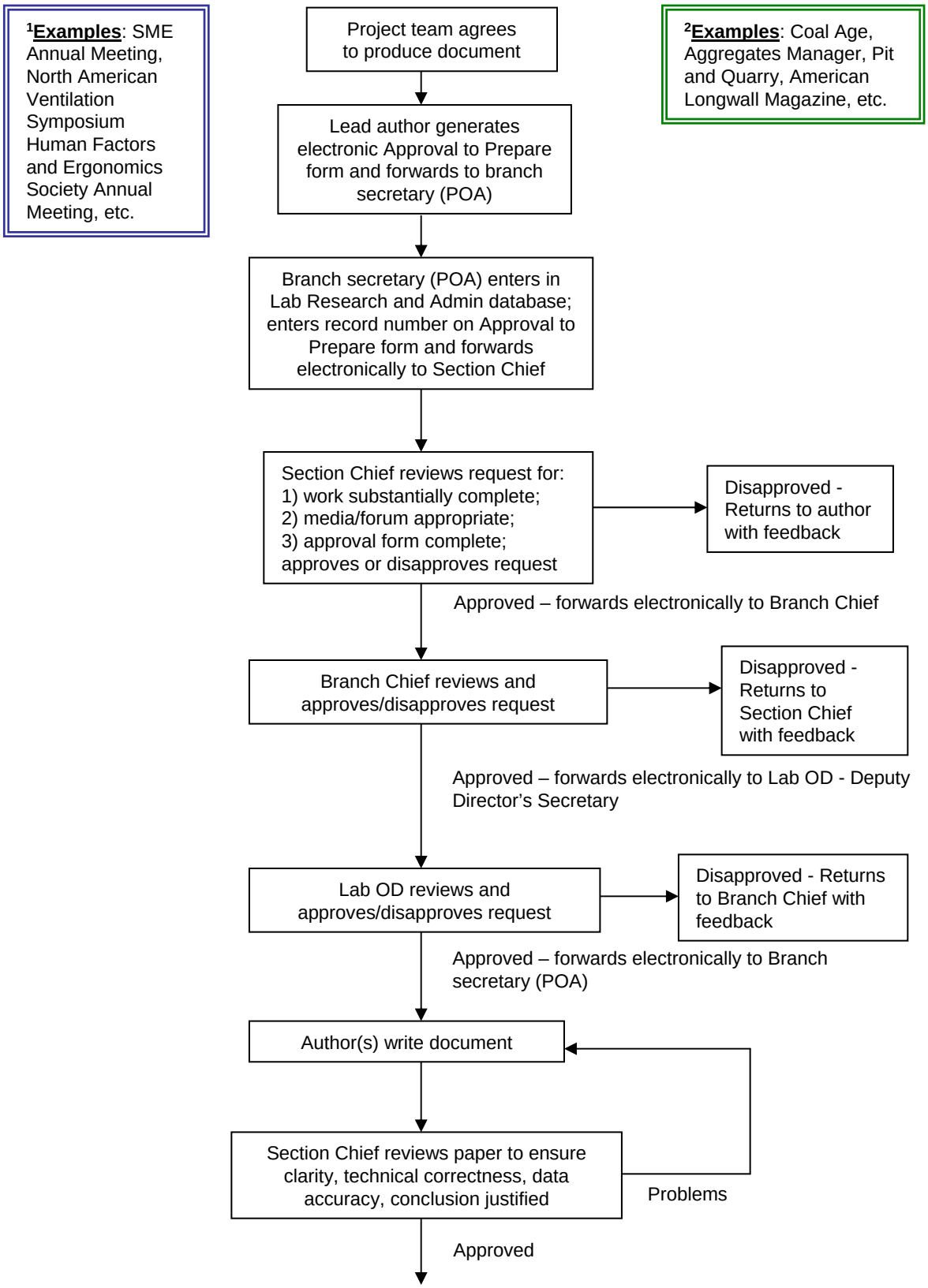
*In the case of news media, the Division of Media Relations can help negotiate with reporters if there is sensitive information that one does not want to see in the press. However, if the news media insist, the slides must be made available. Therefore, it is best not to project anything that is not ready for the press.

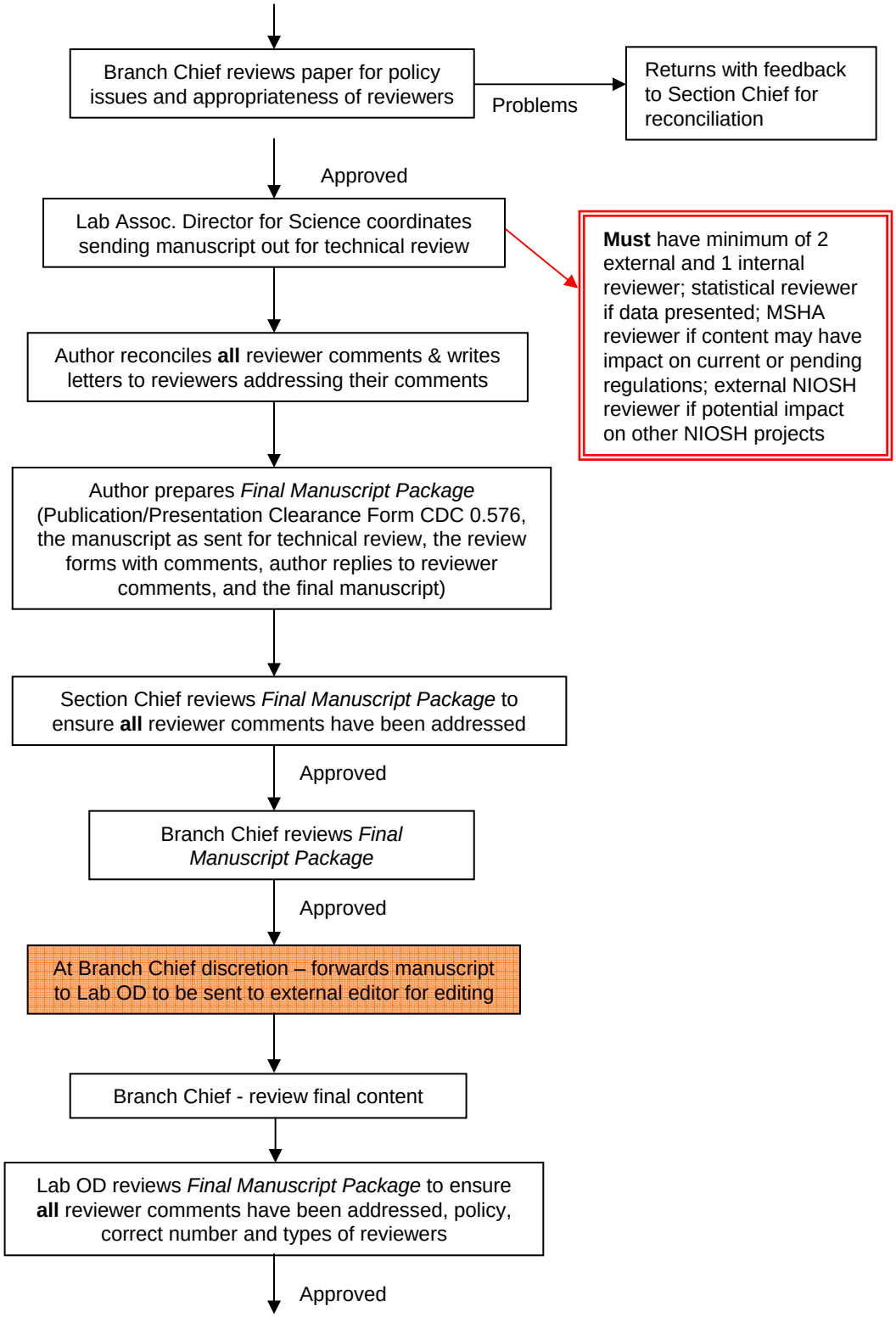
References:

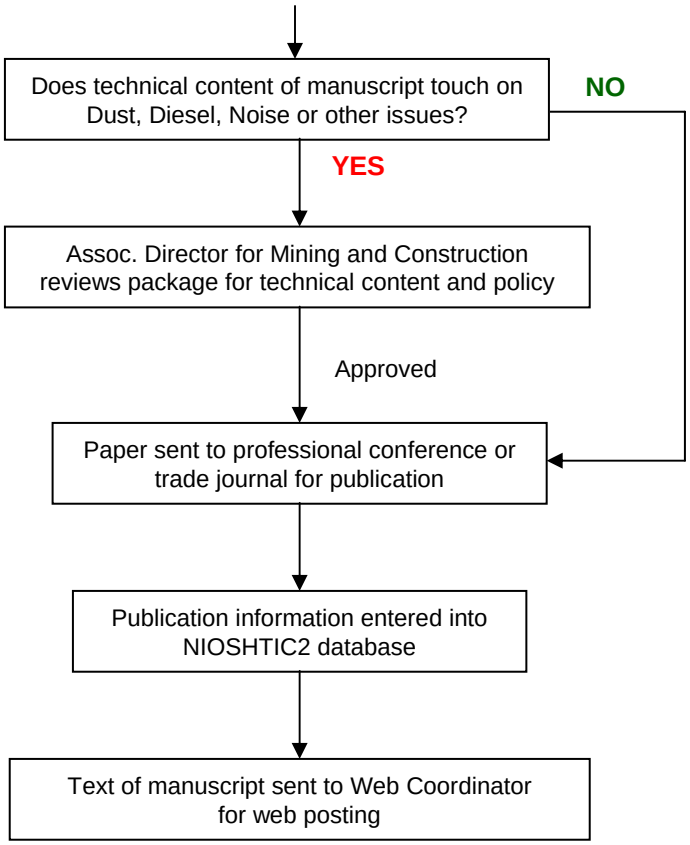
A. CDC Division of Media Relations
B. CDC Freedom of Information Act Policy

For further information contact: Ms. Cathy Spruill at (404) 639-7260 or Dr. Dixie Snider at (404) 639-7240.

Conference Papers[1] and Non-peer Reviewed Publications[2]




Branch Chief reviews paper for policy issues and appropriateness of reviewers
Problems
Returns with feedback to Section Chief for reconciliation
Approved
Lab Assoc. Director for Science coordinates sending manuscript out for technical review
Must have minimum of 2 external and 1 internal reviewer; statistical reviewer if data presented; MSHA reviewer if content may have impact on current or pending regulations; external NIOSH reviewer if potential impact on other NIOSH projects
Author reconciles **all** reviewer comments & writes letters to reviewers addressing their comments
Author prepares *Final Manuscript Package* (Publication/Presentation Clearance Form CDC 0.576, the manuscript as sent for technical review, the review forms with comments, author replies to reviewer comments, and the final manuscript)
Section Chief reviews *Final Manuscript Package* to ensure **all** reviewer comments have been addressed
Approved
Branch Chief reviews *Final Manuscript Package*
Approved
At Branch Chief discretion – forwards manuscript to Lab OD to be sent to external editor for editing
Branch Chief - review final content
Lab OD reviews *Final Manuscript Package* to ensure **all** reviewer comments have been addressed, policy, correct number and types of reviewers
Approved


Does technical content of manuscript touch on Dust, Diesel, Noise or other issues?
NO
YES
Assoc. Director for Mining and Construction reviews package for technical content and policy
Approved
Paper sent to professional conference or trade journal for publication
Publication information entered into NIOSHTIC2 database
Text of manuscript sent to Web Coordinator for web posting

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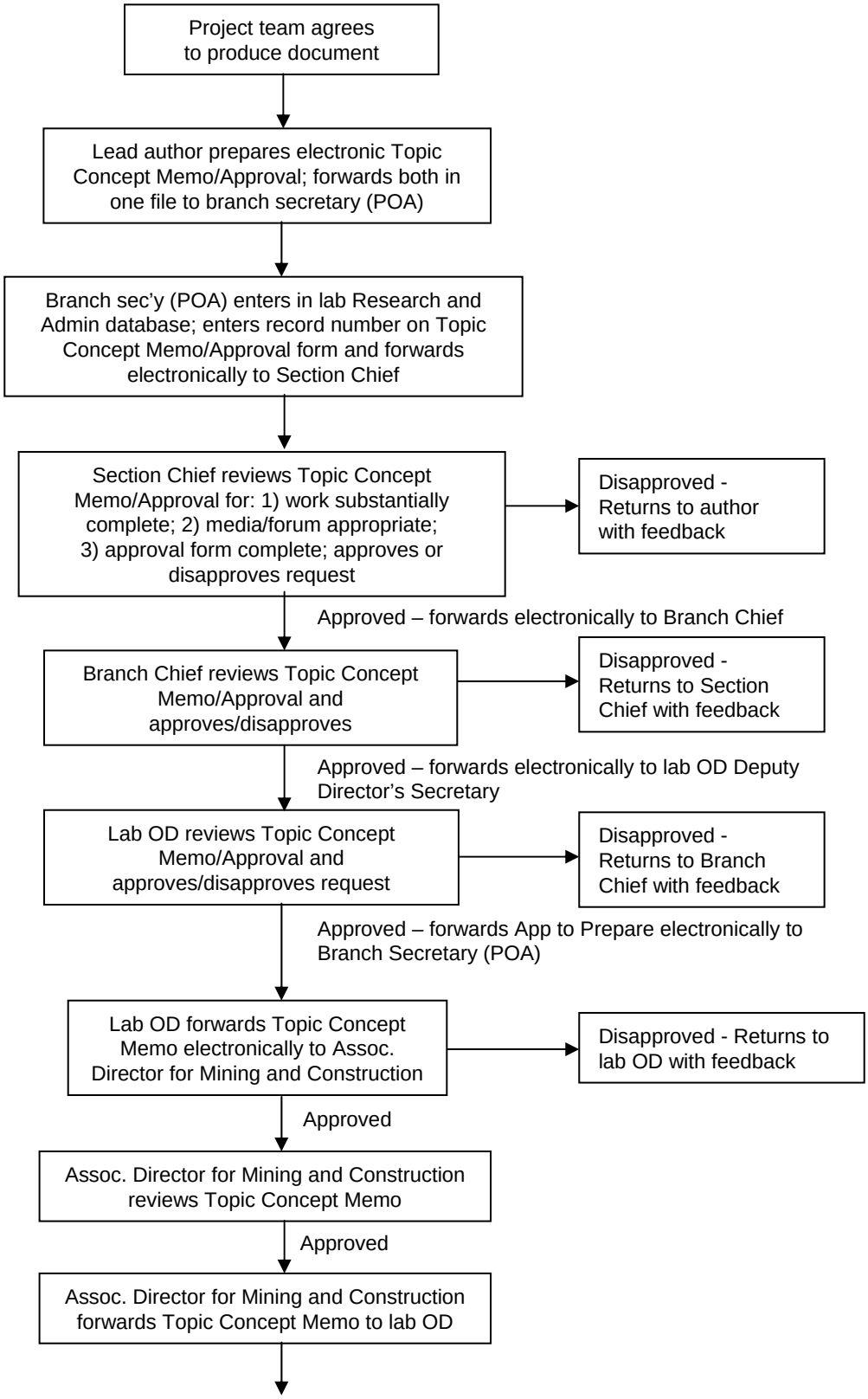
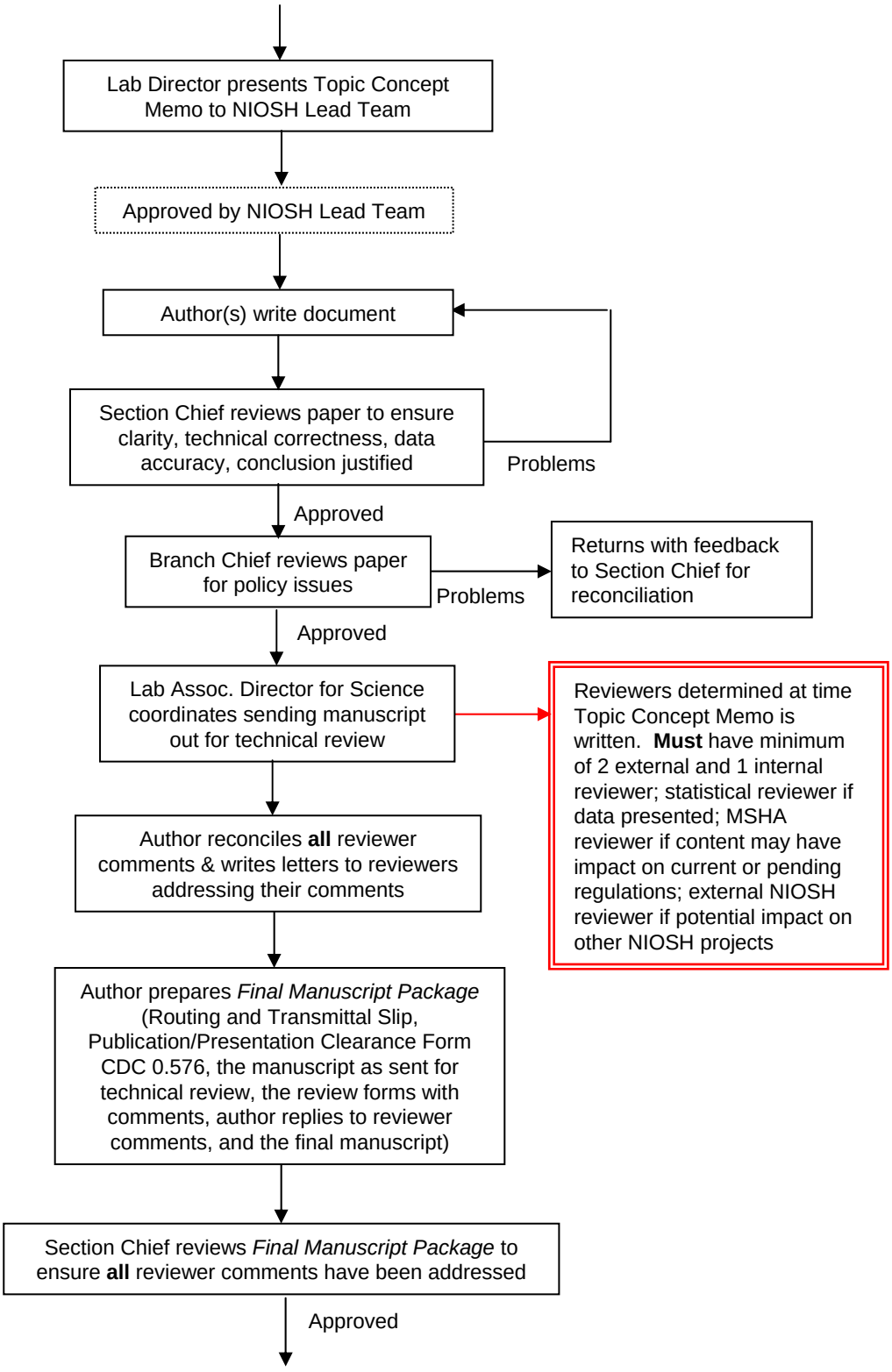
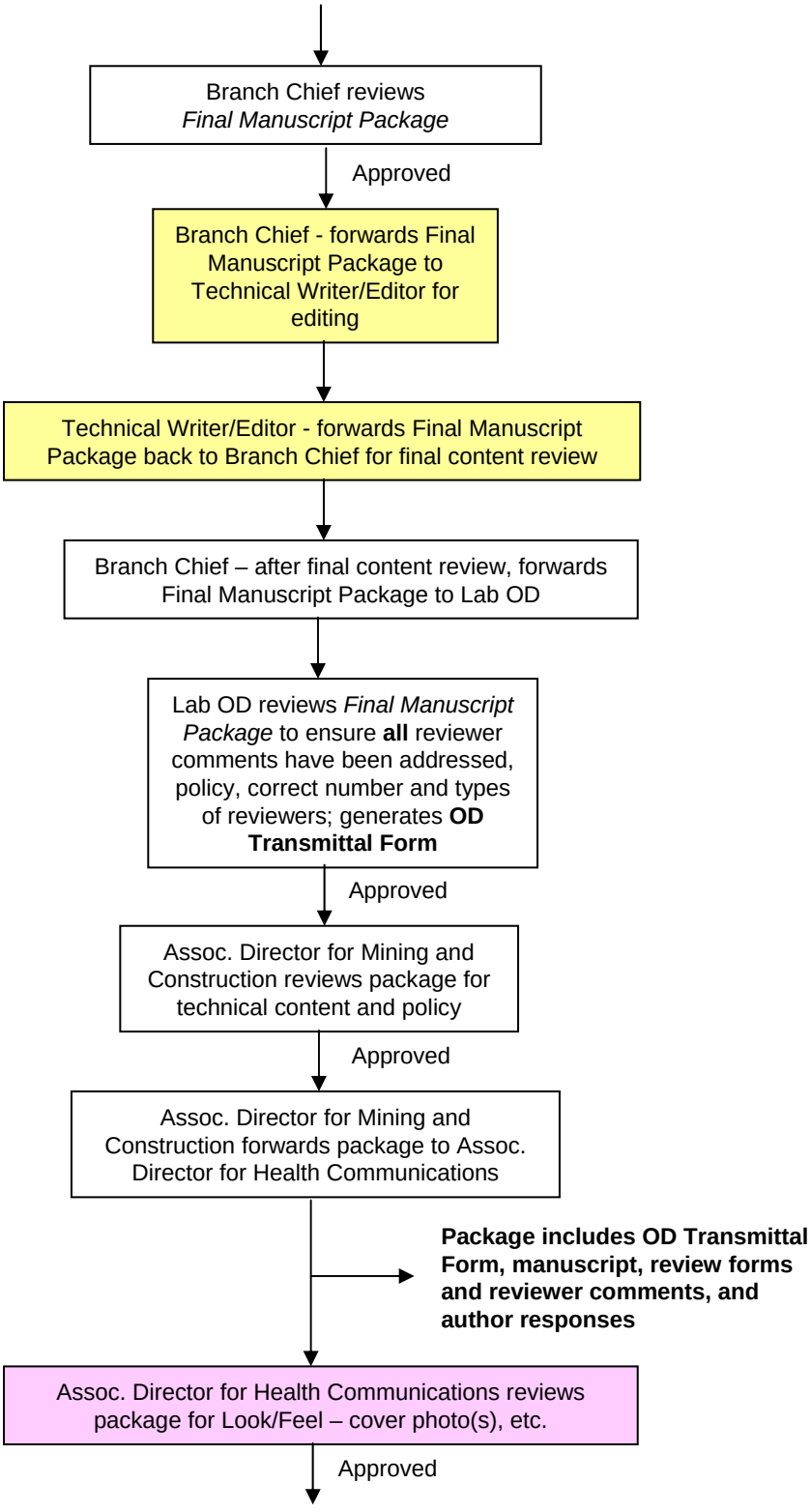
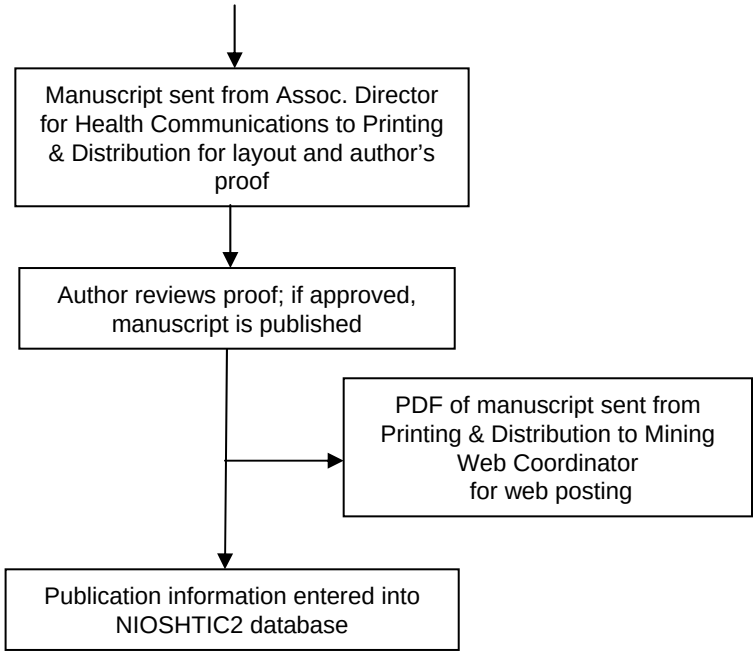
ICs and RIs

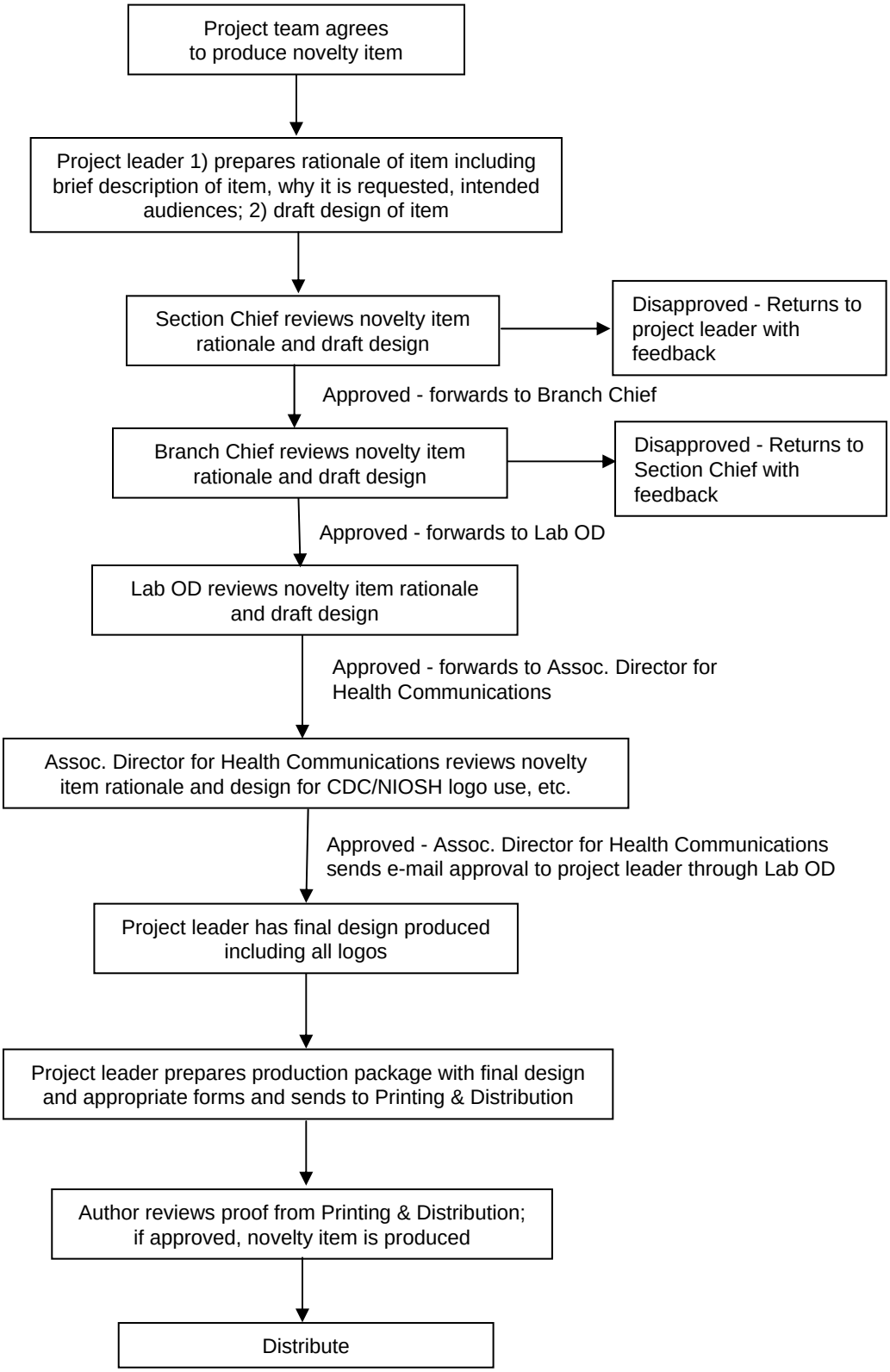

Project team agrees to produce document
Lead author prepares electronic Topic Concept Memo/Approval; forwards both in one file to branch secretary (POA)
Branch sec'y (POA) enters in lab Research and Admin database; enters record number on Topic Concept Memo/Approval form and forwards electronically to Section Chief
Section Chief reviews Topic Concept Memo/Approval for: 1) work substantially complete; 2) media/forum appropriate; 3) approval form complete; approves or disapproves request
Disapproved - Returns to author with feedback
Approved – forwards electronically to Branch Chief
Branch Chief reviews Topic Concept Memo/Approval and approves/disapproves
Disapproved - Returns to Section Chief with feedback
Approved – forwards electronically to lab OD Deputy Director's Secretary
Lab OD reviews Topic Concept Memo/Approval and approves/disapproves request
Disapproved - Returns to Branch Chief with feedback
Approved – forwards App to Prepare electronically to Branch Secretary (POA)
Lab OD forwards Topic Concept Memo electronically to Assoc. Director for Mining and Construction
Disapproved - Returns to lab OD with feedback
Approved
Assoc. Director for Mining and Construction reviews Topic Concept Memo
Approved
Assoc. Director for Mining and Construction forwards Topic Concept Memo to lab OD


Lab Director presents Topic Concept Memo to NIOSH Lead Team
Approved by NIOSH Lead Team
Author(s) write document
Section Chief reviews paper to ensure clarity, technical correctness, data accuracy, conclusion justified
Problems
Approved
Branch Chief reviews paper for policy issues
Problems
Returns with feedback to Section Chief for reconciliation
Approved
Lab Assoc. Director for Science coordinates sending manuscript out for technical review
Reviewers determined at time Topic Concept Memo is written. **Must** have minimum of 2 external and 1 internal reviewer; statistical reviewer if data presented; MSHA reviewer if content may have impact on current or pending regulations; external NIOSH reviewer if potential impact on other NIOSH projects
Author reconciles **all** reviewer comments & writes letters to reviewers addressing their comments
Author prepares *Final Manuscript Package* (Routing and Transmittal Slip, Publication/Presentation Clearance Form CDC 0.576, the manuscript as sent for technical review, the review forms with comments, author replies to reviewer comments, and the final manuscript)
Section Chief reviews *Final Manuscript Package* to ensure **all** reviewer comments have been addressed
Approved


Branch Chief reviews
Final Manuscript Package
Approved
Branch Chief - forwards Final Manuscript Package to Technical Writer/Editor for editing
Technical Writer/Editor - forwards Final Manuscript Package back to Branch Chief for final content review
Branch Chief – after final content review, forwards Final Manuscript Package to Lab OD
Lab OD reviews *Final Manuscript Package* to ensure **all** reviewer comments have been addressed, policy, correct number and types of reviewers; generates **OD Transmittal Form**
Approved
Assoc. Director for Mining and Construction reviews package for technical content and policy
Approved
Assoc. Director for Mining and Construction forwards package to Assoc. Director for Health Communications
Package includes OD Transmittal Form, manuscript, review forms and reviewer comments, and author responses
Assoc. Director for Health Communications reviews package for Look/Feel – cover photo(s), etc.
Approved


Manuscript sent from Assoc. Director for Health Communications to Printing & Distribution for layout and author's proof
Author reviews proof; if approved, manuscript is published
PDF of manuscript sent from Printing & Distribution to Mining Web Coordinator for web posting
Publication information entered into NIOSHTIC2 database

Novelty items (Stickers, bookmarkers, etc.)



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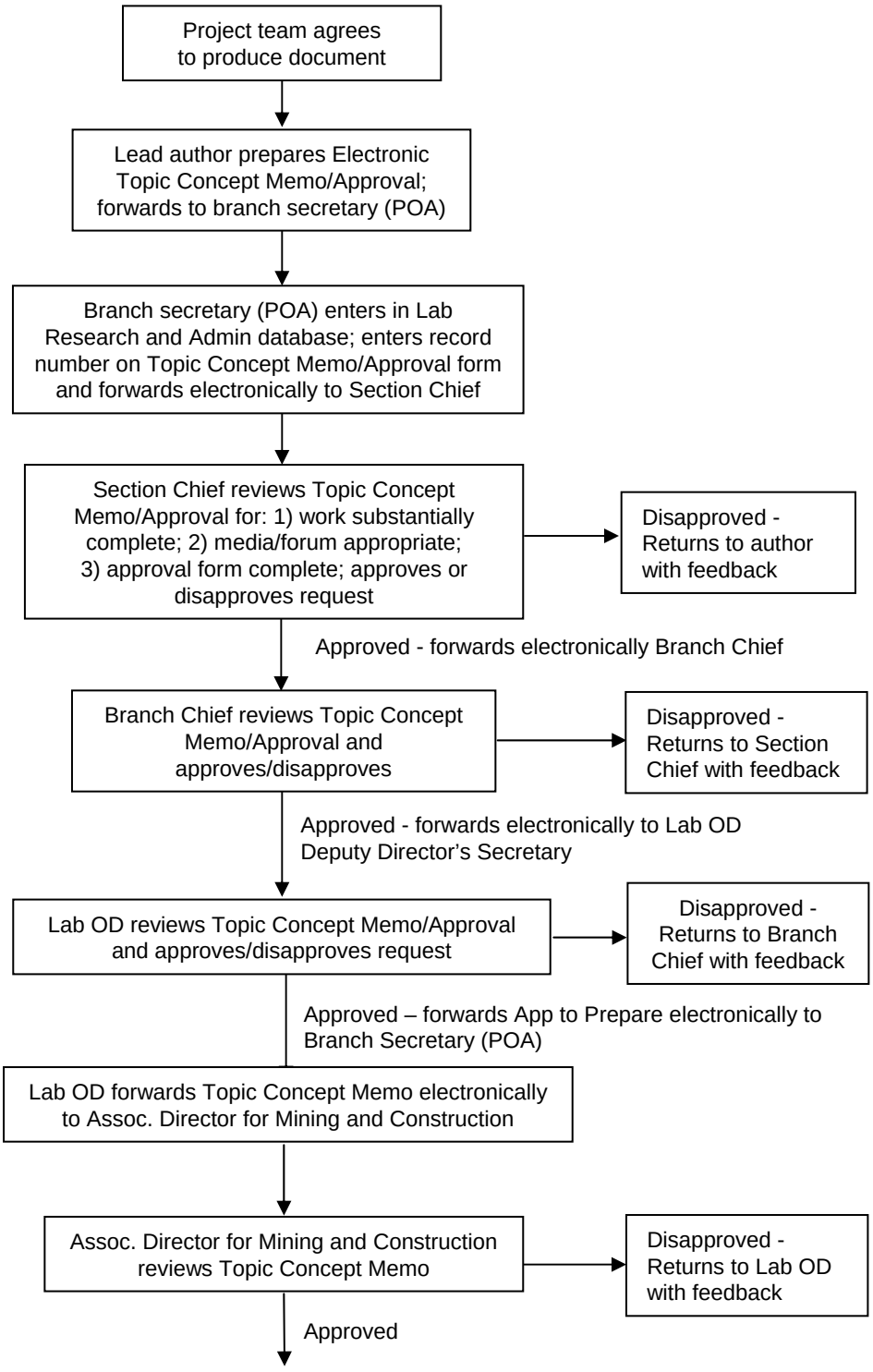
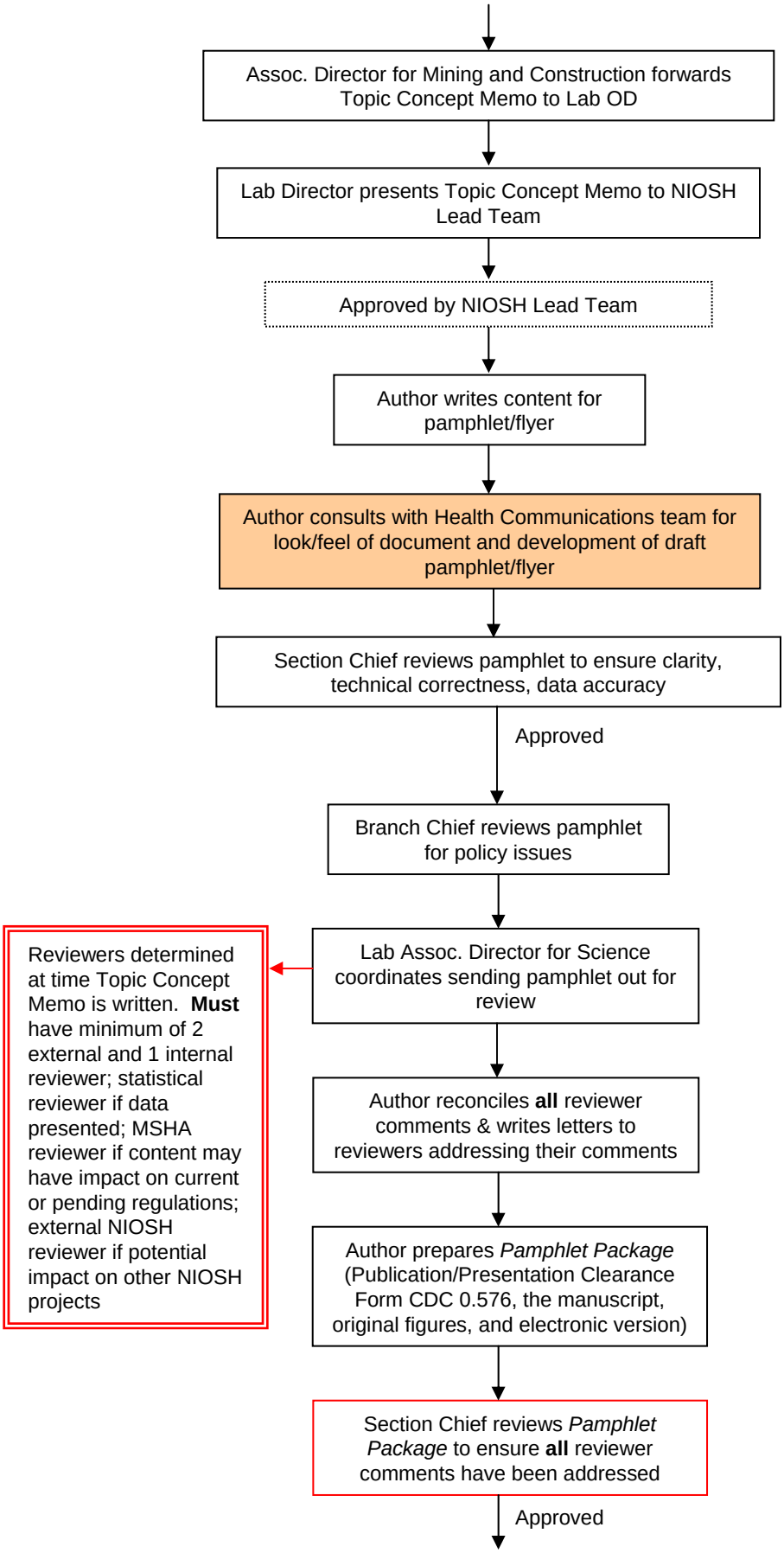
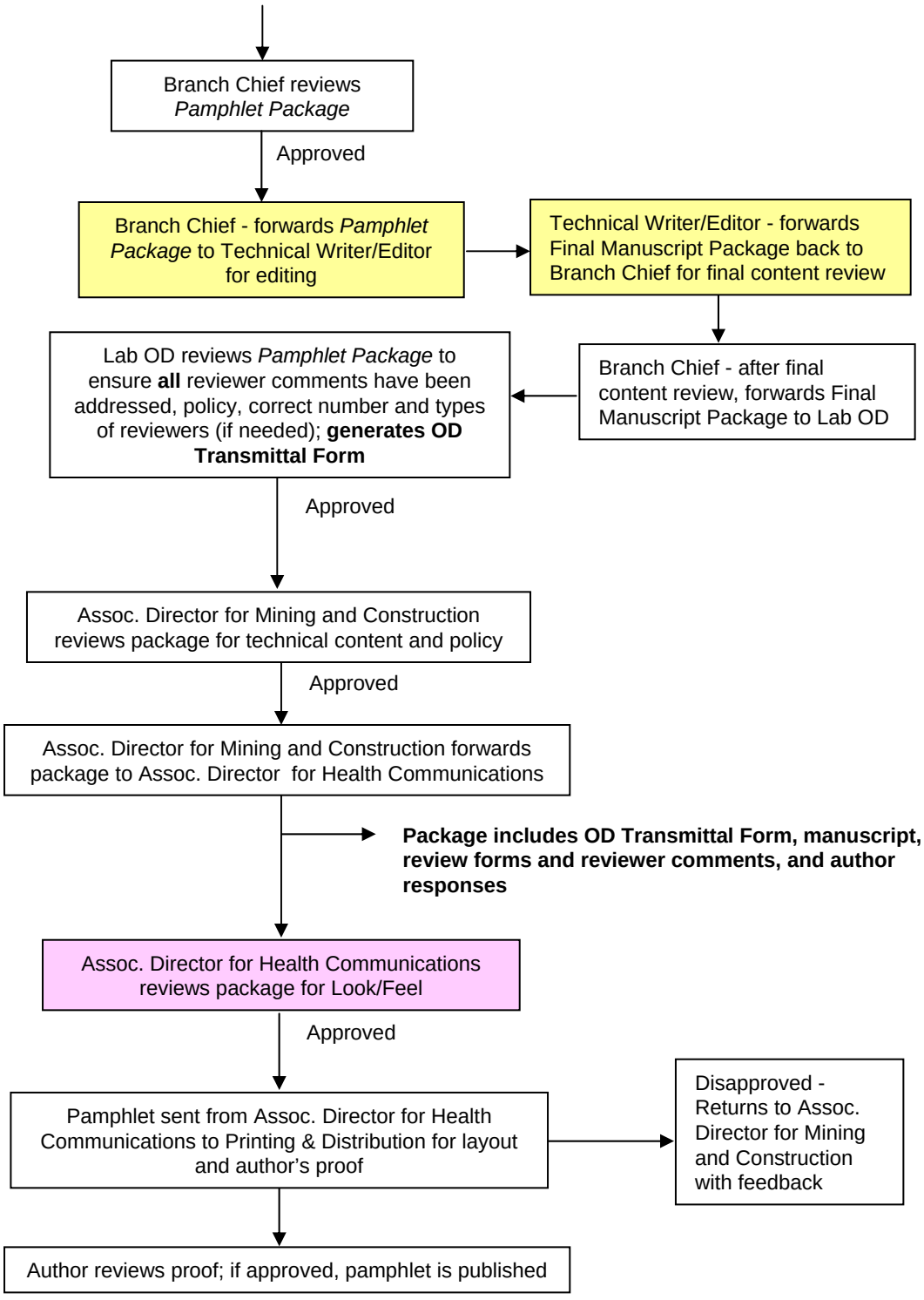
Pamphlets and Flyers




Assoc. Director for Mining and Construction forwards Topic Concept Memo to Lab OD
Lab Director presents Topic Concept Memo to NIOSH Lead Team
Approved by NIOSH Lead Team
Author writes content for pamphlet/flyer
Author consults with Health Communications team for look/feel of document and development of draft pamphlet/flyer
Section Chief reviews pamphlet to ensure clarity, technical correctness, data accuracy
Approved
Branch Chief reviews pamphlet for policy issues
Lab Assoc. Director for Science coordinates sending pamphlet out for review
Reviewers determined at time Topic Concept Memo is written. Must have minimum of 2 external and 1 internal reviewer; statistical reviewer if data presented; MSHA reviewer if content may have impact on current or pending regulations; external NIOSH reviewer if potential impact on other NIOSH projects
Author reconciles all reviewer comments & writes letters to reviewers addressing their comments
Author prepares Pamphlet Package (Publication/Presentation Clearance Form CDC 0.576, the manuscript, original figures, and electronic version)
Section Chief reviews Pamphlet Package to ensure all reviewer comments have been addressed
Approved


Branch Chief reviews *Pamphlet Package*
Approved
Branch Chief - forwards *Pamphlet Package* to Technical Writer/Editor for editing
Technical Writer/Editor - forwards Final Manuscript Package back to Branch Chief for final content review
Branch Chief - after final content review, forwards Final Manuscript Package to Lab OD
Lab OD reviews *Pamphlet Package* to ensure **all** reviewer comments have been addressed, policy, correct number and types of reviewers (if needed); **generates OD Transmittal Form**
Approved
Assoc. Director for Mining and Construction reviews package for technical content and policy
Approved
Assoc. Director for Mining and Construction forwards package to Assoc. Director for Health Communications
Package includes OD Transmittal Form, manuscript, review forms and reviewer comments, and author responses
Assoc. Director for Health Communications reviews package for Look/Feel
Approved
Pamphlet sent from Assoc. Director for Health Communications to Printing & Distribution for layout and author's proof
Disapproved - Returns to Assoc. Director for Mining and Construction with feedback
Author reviews proof; if approved, pamphlet is published

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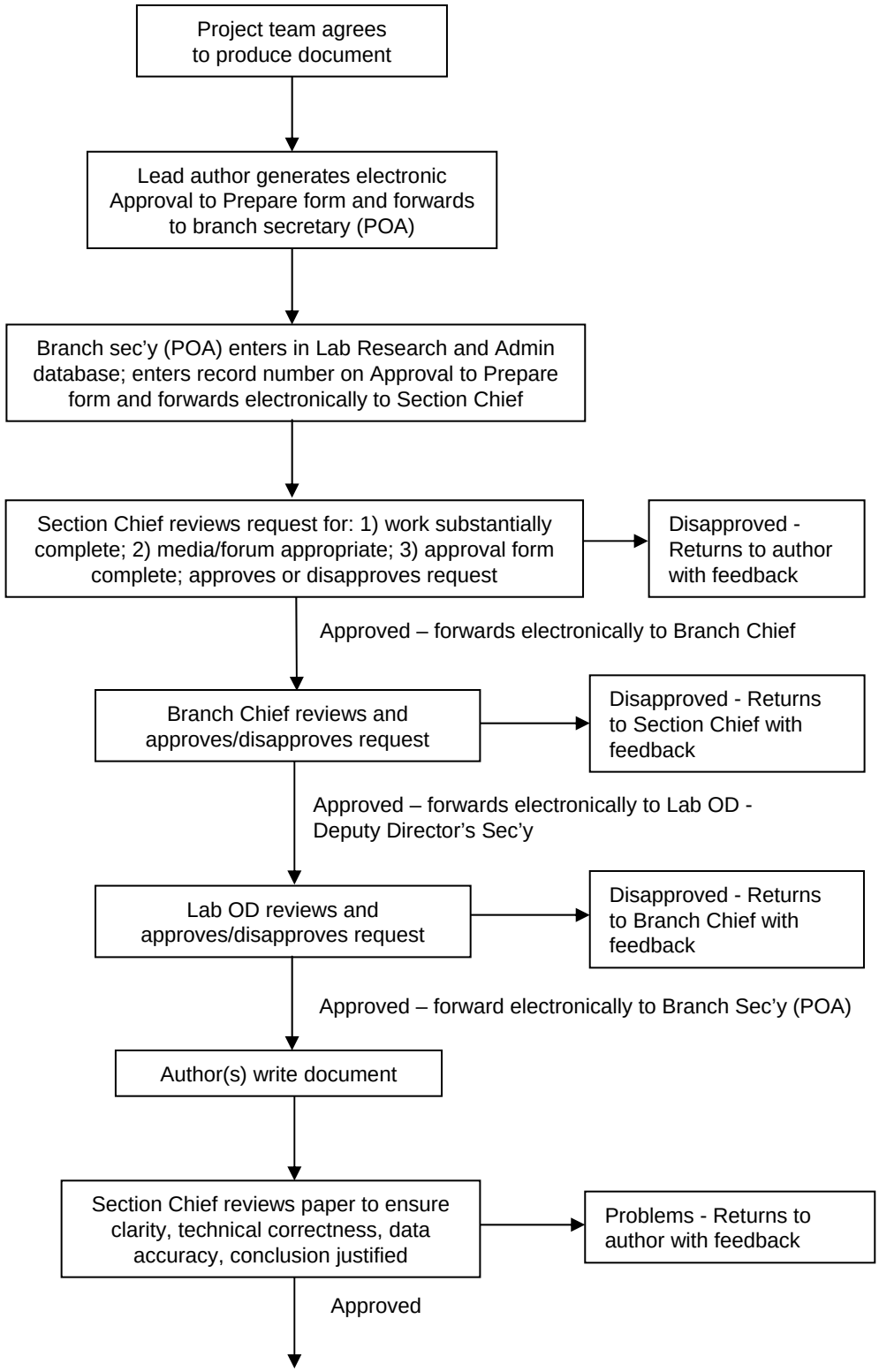
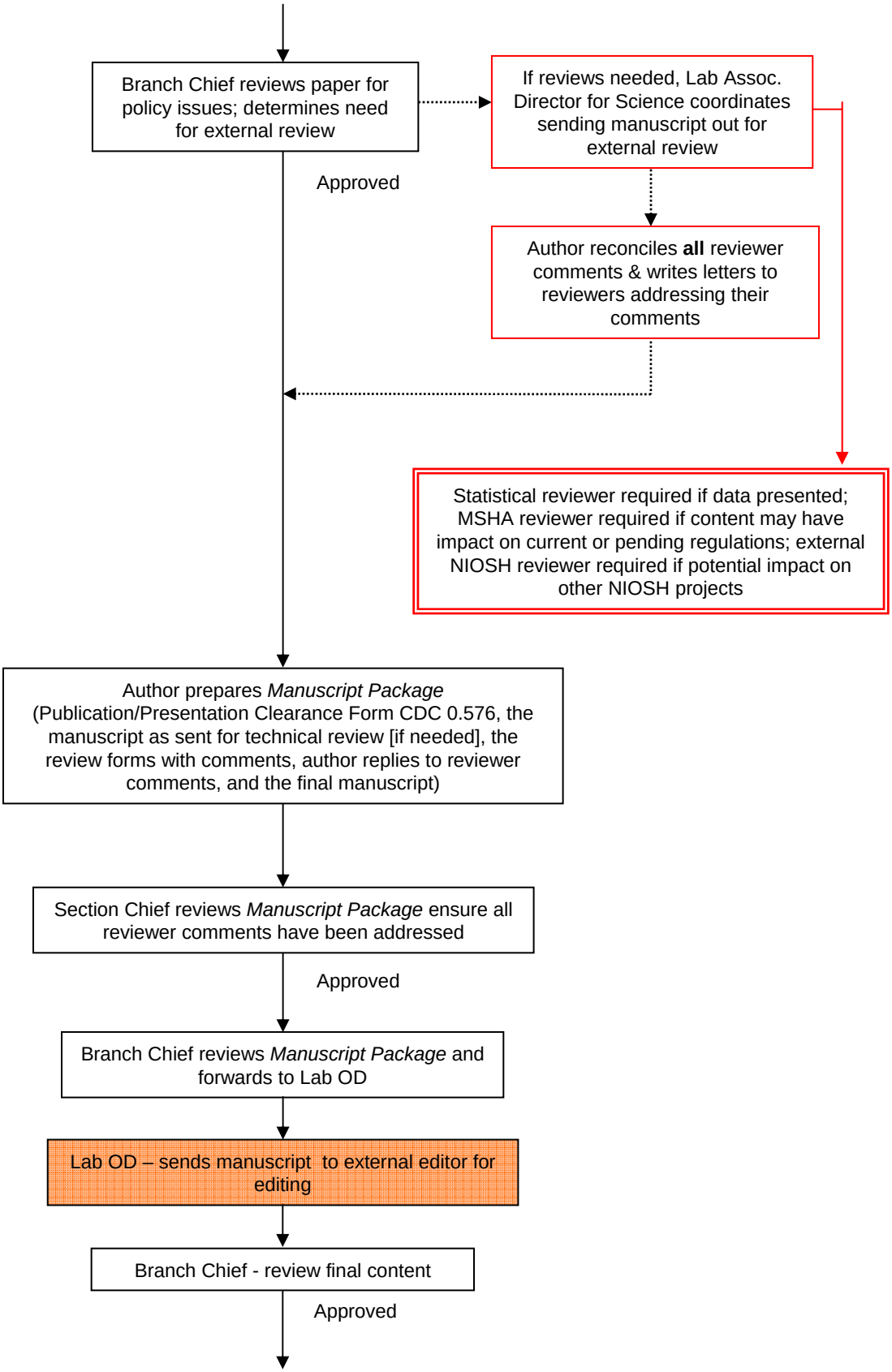
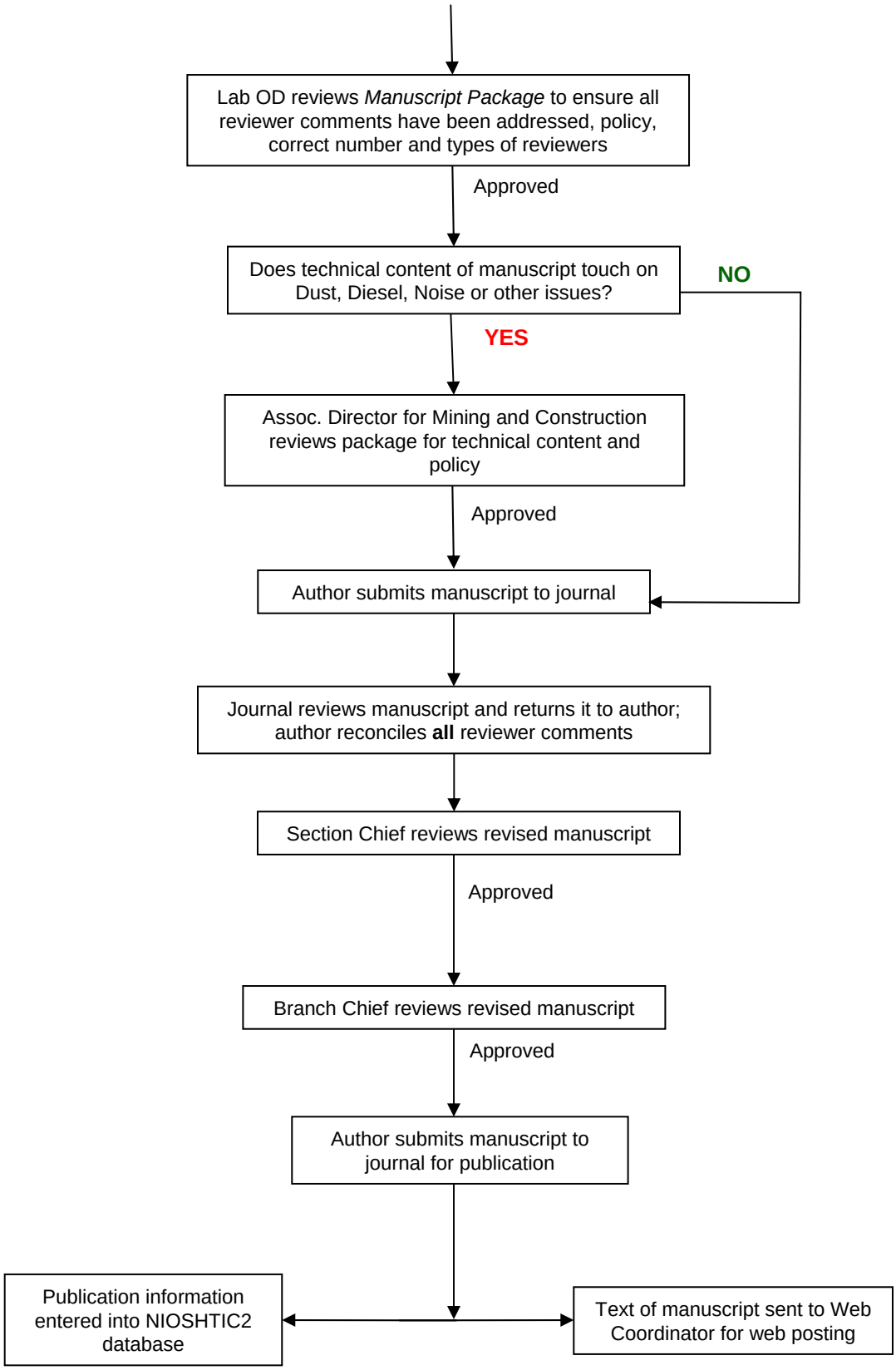
Peer-Reviewed Publications




Branch Chief reviews paper for policy issues; determines need for external review
If reviews needed, Lab Assoc. Director for Science coordinates sending manuscript out for external review
Approved
Author reconciles **all** reviewer comments & writes letters to reviewers addressing their comments
Statistical reviewer required if data presented; MSHA reviewer required if content may have impact on current or pending regulations; external NIOSH reviewer required if potential impact on other NIOSH projects
Author prepares *Manuscript Package* (Publication/Presentation Clearance Form CDC 0.576, the manuscript as sent for technical review [if needed], the review forms with comments, author replies to reviewer comments, and the final manuscript)
Section Chief reviews *Manuscript Package* ensure all reviewer comments have been addressed
Approved
Branch Chief reviews *Manuscript Package* and forwards to Lab OD
Lab OD – sends manuscript to external editor for editing
Branch Chief - review final content
Approved


Lab OD reviews *Manuscript Package* to ensure all reviewer comments have been addressed, policy, correct number and types of reviewers
Approved
Does technical content of manuscript touch on Dust, Diesel, Noise or other issues?
NO
YES
Assoc. Director for Mining and Construction reviews package for technical content and policy
Approved
Author submits manuscript to journal
Journal reviews manuscript and returns it to author; author reconciles **all** reviewer comments
Section Chief reviews revised manuscript
Approved
Branch Chief reviews revised manuscript
Approved
Author submits manuscript to journal for publication
Publication information entered into NIOSHTIC2 database
Text of manuscript sent to Web Coordinator for web posting

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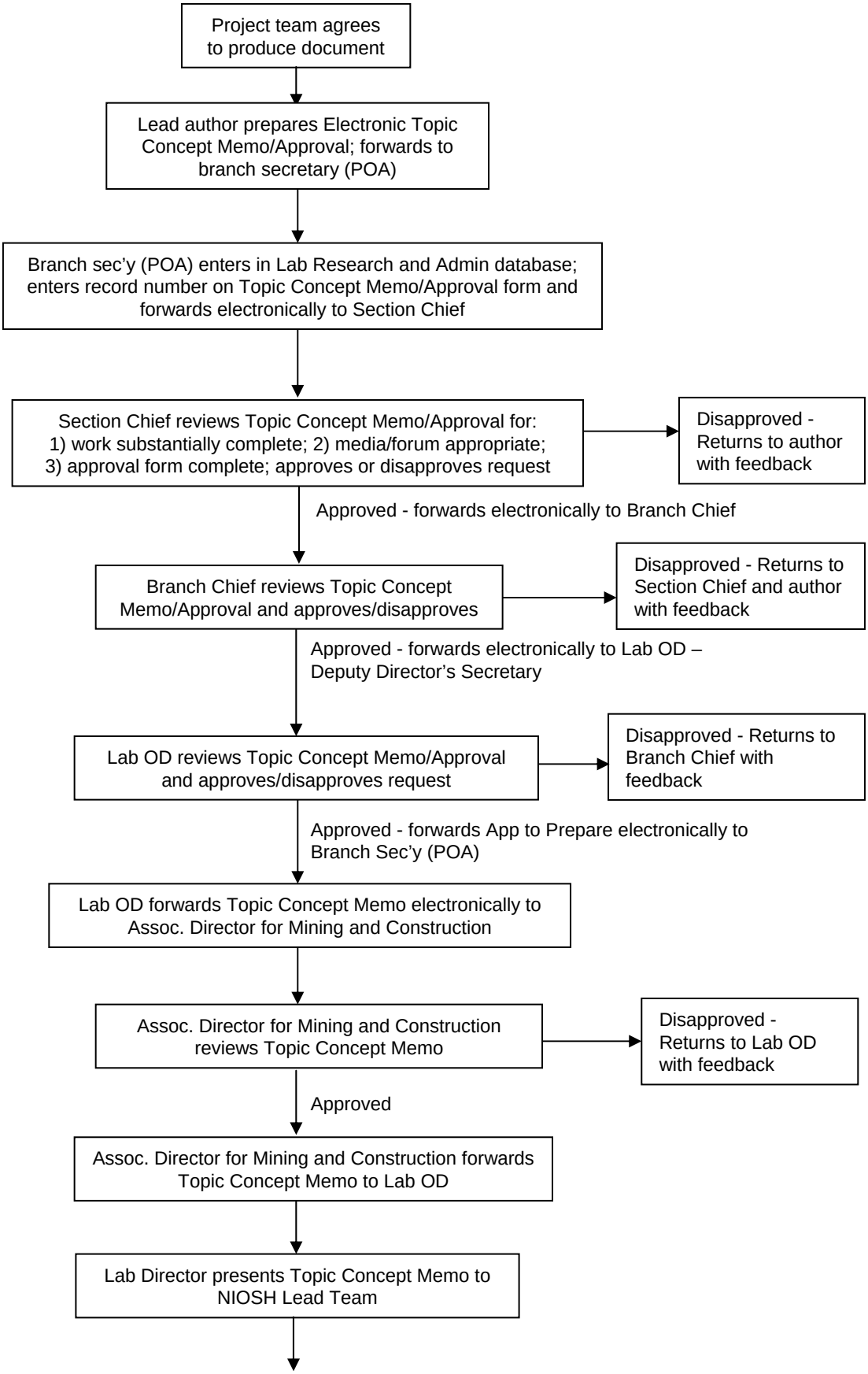
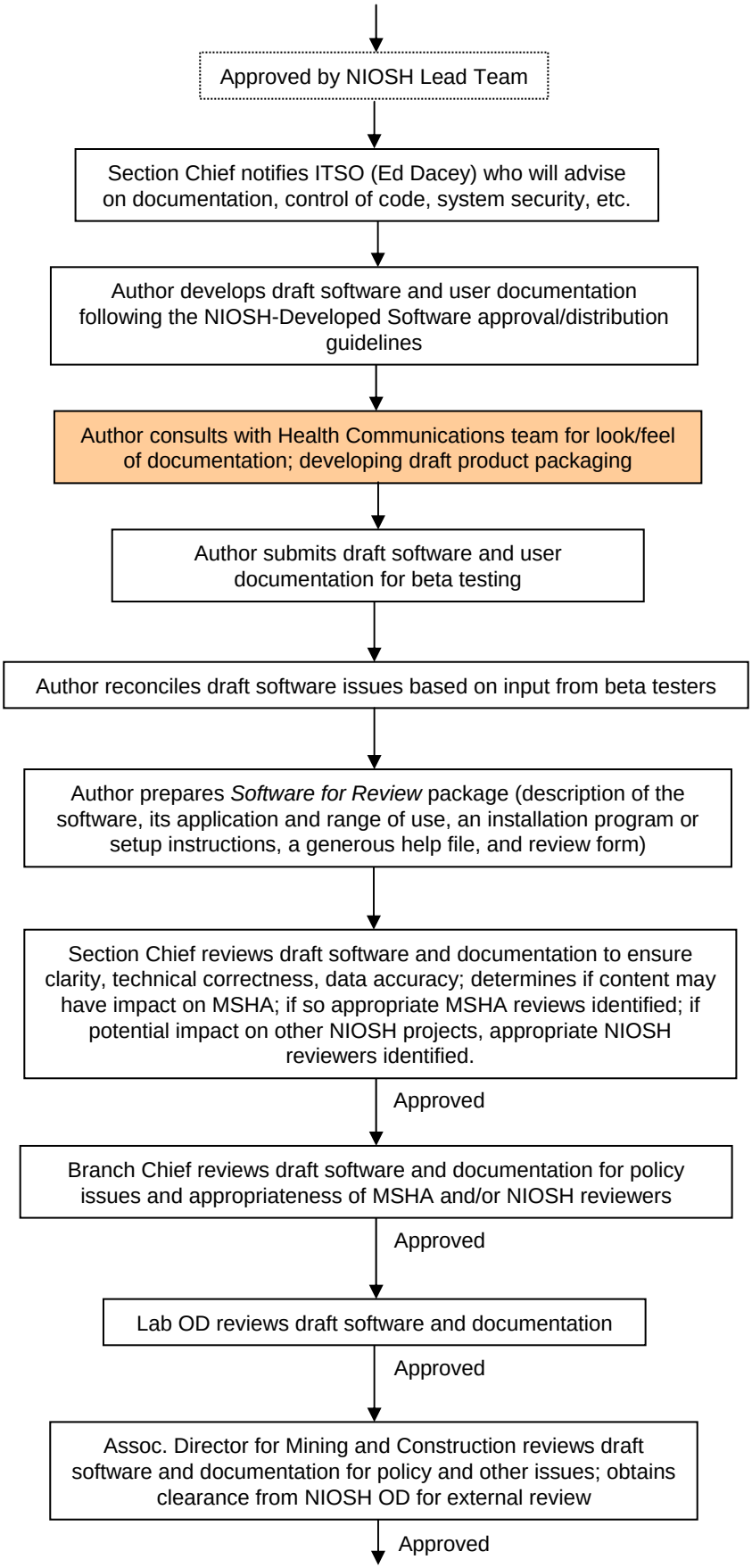
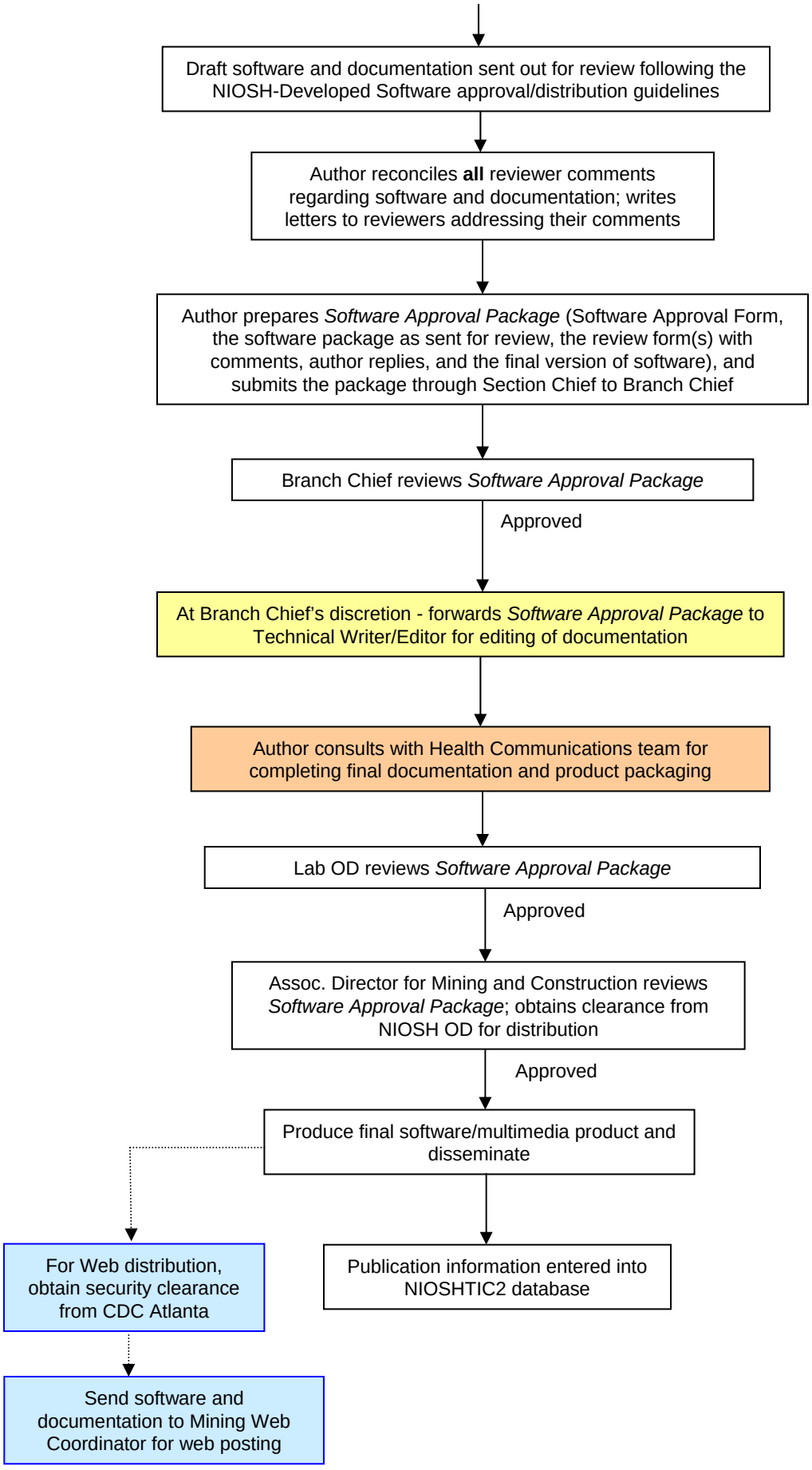
Software and multimedia




Approved by NIOSH Lead Team
Section Chief notifies ITSO (Ed Dacey) who will advise on documentation, control of code, system security, etc.
Author develops draft software and user documentation following the NIOSH-Developed Software approval/distribution guidelines
Author consults with Health Communications team for look/feel of documentation; developing draft product packaging
Author submits draft software and user documentation for beta testing
Author reconciles draft software issues based on input from beta testers
Author prepares *Software for Review* package (description of the software, its application and range of use, an installation program or setup instructions, a generous help file, and review form)
Section Chief reviews draft software and documentation to ensure clarity, technical correctness, data accuracy; determines if content may have impact on MSHA; if so appropriate MSHA reviews identified; if potential impact on other NIOSH projects, appropriate NIOSH reviewers identified.
Approved
Branch Chief reviews draft software and documentation for policy issues and appropriateness of MSHA and/or NIOSH reviewers
Approved
Lab OD reviews draft software and documentation
Approved
Assoc. Director for Mining and Construction reviews draft software and documentation for policy and other issues; obtains clearance from NIOSH OD for external review
Approved


Draft software and documentation sent out for review following the NIOSH-Developed Software approval/distribution guidelines
Author reconciles **all** reviewer comments regarding software and documentation; writes letters to reviewers addressing their comments
Author prepares *Software Approval Package* (Software Approval Form, the software package as sent for review, the review form(s) with comments, author replies, and the final version of software), and submits the package through Section Chief to Branch Chief
Branch Chief reviews *Software Approval Package*
Approved
At Branch Chief's discretion - forwards *Software Approval Package* to Technical Writer/Editor for editing of documentation
Author consults with Health Communications team for completing final documentation and product packaging
Lab OD reviews *Software Approval Package*
Approved
Assoc. Director for Mining and Construction reviews *Software Approval Package*; obtains clearance from NIOSH OD for distribution
Approved
Produce final software/multimedia product and disseminate
For Web distribution, obtain security clearance from CDC Atlanta
Publication information entered into NIOSHTIC2 database
Send software and documentation to Mining Web Coordinator for web posting

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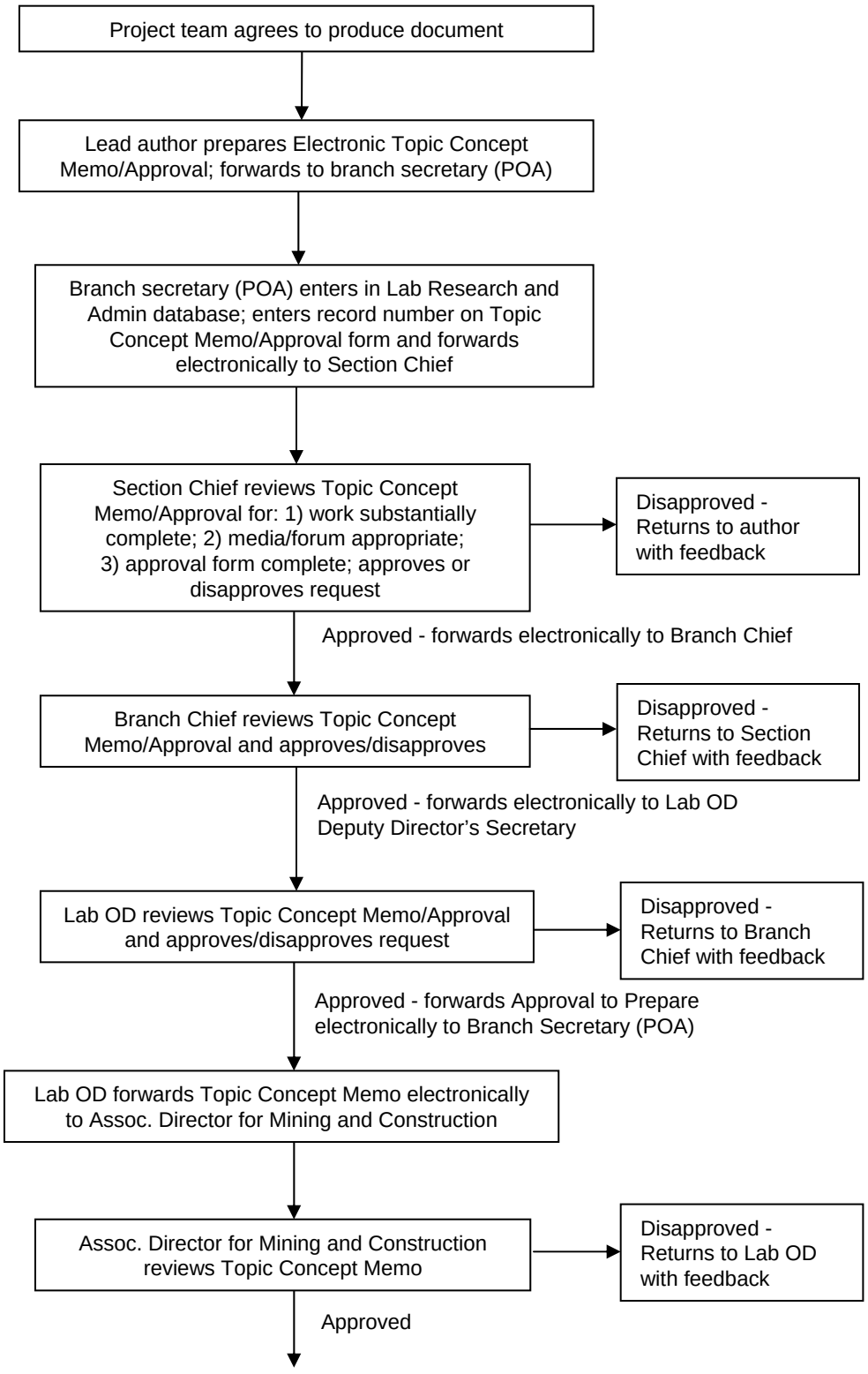
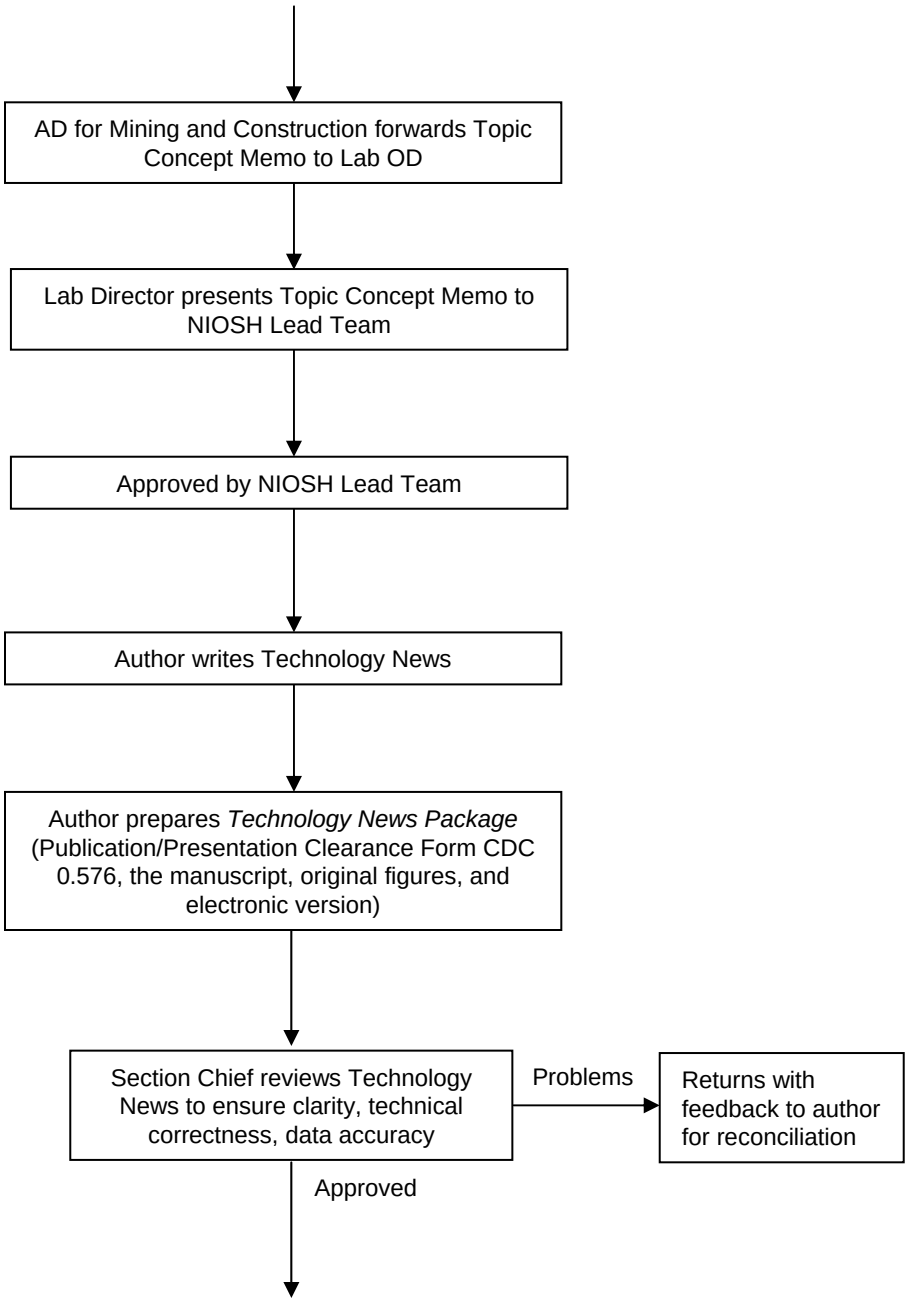
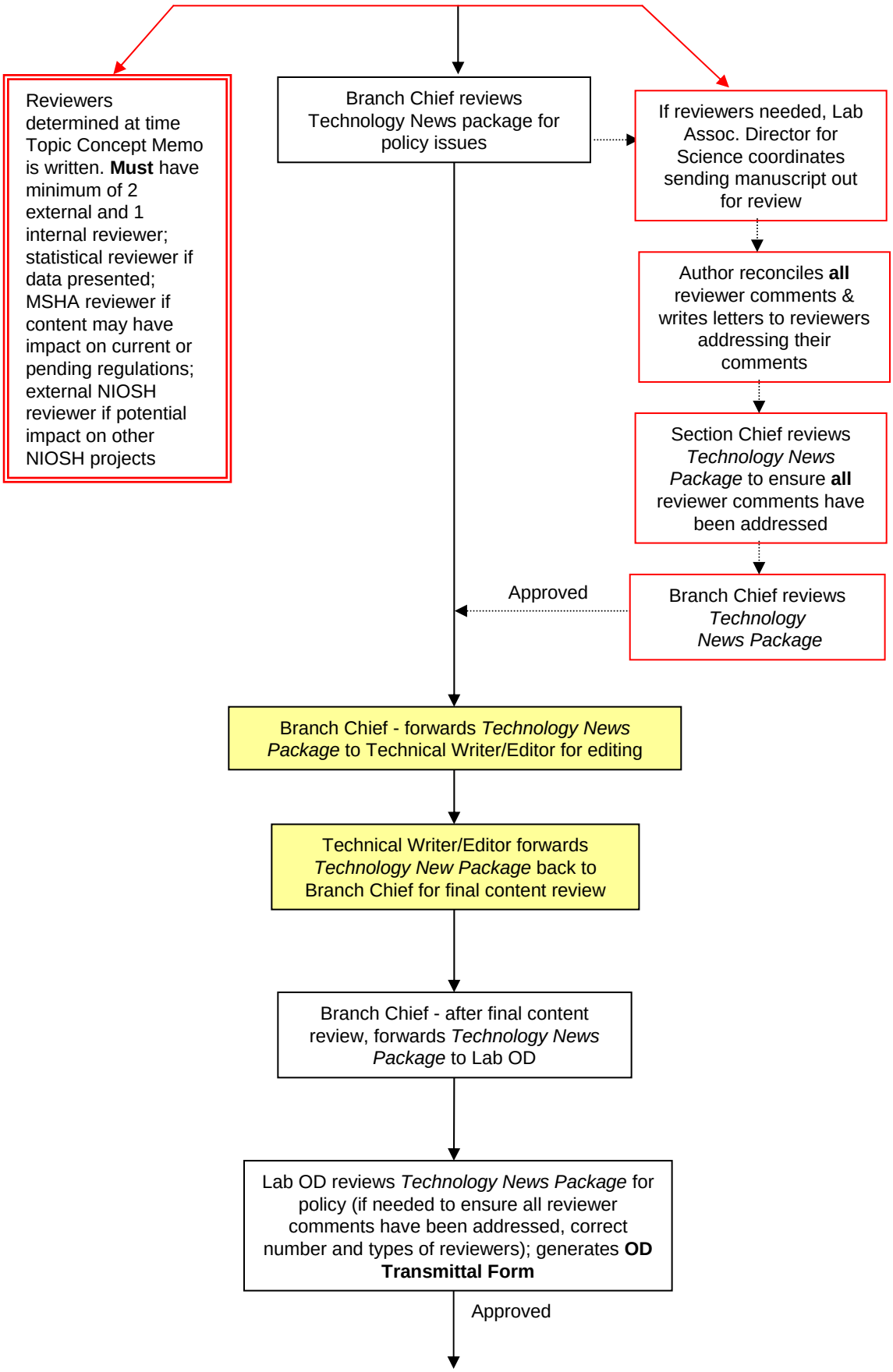
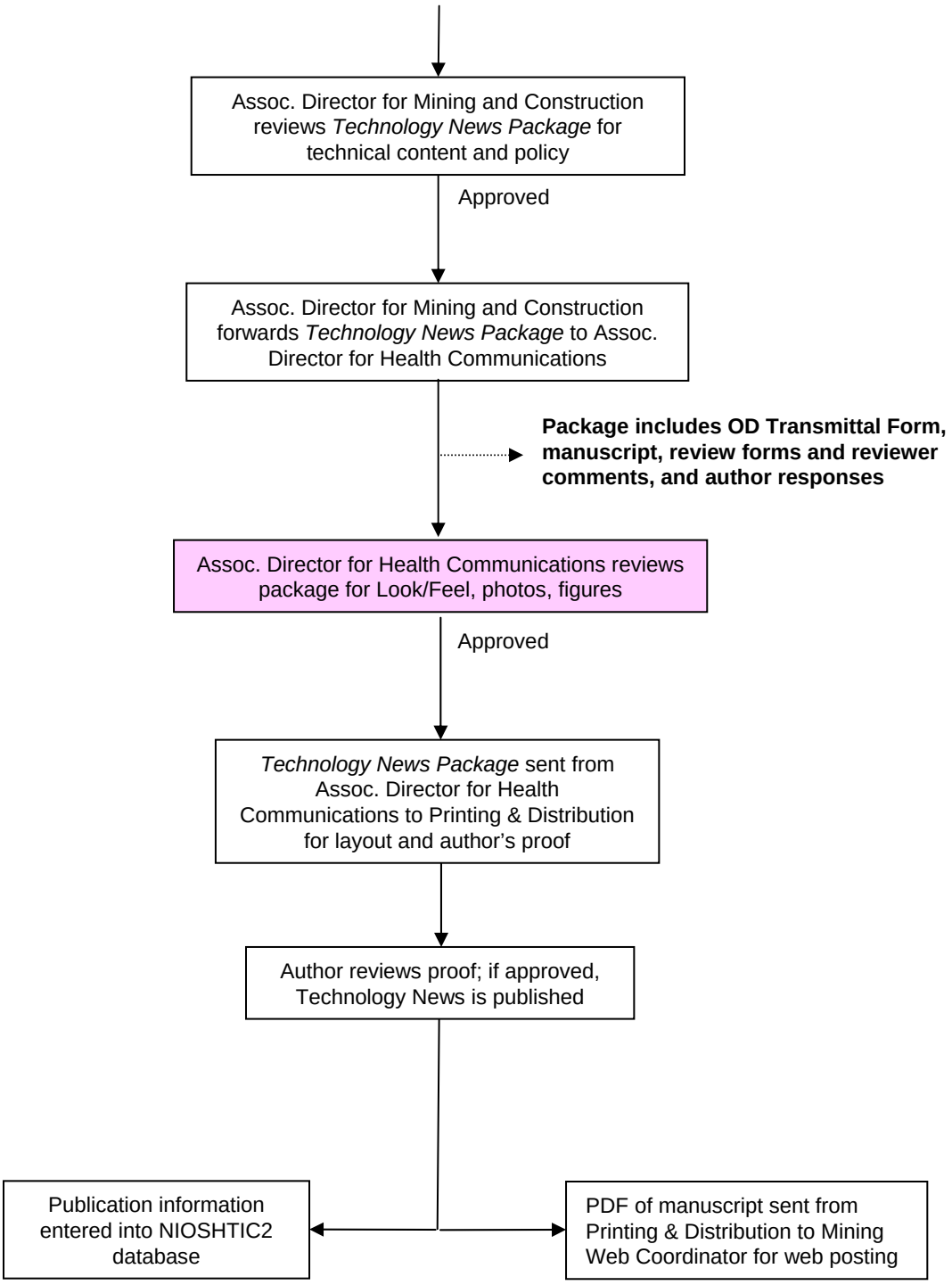
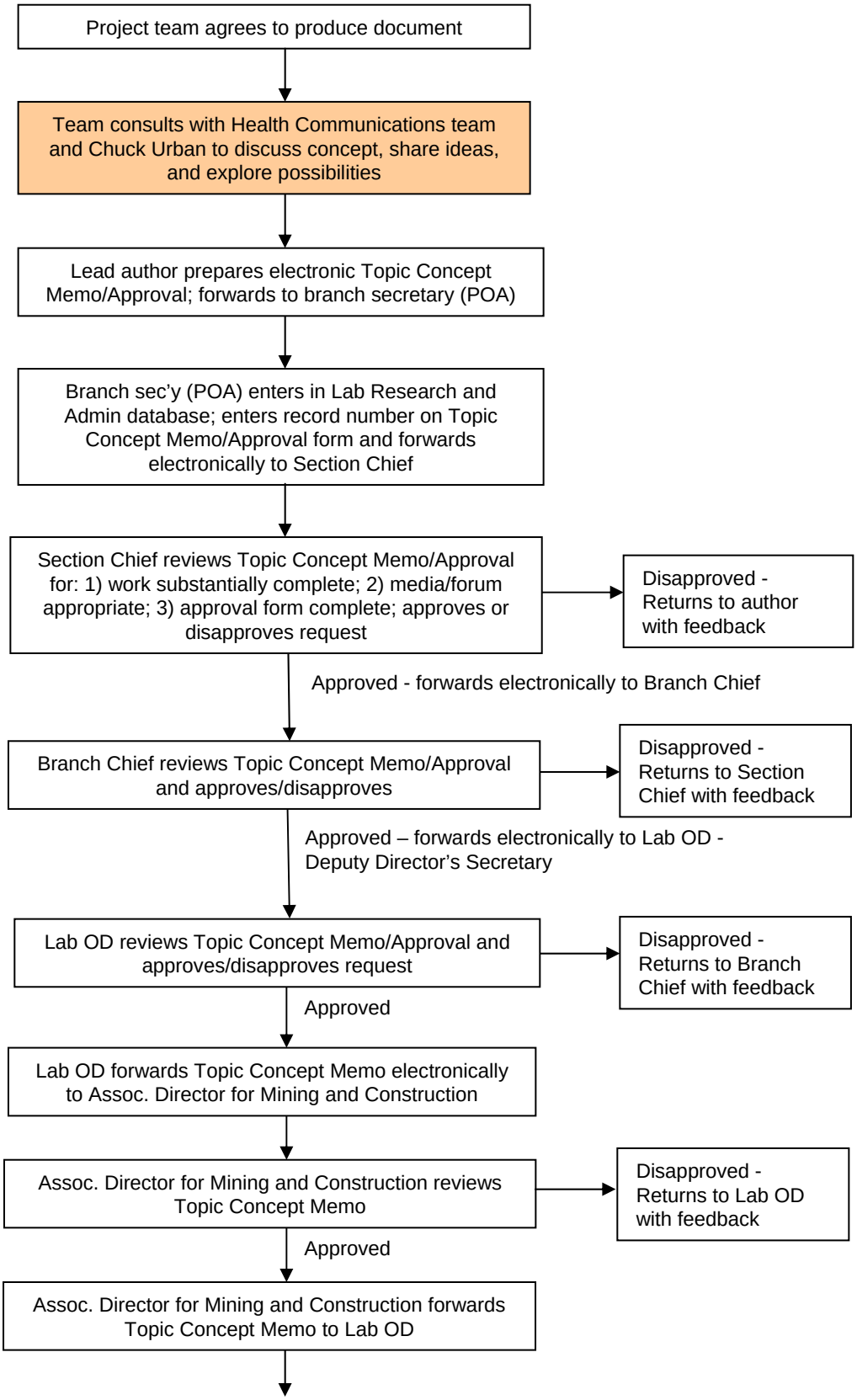

Project team agrees to produce document
Lead author prepares Electronic Topic Concept Memo/Approval; forwards to branch secretary (POA)
Branch secretary (POA) enters in Lab Research and Admin database; enters record number on Topic Concept Memo/Approval form and forwards electronically to Section Chief
Section Chief reviews Topic Concept Memo/Approval for: 1) work substantially complete; 2) media/forum appropriate; 3) approval form complete; approves or disapproves request
Disapproved - Returns to author with feedback
Approved - forwards electronically to Branch Chief
Branch Chief reviews Topic Concept Memo/Approval and approves/disapproves
Disapproved - Returns to Section Chief with feedback
Approved - forwards electronically to Lab OD Deputy Director's Secretary
Lab OD reviews Topic Concept Memo/Approval and approves/disapproves request
Disapproved - Returns to Branch Chief with feedback
Approved - forwards Approval to Prepare electronically to Branch Secretary (POA)
Lab OD forwards Topic Concept Memo electronically to Assoc. Director for Mining and Construction
Assoc. Director for Mining and Construction reviews Topic Concept Memo
Disapproved - Returns to Lab OD with feedback
Approved

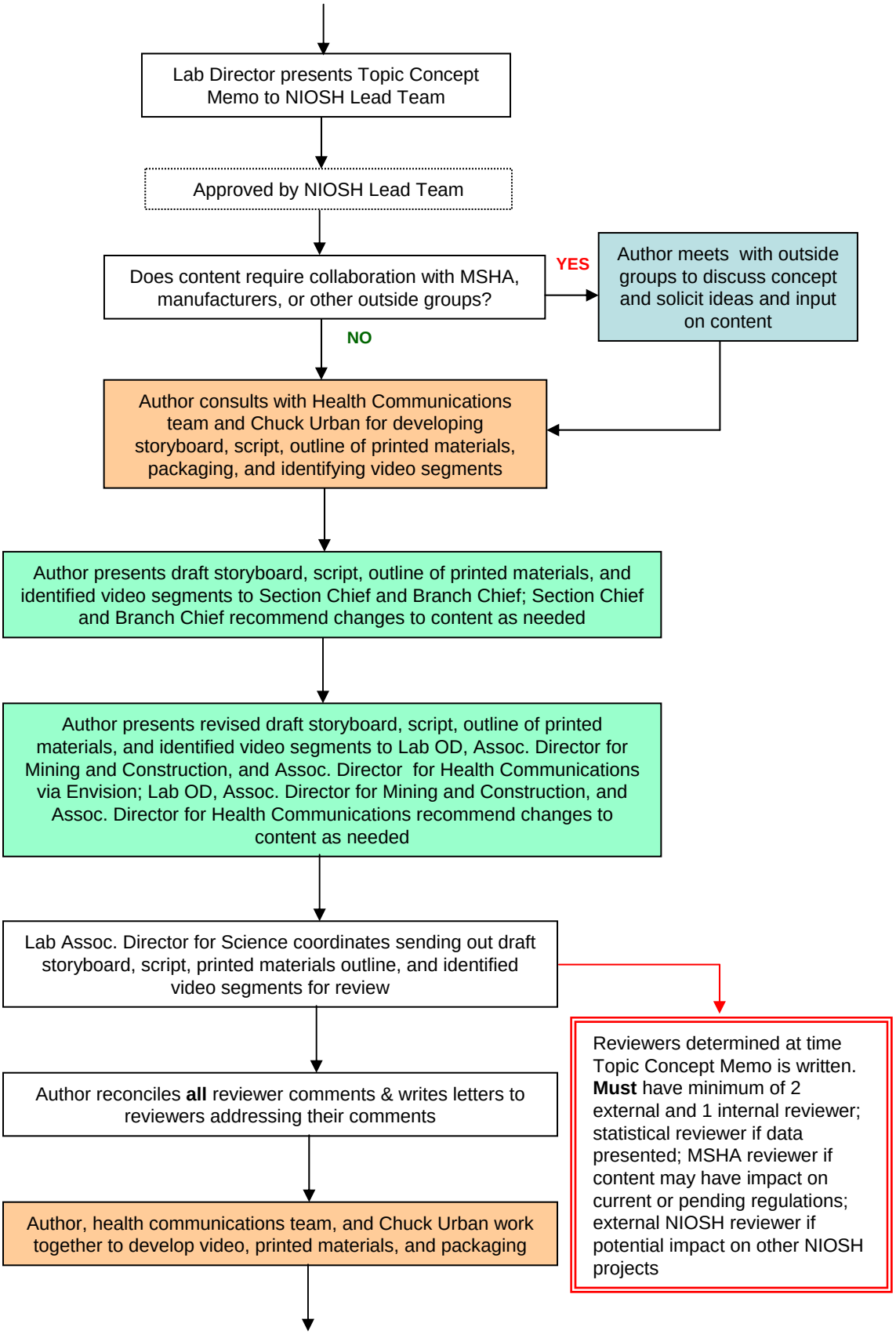

AD for Mining and Construction forwards Topic Concept Memo to Lab OD
Lab Director presents Topic Concept Memo to NIOSH Lead Team
Approved by NIOSH Lead Team
Author writes Technology News
Author prepares *Technology News Package* (Publication/Presentation Clearance Form CDC 0.576, the manuscript, original figures, and electronic version)
Section Chief reviews Technology News to ensure clarity, technical correctness, data accuracy
Problems
Returns with feedback to author for reconciliation
Approved

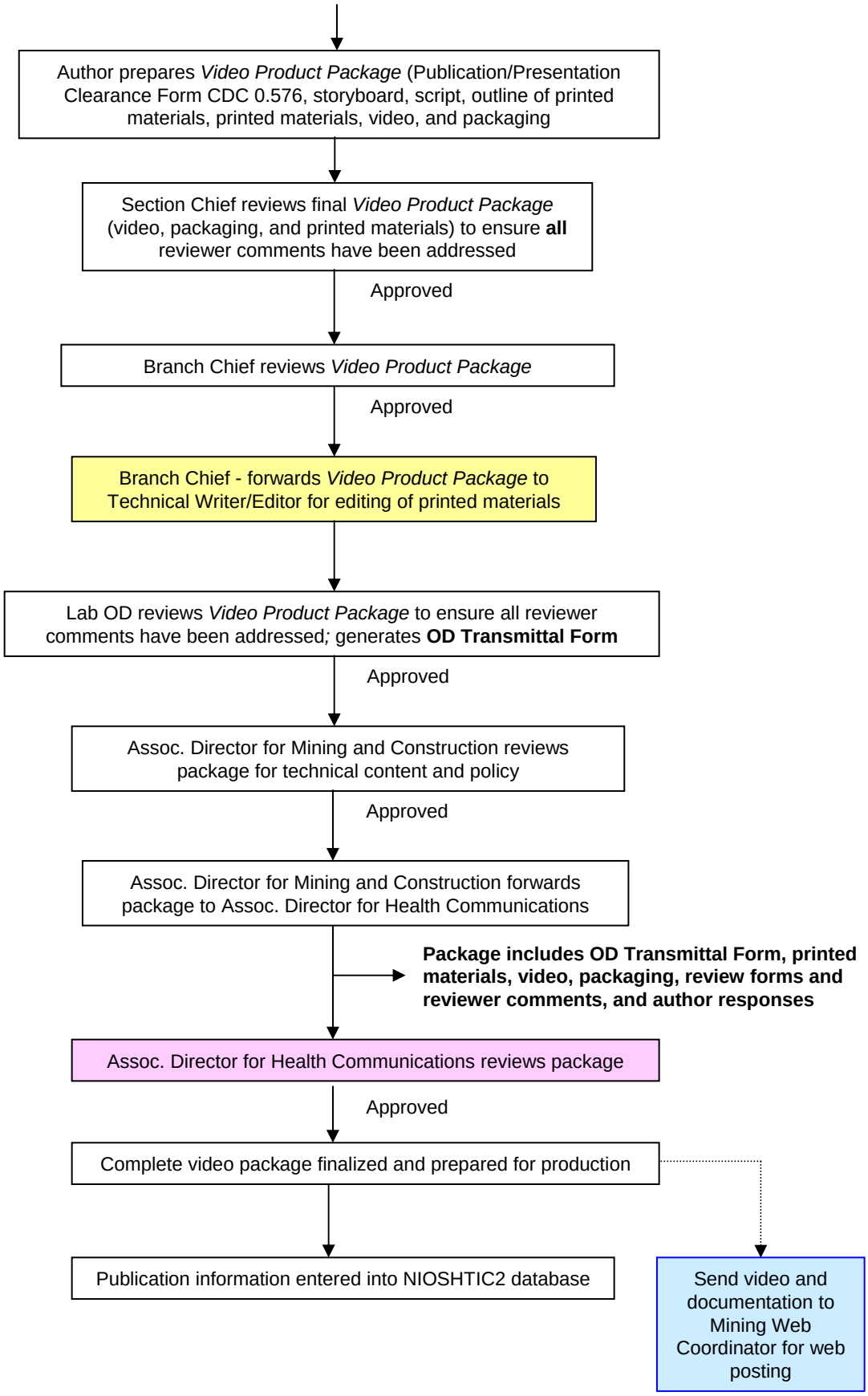

Reviewers determined at time Topic Concept Memo is written. **Must** have minimum of 2 external and 1 internal reviewer; statistical reviewer if data presented; MSHA reviewer if content may have impact on current or pending regulations; external NIOSH reviewer if potential impact on other NIOSH projects
Branch Chief reviews Technology News package for policy issues
If reviewers needed, Lab Assoc. Director for Science coordinates sending manuscript out for review
Author reconciles **all** reviewer comments & writes letters to reviewers addressing their comments
Section Chief reviews *Technology News Package* to ensure **all** reviewer comments have been addressed
Branch Chief reviews *Technology News Package*
Approved
Branch Chief - forwards *Technology News Package* to Technical Writer/Editor for editing
Technical Writer/Editor forwards *Technology New Package* back to Branch Chief for final content review
Branch Chief - after final content review, forwards *Technology News Package* to Lab OD
Lab OD reviews *Technology News Package* for policy (if needed to ensure all reviewer comments have been addressed, correct number and types of reviewers); generates **OD Transmittal Form**
Approved


Assoc. Director for Mining and Construction reviews *Technology News Package* for technical content and policy
Approved
Assoc. Director for Mining and Construction forwards *Technology News Package* to Assoc. Director for Health Communications
Package includes OD Transmittal Form, manuscript, review forms and reviewer comments, and author responses
Assoc. Director for Health Communications reviews package for Look/Feel, photos, figures
Approved
Technology News Package sent from Assoc. Director for Health Communications to Printing & Distribution for layout and author's proof
Author reviews proof; if approved, Technology News is published
Publication information entered into NIOSHTIC2 database
PDF of manuscript sent from Printing & Distribution to Mining Web Coordinator for web posting

Video Products




Lab Director presents Topic Concept Memo to NIOSH Lead Team
Approved by NIOSH Lead Team
Does content require collaboration with MSHA, manufacturers, or other outside groups?
YES
Author meets with outside groups to discuss concept and solicit ideas and input on content
NO
Author consults with Health Communications team and Chuck Urban for developing storyboard, script, outline of printed materials, packaging, and identifying video segments
Author presents draft storyboard, script, outline of printed materials, and identified video segments to Section Chief and Branch Chief; Section Chief and Branch Chief recommend changes to content as needed
Author presents revised draft storyboard, script, outline of printed materials, and identified video segments to Lab OD, Assoc. Director for Mining and Construction, and Assoc. Director for Health Communications via Envision; Lab OD, Assoc. Director for Mining and Construction, and Assoc. Director for Health Communications recommend changes to content as needed
Lab Assoc. Director for Science coordinates sending out draft storyboard, script, printed materials outline, and identified video segments for review
Reviewers determined at time Topic Concept Memo is written. Must have minimum of 2 external and 1 internal reviewer; statistical reviewer if data presented; MSHA reviewer if content may have impact on current or pending regulations; external NIOSH reviewer if potential impact on other NIOSH projects
Author reconciles all reviewer comments & writes letters to reviewers addressing their comments
Author, health communications team, and Chuck Urban work together to develop video, printed materials, and packaging


Author prepares *Video Product Package* (Publication/Presentation Clearance Form CDC 0.576, storyboard, script, outline of printed materials, printed materials, video, and packaging
Section Chief reviews final *Video Product Package* (video, packaging, and printed materials) to ensure **all** reviewer comments have been addressed
Approved
Branch Chief reviews *Video Product Package*
Approved
Branch Chief - forwards *Video Product Package* to Technical Writer/Editor for editing of printed materials
Lab OD reviews *Video Product Package* to ensure all reviewer comments have been addressed; generates **OD Transmittal Form**
Approved
Assoc. Director for Mining and Construction reviews package for technical content and policy
Approved
Assoc. Director for Mining and Construction forwards package to Assoc. Director for Health Communications
Package includes OD Transmittal Form, printed materials, video, packaging, review forms and reviewer comments, and author responses
Assoc. Director for Health Communications reviews package
Approved
Complete video package finalized and prepared for production
Publication information entered into NIOSHTIC2 database
Send video and documentation to Mining Web Coordinator for web posting