National Strategy for Personal Protective Technologies Research for Manufacturing

A DRAFT Prepared for NIOSH

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March 1, 2006

This draft is formatted into four parts: an overview, assessment, research plan, and appendixes. The assessment is structured using the five questions that NIOSH is using for its NORA town hall meetings, and the research plan is structured similar to the White House strategy for preventing a pandemic.

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National Strategy for Personal Protective Technologies Research for Manufacturing

"Providing National and World Leadership to Prevent Illnesses and Injuries"

Overview

Every day, in nearly every type of U.S. work setting, personal protective technologies are used to reduce workers' risk of job-related injury, illness, and death. These technologies include personal protective devices such as respirators, chemical-resistant clothing, hearing protectors, and safety goggles and glasses that provide a barrier between the worker and an occupational safety or health risk. In particular, respirators are a required component of many occupational safety and health programs, and may represent a worker's last line of defense against exposure to toxic fumes, vapors, or dust. More generally, personal protective equipment (PPE) is a last line defense after engineering controls.

PPE are tools that ensure the basic health protection and safety of users. PPE is any device designed to be worn by an individual when exposed to one or more safety and health hazards. PPE includes all clothing and other work accessories designed to create a barrier against or restraints from workplace hazards, and using PPE requires hazard awareness and training on the part of the user. Employees must be aware that the equipment does not eliminate the hazard; if the equipment fails, exposure will occur. To reduce the possibility of failure, equipment must be properly fitted and maintained in a clean and serviceable condition. Personal protective technologies also include devices that provide a worker with early warning of a hazard or otherwise help keep the worker safe from harm, such as sensors that detect toxic atmospheres and communication devices used for safe deployment of emergency workers.

At the request of the Congress, the National Institute for Occupational Safety and Health (NIOSH) established the National Personal Protective Technology Laboratory (NPPTL) in Pittsburgh, PA in 1999.[1] NPPTL focuses expertise from many scientific disciplines to advance federal research on respirators and other personal protective technologies for workers. NPPTL's efforts are essential for applying state-of-the-art science to meet the increasingly complex occupational safety and health challenges of the 21st Century. NPPTL's strategic research program ensures that the development of new PPE keeps pace with employer and worker needs as work settings and worker populations change and new technologies emerge. NPPTL research also responds to the need for effective protective technologies for first responders in terrorist events and other disasters. NPPTL incorporates NIOSH's longstanding program for testing and approving respirators for use in traditional work settings.

The mission of NPPTL is to prevent work-related illness and injury by ensuring the development, certification, deployment, and use of PPE and fully integrated, intelligent ensembles. This will be accomplished through the advancement and application of personal protective technology standards.

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[1] *Senate Rpt. 106-293 Departments of Labor, Health and Human Services, and Education and Related Agencies Appropriation Bill, 2001 Filed Under Authority of the Order of the Senate January 6, 1999*,

Assessment

1. Who is most at risk?

Manufacturing is a diverse sector representing more than 14 million workers engaged in the production of commodities such as food, textiles, chemicals, machinery, metals, electrical equipment, and nanomaterials. The manufacturing industry is comprised of 21 subsectors as shown in Table 1 and described in Appendix 1. The manufacturing sector involved establishments engaged in the mechanical, physical, or chemical transformation of materials, substances, or components into new products. Manufacturing occurs in plants, factories, or mills but may include transformed materials or substances by hand or in the worker's home. The following activities are considered to be within the boundary of manufacturing: milk or water bottling, fish packaging, ready-mixed concrete production, prescription lenses grinding; wood preserving, electroplating or lapidary for the trades; fabricating signs, rebuilding machinery, ship repair, machine shops, and tire retreading.

Table 1. List of Manufacturing Subsectors

Code*	Manufacturing Subsector	Goods Produced	Employment Jan. 2005	Rates, 2003‡	
				injury	illness
311	Food Manufacturing	Nondurable	1,484,700	**7.1**	**150.3**
312	Beverage & Tobacco Product Manufacturing	Nondurable	193,000	**10.3**	36.3
313	Textile Mills	Nondurable	227,400	4.4	56.5
314	Textile Product Mills	Nondurable	172,800	5.2	32.5
315	Apparel Manufacturing	Nondurable	271,600	3.1	49.9
316	Leather & Allied Product Manufacturing	Nondurable	40,100	**6.5**	**135.3**
321	Wood Product Manufacturing	Durable	556,800	**9.5**	54.1
322	Paper Manufacturing	Nondurable	490,200	4.4	44.6
323	Printing & Related Support Activities	Nondurable	653,000	4.2	30.3
324	Petroleum & Coal Products Manufacturing	Nondurable	111,800	2.5	27.0
325	Chemical Manufacturing	Nondurable	878,000	2.9	46.8
326	Plastics & Rubber Products Manufacturing	Nondurable	802,000	**6.9**	52.2
327	Nonmetallic Mineral Product Manufacturing	Durable	505,500	**7.4**	40.9
331	Primary Metal Manufacturing	Durable	467,400	**8.8**	**81.9**
332	Fabricated Metal Product Manufacturing	Durable	1,512,300	**8.0**	53.3
333	Machinery Manufacturing	Durable	1,150,100	**6.4**	55.1
334	Computer & Electronic Product Manufacturing	Durable	1,317,500	1.9	44.6
335	Electrical Equipment, Appliance Manufacturing	Durable	440,700	5.3	72.3
336	Transportation Equipment Manufacturing	Durable	1,766,600	**7.4**	**184.1**
337	Furniture & Related Product Manufacturing	Durable	571,700	**7.9**	**80.7**
339	Miscellaneous Manufacturing	Durable	654,200	4.4	60.7
30-31	Manufacturing		14,268,000	6.0	79.2

* North American Industry Classification System (NAICS)
‡ [**above average in bold**] injury rates per 100 employees/yr; illness rates per 10,000 employees/yr

Injury and illness rates provide a measure of the success of worker protection strategies. Those portions of industry with the highest rates indicate failures in protection and opportunities for research to intervene to improve the safety and health of these workers. Using 2003 data, Table 1 shows those subsectors of the manufacturing industry that exceed this average injury and illness rate.

Injuries

Beverage and Tobacco Product Manufacturing has the highest rate of injuries with 20,400 injuries per year. This is in contrast with lower rate of injuries/illnesses but higher frequency of 162,100 injuries/illnesses in Transportation Equipment, 129,100 in Food, and 123,500 in Fabricated Metal Product Manufacturing.

Eye Injuries

Each day about 2,000 U.S. workers, including manufacturing workers, have a job-related eye injury that requires medical treatment. About one third of the injuries are treated in hospital emergency departments and more than 100 of these injuries result in one or more days of lost work. The majority of these injuries result from small particles or objects striking or abrading the eye. Examples include metal slivers, wood chips, dust, and cement chips that are ejected by tools, wind blown, or fall from above a worker. Some of these objects, such as nails, staples, or slivers of wood or metal penetrate the eyeball and result in a permanent loss of vision. Large objects may also strike the eye/face, or a worker may run into an object causing blunt force trauma to the eyeball or eye socket. Chemical burns to one or both eyes from splashes of industrial chemicals or cleaning products are common. Thermal burns to the eye occur as well. Among welders, their assistants, and nearby workers, UV radiation burns (welder's flash) routinely damage workers' eyes and surrounding tissue.

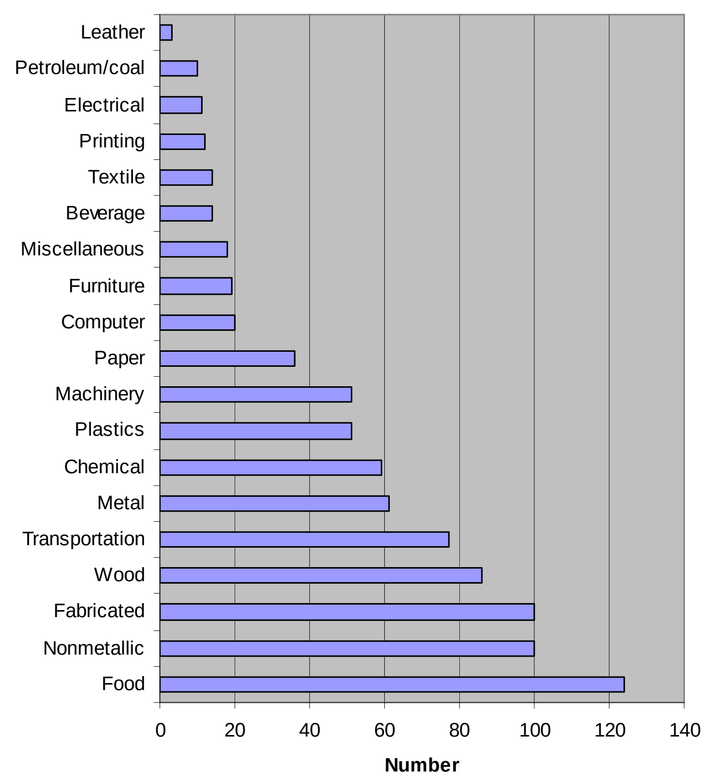
Illnesses

Apart from injuries as shown in Table 1, transportation equipment manufacturing followed by food then leather manufacturing had the highest rates of occupational illness.

Skin Exposures

Estimates indicate that more than 13 million workers, including manufacturing workers, in the United States are potentially exposed to chemicals that can be absorbed through the skin. A worker's skin may be exposed to hazardous chemicals through direct contact with contaminated surfaces, deposition of aerosols, immersion, or splashes. When substantial amounts of chemicals are absorbed, systemic toxicity can result. Contact dermatitis can also result when chemicals are absorbed through a worker's skin. Contact dermatitis is one of the most common chemically induced occupational illness, accounting for 10-15 percent of all occupational illnesses at an estimated annual cost to the nation of at least $1 billion.

Figure 1. Fatalities by Manufacturing Sector, 2003-04



2. How serious is the issue?

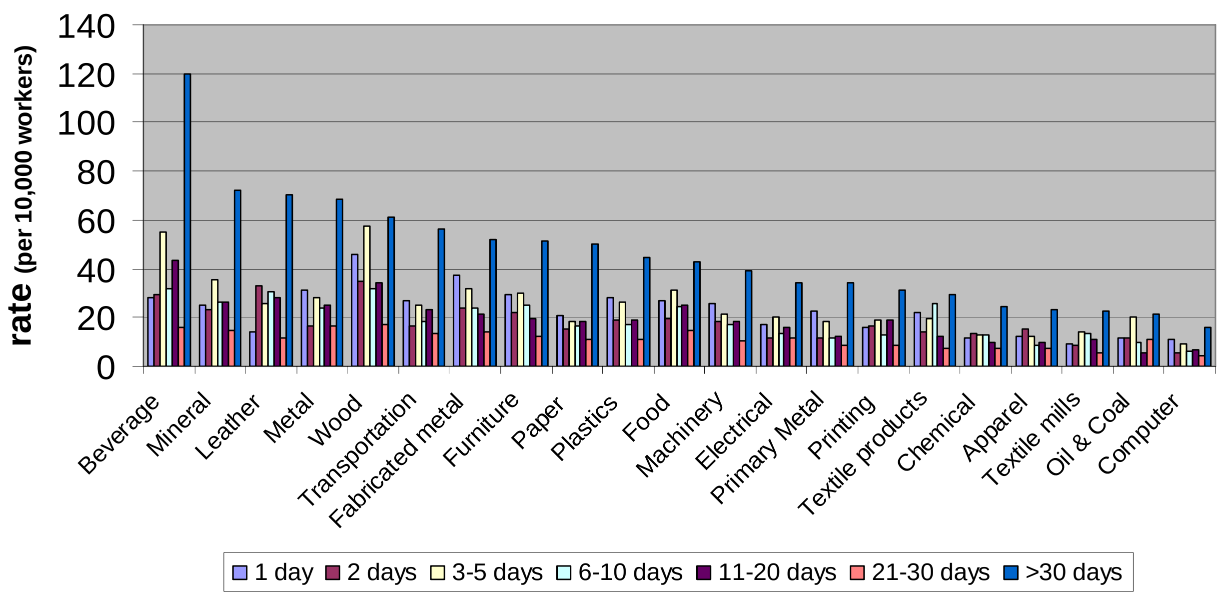
Fatalities

In 2004, the manufacturing sector recorded more than 400 work-related fatalities. Figure 1 shows the frequency of occupational fatalities for each of the manufacturing subsectors. The subsectors with the most fatalities include food, nonmetallic mineral product, fabricated metal product, wood product, and transportation equipment manufacturing subsectors.

Days Off Work

Figure 2 shows the ranking of severity of injuries (>30 days off work) by subsector in the manufacturing industry in the United States. *Beverage and Tobacco Product Manufacturing* leads the industry with the most severe injuries with 119.2 cases per 10,000 workers with more than 31 days off-of-work as a result of an injury as compared with the industry average of 43.5 days. Within this subsector, soft drink and bottled water manufacturing leads with the highest rates of injuries. After the beverage subsector, mineral, leather, primary metal, and wood manufacturing exhibit the most severe injuries.

Figure 2. Days off work related by injury
Rank ordered by more than 30 days off



Injury and illness characteristics of high severity and frequency industries are shown in Table 2. This table shows the manufacturing subsectors with the highest rates of injury and illness by their nature for which the highest rate was for sprains and strains.

Sprains and strains

The average rate of injury and illness for the manufacturing sector is 59.2 sprains and strains with the *beverage and tobacco product* subsector contributing nearly more than double this average rate at 176.1 injuries per 10,000 employees. The next highest rate was recorded from the wood manufacturing subsector.

Fractures

The average injury rate of fractures in the manufacturing sector is 11.7 injuries per 10,000 workers. The subsector with the highest rate of fracture injury is *wood manufacturing*. Within this subsector, mobile home and truss manufacturing have the highest rates. In addition to wood manufacturing, the beverage and primary metal subsectors also exhibit high injury rates.

Table 2. Injury Rates* by Nature of Injury or Illness and High Risk Subsectors

	Sector Average	Beverage	Wood	Primary Metal	Fabricat-ed Metal	Trans-portation	Food	Leather
Sprains/strains	59.2	176.1	96.7	71.0	65.9	79.7	62.0	56.5
Fractures	11.7	22.5	25.0	20.4	15.0	10.2	13.3	9.4
Cuts	15.7	13.1	46.9	18.9	24.1	12.8	14.9	25.9
Heat burns	2.7	4.7	2.5	10.3	4.2	0.7	4.5	4.7
Chemical burns	1.5	1.0	0.4	1.7	1.7	0.6	4.4	4.7
Amputations	2.6	-	5.4	3.4	5.9	1.0	3.0	-

*injuries and illnesses per 10,000 employees, 2003

Cuts

The average rate of injury from cuts in the manufacturing sector is 15.7 injuries per 10,000 workers. Triple this rate, *wood manufacturing* has a high rate of 46.9 cut injuries followed by leather at 25.9 and fabricated metal at 24.1 cut injuries. As described regarding fractures, within the wood subsector, mobile home and truss manufacturing have the highest injury rates.

Heat burns

Burns are a costly injury to treat.[2] The average rate of heat burn injuries in the manufacturing sector is 2.7 injuries per 10,000 workers. The *primary metal* subsector has more than triple this rate at 10.3 injuries.

Chemical burns

The average rate of chemical burns in the manufacturing sector is 1.5 injuries per 10,000 workers. However, both the *food and the leather manufacturing* subsectors exhibit triple this rate.

Amputations

The average rate of amputations in the manufacturing sector is 2.6 injuries per 10,000 workers. Two subsectors exceed twice this rate: *fabricated metal and wood* subsectors at a rate of 5.9 and 5.4 amputations, respectively. Each year there are an estimated 4.2-6.7 amputations per 10,000 workers in the metal fabrication trades in the United States.[3]

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2 Horwitz IB, McCall BP. Quantification and risk analysis of occupational burns: Oregon workers' compensation claims, 1990 to 1997. *J Burn Care Rehabil*. 2004 May-Jun;25(3):328-36.
3 Munshi K, Parker D, Samant Y, Brosseau L, Pan W, Xi M. Machine safety evaluation in small metal working facilities: an evaluation of inter-rater reliability in the quantification of machine-related hazards. *Am J Ind Med.* 2005 Nov;48(5):381-8.

3. What research is needed?

Incident Response

The Congress outlined the need for PPE research; "It has been brought to the Committee's attention the need for design, testing and state-of-the-art equipment for this nation's... miners, firefighters, health care, agricultural and industrial workers... (Also) the Committee encourages NIOSH to carry out research, testing and related activities aimed at protecting workers who respond to public health needs in the event of a terrorist incident. The Committee encourages CDC to organize and implement a national personal protective equipment laboratory."

Surveillance

More detailed investigations through surveillance methods are needed to identify and prioritize manufacturing technologies for research. These investigations include disaggregating the high risk areas in manufacturing by nature of injury and exposure further to gain better detail regarding the population at risk. PPE interventions can be identified by conducting case studies of investigation reports by OSHA and by NIOSH in their Health Hazard Evaluations (HHE's) and Fatality Assessment and Control Evaluation (FACE) Programs.

OSHA provides a rich source of recorded injuries that could be prevented with the use of PPE. As an example, OSHA inspection no. 115086662 at a Meat Packing Plant reported on an employee that was using a meat slicer to cut bacon when his hand slipped and part of his right thumb was sliced off. The grease from the bacon caused his hand to slip.

An example of an HHE is an investigation of exposures to isocyanates, inorganic acids, ammonia, solvents, lead, cutting fluids, and noise. This manufacturing plant was one of many plants around the world involved in the manufacture of engine control devices.[4] HHE's serve to identify needs for PPE where other controls are lacking.

The NIOSH FACE program investigates occupational fatalities, many of which could be prevented by the use of functional PPE. A 1997 NIOSH report summarized several of these investigations that related to confined spaces.[5] The report addressed atmospheric hazards including flammable and explosive gases, inert gases and asphyxiants, oxygen deficient air, and toxic gases. It also addressed physical hazards including engulfments, falls, electrocutions, and drownings. The FACE program can also identify PPE failures.[6]

Technology Assessments

There is a need to analyze technologies so that critical PPE needs with a standards perspective can be filled via research agendas for specific new technologies. Textile-based wearable electronics that can be integrated into military protective clothing are being developed, and these

4 McCammon-CS; Tubbs-RL; Reh-BD; Reh-CM. Health Hazard Evaluation Report HETA 97-0084-2669, Woodward Governor Company, Fort Collins, Colorado.

5 NIOSH. Worker Deaths in Confined Spaces: A Summary of NIOSH Surveillance and Investigative Findings. January, 1994. DHHS (NIOSH) Publication No. 94-103.

6 NIOSH. Worker Dies in 20,000 Gallon Gasoline Bulk Tank While Wearing Closed Circuit SCBA in Vermont. FACE-8509.

systems may be adaptable to manufacturing environments for monitoring human presence in complex operations.[7] Substantial research is underway regarding PPE to protect workers involved in removing mines in previous war-torn areas. These new technologies can have a broader benefit for other workers potentially exposed to explosions. Conversely, an emerging nanotechnology is presenting challenges to worker protection with particles that are so small that they can easily pass through existing protective clothing, and at the nanometer-level pass through HEPA filters as well (<3ηm). In addition, PPE imports from emerging global markets need to be evaluated.[8]

Intervention Research

There is a need to develop interventions to address knowledge gaps and develop efforts for broad adoption of successful PPE interventions in targeted manufacturing technologies. As mentioned above, there is a need to design respiratory and dermal protection for very small particles.

Sprains and strains receive scant attention from the PPE industry because of their association with overexertion. Nonetheless, PPE may have an important role to serve in reducing the severity of these injuries with creative applications of personal protective strategies to reduce overexertion—e.g., the contentious area of extra-skeletal bracing[9]—as well as other causes of sprains and stains, e.g., slips and falls.[10] Anthropometric information such as body size or body segment measurements of some occupational groups differs significantly.[11] Products that enter the market need to be evaluated for their efficacy and effectiveness, e.g., back or limb supports. In addition, personal protection devices for disabled workers also need to be evaluated. Body shields such as hard hats have been used to reduce fractures and other injuries.[12] Personal detection system innovations may offer solutions to amputations when other controls fail, such as saws equipped with a safety system that detects when someone accidentally contacts the spinning saw blade, and then stops the blade in milliseconds.[13]

Dermal exposures are another area requiring PPE research. Toxic hepatitis from dimethylacetamide occurred among employees on a new acrylic-fiber production line at a U.S. manufacturing plant in which inadequate personal protective equipment for dermal exposures was provided.[14] NIOSH found that approximately 60% of workers monitored were exposed to uncured epoxy resins, mostly to the arms, hands, and torso, as a result of deficient PPE in a

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7 Winterhalter CA, et al. 2005. Development of electronic textiles to support networks, communications, and medical applications in future U.S. military protective clothing systems. *IEEE Trans Inf Technol Biomed*. 9(3):402-6.

8 http://www.trade-india.com/TradeLeads/sell/Industrial_Supplies/Industrial_Clothing

9 Kraus, J., K. Brown, D. McArthur, C. Peek-Asa, L. Zhou, Reduction of Acute Low Back Injuries by Use of Back Supports. *International Journal of Occupational and Environmental Health*, 1996, pp. 264-273.

10 Manning, D.P. *Spine*, Volume 9, November 7, 1984.

11 Hsiao H, Long D, Snyder K. 2002. Anthropometric differences among occupational groups. *Ergonomics*. 45(2):136-152.

12 Makris A. Nerenberg J, "Full Scale Evaluation of Lightweight Personal Protective Ensembles for Demining in Providing Protection Against Blast-Type Anti-Personnel Mines," *Journal of Mine Action*, James Madison University, Harrisonburg, Va., Version 4.2, June 2000.

13 http://www.sawstop.com/how-it-works-overview.htm

14 Baum SL, Suruda AJ. 1997. Toxic Hepatitis from Dimethylacetamide. *Int J Occup Environ Health*. 3(1):1-4.

windblade manufacturing firm.[15] A study at munitions and pharmaceutical manufacturing sites found that the use of PPE was ineffective in preventing dermal absorption of nitroglycerin.[16] Research has been recommended into personal protective clothing to control contact dermatitis in the chemical manufacturing and processing industry.[17] A packer in a chicken factory developed campylobacteriosis from contaminated droplets into the mouth, and face masks were recommended as a control.[18] "Protection against the effects of heat and flame is available in the form of special clothing. But this clothing has to be matched carefully to the working environment, the job being done, and the individual wearer. Different clothing designs and materials are needed for different types of heat and flame protection. Clothing designed to protect against radiant heat may be totally unsuitable for use where there is a risk of molten metal splash; clothing protecting against splashes of molten iron may perform badly against molten aluminum."[19]

PPE Program Effectiveness

A PPE program must be comprehensive to be effective. It requires commitment and active participation at the planning, development, and implementation stages from all levels: senior management, supervisors, and workers. A good PPE program consists of several essential elements: workplace survey, selection of appropriate controls, selection of appropriate PPE, fitting, training, management support, and PPE storage, maintenance and care as well as auditing of the program. Research is needed to remove barriers to an effective program and develop methods to simplify the program.

Protection of Non-Production Personnel

In line-paced manufacturing assembly operations, hand laceration annual rate of 83/100 workers are progressively higher among workers assigned to less routine (more variable) work patterns, and PPE is seen as the appropriate strategy for preventing these lacerations.[20] The atypical worker in manufacturing such as contract workers, the trades, and repair and maintenance workers require increased personal protection.

Improve Existing PPE

Hazard reduction with the use of PPE to protect manufacturing workers needs continuous attention, not only to improve the protective technologies but also to improve the proper use and care for these technologies. Known hazards and PPE include the following (Also see Appendix 2):

- Lung and respiratory protection (inhalation) – dust, chemicals, fumes, aerosols

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15 Mattorano DA, Dowell CH. 2005. Assessing dermal exposures to epoxy resins in the windblade manufacturing industry. Occupational and Environmental Exposures of Skin to Chemicals, Stockholm, Sweden, June 12-15, 2005. Morgantown, WV: National Institute for Occupational Safety and Health, 2005.

16 Akrill P, et al. 2002. Biological monitoring of nitroglycerin exposure by urine analysis. *Toxicol Lett*. 134(1-3):271-6.

17 Sen D et al, 2001. Self-reported skin problems among physical processors in the chemical industry in Great Britain. *Occup Med (Lond)*. 51(1):12-24.

18 Wilson IG. 2004. Airborne *Campylobacter* infection in a poultry worker: case report and review of the literature. *Commun Dis Public Health*. 7(4): 349-53.

19 http://www.hsl.gov.uk/capabilities/ppe_heat.htm

20 Bell JL, MacDonald LA. 2003. Hand lacerations and job design characteristics in line-paced assembly. *J Occup Environ Med*. 45(8):848-56.

- Whole body protection – air supplied suit (corrosive environment), encapsulating suit
- Skin and dermal protection – protective clothing and garments around toxic and irritating chemicals, heat, hot metal, flame-retardant clothing, cold
- Electromagnetic radiation – electromagnetic radiation suit
- Hand protection – gloves, barrier creams, hand leathers, and arm protectors
- Foot protection – safety shoes and boots with non-slip soles and heels
- Head and hair protection – hard hats, hair nets, cold
- Eye and vision protection – protective eyewear, welding helmets, laser protection (with caution)
- Hearing protection – acoustic earmuffs and plugs
- Electrical protection – insulated gloves, clothing, tools
- Slaughterhouse worker protection – chain link mail aprons and vests, Plexiglas arm guards, gloves, face mask or shield, sanitary outer garment, plastic hardhat, hair net, ear plugs, goggles, liquid-repelling sleeves, apron and leggings, safety boots or shoes (and weight belt?)
- Body loads or impacts – shoulder pads, padded aprons, shin guards, knee pads, gloves
- Fall protection – lifelines, body support

4. Who are our partners?

PPE Manufacturing Industry

A significant partner in PPE research is the PPE manufacturing and marketing industry. As an example, NIOSH held a meeting for all respirator manufacturers on December 12, 2005, at the NIOSH site in Pittsburgh, Pennsylvania. The meeting addressed replacement rates, and alternatives to the silica dust tests for powered, air-purifying respirators (PAPRs), labeling for filtering face piece respirators, and other topics and included a Standard Application Procedures Workshop. Manufacturer representatives attended. One organization representing this industry is the International Safety Equipment Association.

Professional and Standard-setting Organizations

Professional organizations also provide viable partners in PPE research. These include the National Safety Council, American Conference of Governmental Industrial Hygienists, American Industrial Hygiene Association, and American Society of Safety Engineers. Standard-setting organizations include the American National Standards Institute, American Society of Testing Materials, European Committee for Standardization, International Organization for Standardization, National Fire Protection Association, and Standards Council of Canada. Several PPE standards that apply to manufacturing industry workers are listed in Appendix 3.

Manufacturing Trade Organizations

The manufacturing industry and its many trade organizations also provide opportunities for partnership. These organizations include the Advanced Manufacturing Leadership Forum, which is a body of leaders from business, research, education and governmental organizations. The Forum provides policy advice and research guidance to the National Council for Advanced Manufacturing on strategies for the success of U.S.-based manufacturing in a new industrial era.

Governmental Agencies

Another partner is the Occupational Safety and Health Administration (OSHA)[21] with its agreements with industrial entities such as through its Voluntary Protection Program. In addition, the Department of Commerce[22] is an important partner as it leads the United States effort for a more competitive manufacturing sector. The National Science Foundation is another potential partner as it funds collaborative university-business programs. Important research regarding PPE is also performed by the Defense Advanced Research Projects Agency of the Department of Defense and the Department of Homeland Security.

5. How can we make a difference?

Emergency Preparedness

The attacks of September 11, 2001 have demonstrated the need for improved PPE. Improvements are needed in PPE ensembles, guidelines, and effective delivery systems of equipment. There is also a need for quick access to expert information regarding complex emergencies.[23] Communications are an important adjunct to the PPE ensemble as well.

NORA I Priorities

An original NORA priority addressed PPE. That priority addressed chemical protective clothing, noise, respirators, and eye safety. NIOSH's Protective Clothing Program is aimed at protecting the skin from various health hazards that may be encountered in the workplace or during a terrorist attack. The program has evolved over the years to incorporate a broad range of studies of how chemicals seep through barrier materials, leak through small holes, or change the barrier material to reduce its protection

Noise-induced hearing loss is 100 percent preventable but once acquired, hearing loss is permanent and irreversible. Non-linear hearing protectors (NLHPs) have been developed to provide improved communication and ability to hear warning signals while protecting workers from hazardous noise. However, the existing American and international standards for testing linear hearing protectors cannot address the performance and effectiveness of nonlinear (level dependent and active noise cancellation) devices. NIOSH is developing standardized laboratory test methods for acoustic and psycho-acoustic assessment of NLHPs, which addresses the shortcomings of current ANSI and ISO standards.

Respirators protect the user in two basic ways. The first is by the removal of contaminants from the air. Respirators of this type include particulate respirators, which filter out airborne particles; and "gas masks" which filter out chemicals and gases. Other respirators protect by supplying clean respirable air from another source. Respirators that fall into this category include airline

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21 Wallace WJ. Performing the PPE Hazard Analysis. *Occupational Safety and Health*. 2005;74(12):60, 62.

[22] U.S. Department of Commerce. 2004. *Manufacturing in America: A Comprehensive Strategy to Address the Challenges to U.S. Manufacturers*. Washington, DC: U.S. Government Printing Office. http://www.ita.doc.gov/media/Publications/pdf/manuam0104final.pdf

23 Groves WA, Ramani RV, Radomsky MC, Flick JP. Protecting First Responders: Analysis of PPE Guidelines Distributed at the World Trade Center and Pentagon Disaster Sites. *Professional Safety*. 2004;49(11):31-41.

respirators, which use compressed air from a remote source; and self-contained breathing apparatus, which include their own air supply

Personal protective eyewear, such as goggles, face shields, safety glasses, or full face respirators must also be used when an eye hazard exists. The eye protection chosen for specific work situations depends upon the nature and extent of the hazard, the circumstances of exposure, other protective equipment used, and personal vision needs. Eye protection should be fit to an individual or adjustable to provide appropriate coverage. It should be comfortable and allow for sufficient peripheral vision. Selection of protective eyewear appropriate for a given task should be made based on a hazard assessment of each activity, including regulatory requirements when applicable.

Training

Training to respond to emergencies requires planning and evaluation. PPE is critical is part of this response. Common emergencies include fires, medical emergencies, HazMat releases, special rescues (e.g., confined space), workplace violence, bomb threats, external emergencies, weather and power failure.[24] Safety signs have been found to be ineffective in encouraging the donning of PPE.[25] An example of a need is to understand the differences between primary and secondary clothing. Primary clothing is used when the exposure is significant, e.g., molten substance splashes, radiant heat and flame. Secondary protective clothing is designed for continuous wear.[26] Failures or deficiencies in hearing conservation programs can often be traced to inadequacies in the training and education of noise-exposed employees and those who conduct elements of the program.

Research Plan

In addition to the above assessment, an important aspect of this *Research Plan* is to provide a framework for future U.S. Government planning efforts that is consistent with *The National Security Strategy* and the *National Strategy for Homeland Security*. It recognizes that preparing for and responding to emergencies cannot be viewed as a purely federal responsibility, and that the nation must have a system of plans at all levels of government and in all sectors outside of government that can be integrated to address the threat of emergencies whether small or catastrophic. It is guided by the following principles:

• Engineering control or inherently safer systems should be used to negate the need for PPE. PPE should only be used as a "last line of defense" when engineering control systems or hazard elimination are not feasible.
• Employers should have credible preparedness plans to respond to PPE needs within their workplaces. Individual workers should be prepared for the use of PPE and be trained in the use of PPE for their particular working conditions.
• The private sector should play an integral role in PPE research and development and should be part of the national deployment of PPE technologies.

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24 Schroll RC. Emergency Response Training: How to Plan, Conduct, and Evaluate for Success. *Professional Success*. 2002;47(12):16-21.
25 Young SL, Franz JP, Rhoades TP, Darnell KR. Safety Signs and Labels. *Professional Safety*. 2002;47(9)18-23.
26 Gojdics R. Personal protective clothing: purchasing flame-resistant secondary clothing. *Professional Safety*. 2002;47(10):56-57.

• Partnerships will be leveraged to address the threat of uncontrolled hazards, especially the threat of terrorist attacks.
• Three criteria are important in assessing the need for PPE research:
  ► Frequency of the occupational safety and health problem.
  ► Severity of the occupational safety and health problem.
  ► The preventability of the problem with PPE.

The *Research Plan* addresses the full spectrum of manufacturing workplaces from small fabrication shops to large factories, mills, or processing plants in America. While the circumstances of these environments are very different, our strategic principles remain relevant. Four pillars of the *Research Plan* are described below:

Pillar 1. Surveillance

Occupational health surveillance can be viewed as the tracking of occupational injuries, illnesses, hazards, and exposures. Occupational surveillance data are used to guide efforts to improve worker safety and health, and to monitor trends and progress over time. This effort will analyze and interpret existing data, undertakes data collection efforts to fill gaps in surveillance data, provides support to state agencies to conduct occupational surveillance and associated prevention efforts, and works with Federal, State, and private sector partners to improve occupational health surveillance.

Goal: To set priorities for further surveillance and research.

Priorities under this goal include:

■ ***Investigate high risk subsectors and populations for injuries and illnesses that can be prevented with PPE.***

■ ***This surveillance effort involves the review and monitoring of HHEs, FACE, and OSHA inspection reports regarding manufacturing to identify severe injuries and illnesses that PPE could prevent and PPE failures to protect workers.***

■ ***The emergence of new technologies need to be evaluated for both potential hazards as well as use in PPE.***

Pillar 2. Standardization and Certification

NIOSH is developing appropriate standards and test procedures for PPE used to protect workers in hazardous environments. This development work includes the validation of performance-based PPE specifications including shelf life. Concepts, standards (when fully developed), and other documents will be posted when they become available. This development work involves international collaboration in PPE standards as well as with partners from government and industry.

Goal: To establish voluntary standards or 42 CFR certification programs for PPE.

One priority under this goal includes:

■ ***NIOSH issues recommendations for respirator use. Industrial type approvals are in accordance to the NIOSH federal respiratory regulations 42 CFR Part 84.***

Pillar 3. Product Development and Evaluation

PPE such as respirators and protective clothing can be used to isolate workers from the hazard. PPE must not only be effective, but also practical for use in the workplace. PPE must be designed and made available to properly fit and protect the growing numbers of female, minority, and disabled workers. Microsensing devices assess workers' exposure to environmental contaminants, notify workers before chemicals break through protective clothing, and identify failures in containment systems for hazardous materials. New materials in clothing would improve the protection of workers from burns, explosions, and hazardous chemicals. In addition to field surveys of chemical protective clothing (CPC) performance, studies need to examine ways to detect when chemicals have gotten inside CPC, and how to effectively remove chemicals from protective clothing after it has been contaminated. PPE research includes literature searches and data gathering, laboratory and field studies, and materials, shelf-life and design evaluations.

Goal: To incorporate advanced protective technologies into fully-integrated, intelligent, and reliable ensembles.

Goal: To collaborate with partners in the development of PPE to protect workers from high risk, frequency and/or severity hazards.

Priorities under this goal include:

■ ***Continuation of ongoing research, e.g., hearing protectors, respirators, protective clothing, eye protection.***

■ ***Investigation and evaluation of PPE emerging into the marketplace, e.g., barrier creams, extra-skeletal braces, personal detection monitors, armor, personal restraints.***

■ ***Investigation of test methods for PPE effectiveness for different anthropomorphic characteristics.***

Pillar 4. Education, Training, and Feedback

The purpose of training and training-related research is to understand and act on the multiple factors influencing occupational education and training effectiveness. NIOSH evaluates the impact of training programs and their components by investigating theoretical models gleaned from health promotion, psychology, learning and educational perspectives, the role of attitudes, beliefs, behavioral intentions, and other characteristics of the individual that affect learning and transfer of learning into action, barriers affecting adoption of health and safety behaviors promoted by training, and environmental influences on occupational safety and health training.

Goal: To improve and implement PPE training programs, guidelines, and products for optimum use and acceptance by workers.

Appendix 1: Manufacturing Subsector Descriptions

311 Food Manufacturing: Food Manufacturing transforms livestock and agricultural products into products for intermediate or final consumption. The industry groups are distinguished by the raw materials (generally of animal or vegetable origin) processed into food products. The food products manufactured in these establishments are typically sold to wholesalers or retailers for distribution to consumers, but establishments primarily engaged in retailing bakery and candy products made on the premises not for immediate consumption are included.

312 Beverage and Tobacco Product Manufacturing: Beverage and Tobacco Product Manufacturing produces beverages and tobacco products. Beverage Manufacturing includes three types of establishments: (1) those that manufacture nonalcoholic beverages; (2) those that manufacture alcoholic beverages through the fermentation process; and (3) those that produce distilled alcoholic beverages. Tobacco Manufacturing includes two types of establishments: (1) those engaged in redrying and stemming tobacco and, (2) those that manufacture tobacco products, such as cigarettes and cigars.

313 Textile Mills: Textile Mills subsector transform a basic fiber (natural or synthetic) into a product, such as yarn or fabric, that is further manufactured into usable items, such as apparel, sheets towels, and textile bags for individual or industrial consumption. The main processes in this subsector include preparation and spinning of fiber, knitting or weaving of fabric, and the finishing of the textile.

314 Textile Product Mills: Textile Product Mills make textile products (except apparel). With a few exceptions, processes used in these industries are generally cut and sew (i.e., purchasing fabric and cutting and sewing to make nonapparel textile products, such as sheets and towels).

315 Apparel Manufacturing: Apparel Manufacturing has two distinct processes: (1) cut and sew (i.e., purchasing fabric and cutting and sewing to make a garment), and (2) the manufacture of garments in establishments that first knit fabric and then cut and sew the fabric into a garment.

316 Leather and Allied Product Manufacturing: Leather and Allied Product Manufacturing transform hides into leather by tanning or curing and fabricating the leather into products for final consumption. It also includes the manufacture of similar products from other materials, including products (except apparel) made from "leather substitutes," such as rubber, plastics, or textiles. Rubber footwear, textile luggage, and plastics purses or wallets are examples of "leather substitute" products included in this group.

321 Wood Product Manufacturing: Wood Product Manufacturing make wood products, such as lumber, plywood, veneers, wood containers, wood flooring, wood trusses, manufactured homes (i.e., mobile home), and prefabricated wood buildings. The production processes of the Wood Product Manufacturing subsector include sawing, planing, shaping, laminating, and assembling of wood products starting from logs that are cut into bolts, or lumber that then may be further cut, or shaped by lathes or other shaping tools.

322 Paper Manufacturing: Paper Manufacturing makes pulp, paper, or converted paper products. The manufacturing of pulp involves separating the cellulose fibers from other impurities in wood or used paper. The manufacturing of paper involves matting these fibers into a sheet. Converted paper products are made from paper and other materials by various cutting and shaping techniques and includes coating and laminating activities.

323 Printing and Related Support Activities: Printing and Related Support Activities print products, such as newspapers, books, labels, business cards, stationery, business forms, and other materials, and perform support activities, such as data imaging, platemaking services, and bookbinding. Processes used in printing include a variety of methods used to transfer an image from a plate, screen, film, or computer file to some medium, such as paper, plastics, metal, textile articles, or wood.

324 Petroleum and Coal Products Manufacturing: Petroleum and Coal Products Manufacturing is based on the transformation of crude petroleum and coal into usable products. The dominant process is petroleum refining that involves the separation of crude petroleum into component products through such techniques as cracking and distillation. In addition, this subsector includes establishments that primarily further process refined petroleum and coal products and produce products, such as asphalt coatings and petroleum lubricating oils.
325 Chemical Manufacturing: Chemical Manufacturing is based on the transformation of organic and inorganic raw materials by a chemical process and the formulation of products. This subsector distinguishes the production of basic chemicals from the production of intermediate and end products produced by further processing of basic chemicals.
326 Plastics and Rubber Products Manufacturing: Plastics and Rubber Products Manufacturing make goods by processing plastics materials and raw rubber. The core technology employed by establishments in this subsector is that of plastics or rubber product production. Plastics and rubber are combined in the same subsector because plastics are increasingly being used as a substitute for rubber.
327 Nonmetallic Mineral Product Manufacturing: Nonmetallic Mineral Product Manufacturing transforms mined or quarried nonmetallic minerals, such as sand, gravel, stone, clay, and refractory materials, into products for intermediate or final consumption. Processes used include grinding, mixing, cutting, shaping, and honing. Heat often is used in the process and chemicals are frequently mixed to change the composition, purity, and chemical properties for the intended product. For example, glass is produced by heating silica sand to the melting point and then drawn, floated, or blow molded to the desired shape or thickness.
331 Primary Metal Manufacturing: Primary Metal Manufacturing smelt and/or refine ferrous and nonferrous metals from ore, pig or scrap, using electrometallurgical and other process metallurgical techniques. Establishments in this subsector also manufacture metal alloys and superalloys by introducing other chemical elements to pure metals.
332 Fabricated Metal Product Manufacturing: Fabricated Metal Product Manufacturing transform metal into intermediate or end products, other than machinery, computers and electronics, and metal furniture or treating metals and metal formed products fabricated elsewhere. Important fabricated metal processes are forging, stamping, bending, forming, and machining, used to shape individual pieces of metal; and other processes, such as welding and assembling, used to join separate parts together.
333 Machinery Manufacturing: Machinery Manufacturing creates end products that apply mechanical force, for example, the application of gears and levers, to perform work. Some important processes for the manufacture of machinery are forging, stamping, bending, forming, and machining that are used to shape individual pieces of metal. Processes, such as welding and assembling are used to join separate parts together. Machinery manufacturing typically employs multiple metal forming processes in manufacturing the various parts of the machine.
334 Computer and Electronic Product Manufacturing: Computer and Electronic Product Manufacturing makes computers, computer peripherals, communications equipment, and similar electronic products, and establishments that manufacture components for such products. The design and use of integrated circuits and the application of highly specialized miniaturization technologies are common elements in the production technologies of the computer and electronic subsector.
335 Electrical Equipment, Appliance, and Component Manufacturing: Electrical Equipment, Appliance, and Component Manufacturing make products that generate, distribute and use electrical power. These establishments produce electric lamp bulbs, lighting fixtures, and parts and both small and major electrical appliances and parts.
336 Transportation Equipment Manufacturing: Transportation Equipment Manufacturing produces equipment for transporting people and goods. Transportation equipment is a type of machinery. Establishments in this subsector utilize production processes similar to those of

other machinery manufacturing establishments - bending, forming, welding, machining, and assembling metal or plastic parts into components and finished products.

337 Furniture and Related Product Manufacturing: Furniture and Related Product Manufacturing makes furniture and related articles, such as mattresses, window blinds, cabinets, and fixtures. The processes used in the manufacture of furniture include the cutting, bending, molding, laminating, and assembly of such materials as wood, metal, glass, plastics, and rattan.

339 Miscellaneous Manufacturing: Industries in the Miscellaneous Manufacturing subsector make a wide range of products that cannot readily be classified in specific NAICS subsectors in manufacturing. Processes used by these establishments vary significantly, both among and within industries and differ from each other, and the processes differ significantly from the fabrication processes used in making dolls or toys, the melting and shaping of precious metals to make jewelry, and the bending, forming, and assembly used in making medical products.

Appendix 2: Risk Assessment and PPE Results for Manufacturing27

In the United Kingdom, an employer has a duty to provide suitable protective equipment (PPE) to employees, except where risks have been adequately controlled by other equally, or more effective, means. PPE is to be used as a last resort in which steps have been taken to remove hazards or control risks by means of safer processes, systems or conditions. PPE must be appropriate for the risks and conditions involved, capable of fitting the worker after adjustment, and effective in controlling the risk. Risks and PPE countermeasures in manufacturing are identified below.

Risks Associated with Manufacturing Exposures

Setting	Hazard	Risk	PPE Countermeasure
Drill, lathe, milling machine	Sharp swarf	Cuts	Hand protection
	Flying fragment	Eye injury	Eye protection
	Coolants	Dermatitis	Barrier creams
Electrical hand tools	Sharp swarf	Cuts	Hand protection
	Flying fragment	Eye injury	Eye protection
	Dust	Inhalation	Respiratory protection
Grinding wheels	Sparks/fragments	Eye injury	Eye protection
	Wheel bursting	Flying fragments	Eye shields
CNC machine	Sharp swarf	Cuts	Hand protection
	Coolants	Dermatitis	Barrier creams
Welding	Arc	Arc eye	Welding visor
	Flame/heat	Burns	Protective clothing
	Fumes	Inhalation injury	Air-fed visor
	Flying fragment	Eye injury	Visors
Miscellaneous machinery	Moving machine table	Trapping/crushing	Pressure-sensitive mat
	Hot parts	Burns	Protective clothing
	Ejected parts	Eye injury, etc.	Eye protection
Sawing machines	Noise	Hearing damage	Hearing protection
Planning, surfacing, etc	Noise	Hearing damage	Hearing protection
Sanding machines	Noise	Hearing damage	Hearing protection
Toxic substance	Toxic	See data sheet	Respiratory protection
Asbestos	Airborne fibers	Asbestosis, cancer	Respiratory protection
Lead	Absorption, inhalation	Poisoning	Respiratory protection
	Absorption, inhalation	Poisoning	Personal exposure monitoring
General dusts	Inhalation	See data sheet	Respiratory protection Personal exposure monitoring
Biological agents	Bacteria, viruses, fungi, parasites	Infection, allergy, or toxicity	Respiratory protection Personal exposure monitoring
Carcinogens	Cancer-causing	See data sheet	Respiratory protection Personal exposure

27 Siebert I. 2003. Tolley's *Risk Assessment Workbook Series: Manufacturing*. LexisNexis UK, Reigate, Surrey: Reed Elsevier.

			monitoring
Respiratory sensitizers	Inhalation of sensitizer	Asthma	Respiratory protection Personal exposure monitoring
Load handling	Harmful (sharp, hot)	Injury	Protective clothing, shoes
Ionizing radiation	X-rays	Cancer	PPE & warning devices
	Gamma rays	Cell damage	PPE
Optical radiation	Lasers	Eye damage, burns	PPE

Appendix 3: Applicable standards and standards setting organizations

U.S. Department of Human Services
NIOSH
42 CFR PART 84, Approval of respiratory protective devices
U.S. Department of Labor (DOL)
Occupational Safety and Health Administration
29 CFR 1910 – Occupational Safety and Health Standards

- 1910.95 – Hearing Protection
- Subpart I – Personal Protective Equipment
- 1910.132 – General requirements
- 1910.133 – Eye and face protection
- 1910.134 – Respiratory protection
- 1910.135 – Head protection
- 1910.136 – Foot protection
- 1910.138 – Hand protection
- 1910.137, 335 – Electrical workers' clothing and equipment
- 1910.146 – Permit-required confined spaces
- 1910.156 – Fire brigades
- 1910.1001 – Asbestos
- 1910.1018 -- Inorganic arsenic
- 1910.1025 – Lead
- 1910.1027 – Cadmium
- 1910.1028 – Benzene
- 1910. 1030 – Bloodborne pathogens
- 1910.1044 – 1,2-Dibromo-3-chloropropane
- 1910.1045 – Acrylonitrile
- 1910.1047 – Ethylene oxide
- 1910.1048 – Formaldehyde
- 1910.1050 – Methylenedianiline
- 1910.1051 – 1,3-Butadiene
- 1910.1052 – Methylene chloride

U.S. Environmental Protection Agency
40 CFR 211 hearing protector label requirements
American National Standards Institute
ANSI Z88.7-2001, Color Coding of Air-Purifying Respirator Canisters, Cartridges, and Filters
ANSI Z88.10-2001, Respirator Fit Testing Methods
ANSI Z 88.2-1969, Standard Practice for Respirator Protection
ANSI Z41.1-1991, Protective Footwear
ANSI S12.6-1997, Methods for Measuring the Real-Ear Attenuation of Hearing Protectors
ANSI Z87.1-2003, Standard for Occupational and Educational Eye and Face Protection Devices
ANSI Z49.1:2005, Safety in Welding and Cutting
ANSI Z359.1-1992, Safety Requirements for Personal Fall Arrest Systems, Sub-Systems and Components
ANSI Z89.1, Safety Requirements for Industrial Head Protection
ANSI Z89.2, Safety Requirements for Industrial Protective Helmets for Electrical Workers
ANSI Z136.1, Laser Safety Standards
ANSI J6.6-1971, Rubber Insulating Gloves

ANSI/ASSE Z359.1 Safety Requirements for Personal Fall Arrest Systems

American Society for Testing Materials

ASTM F23 Protective Clothing

ASTM F1959 Standard Test Method for Determining the Arc Thermal Performance Value of Material for Clothing

ASTM 1930 Standard Test Method for Evaluation of Flam-Resistant Clothing for Flash Fire Simulations Using Instrumented Manikins

ASTM F955 Standard Test Method for Evaluating Heat Transfer through Materials for Protective Clothing Upon Contact with Molten Substances

International Organization for Standardization

ISO 13.340.01 Protective equipment in general

ISO 13.340.10 Protective clothing, Including flameproof clothing

ISO 13.340.20 Head protective equipment, Including helmets, eye-protectors, hearing protectors, ear muffs, teeth protectors and hoods.

ISO 13.340.30 Respiratory protective devices

ISO 13.340.40 Hand and arm protection, Including protective gloves, sleeves and mits

ISO 13.340.50 Leg and foot protection, Including safety boots and shoes

ISO 13.340.60 Protection against falling and slipping, Including safety ropes, harnesses and fall arrestors

ISO 13.340.99 Other protective equipment

ISO 3873:1977 Industrial safety helmets

ISO 4007:1977 Personal eye-protectors, Vocabulary

ISO 4849:1981 Personal eye-protectors, Specifications

ISO 4850:1979 Personal eye-protectors for welding and related techniques, Filters, Utilization and transmittance requirements

ISO 4851:1979 Personal eye-protectors, Ultra-violet filters, Utilization and transmittance requirements

ISO 4852:1978 Personal eye-protectors, Infra-red filters, Utilization and transmittance requirements

ISO 4854:1981 Personal eye-protectors, Optical test methods

ISO 4855:1981 Personal eye-protectors, Non-optical test methods

ISO 4856:1982 Personal eye-protectors, Synoptic tables of requirements for oculars and eye-protectors

ISO 4869-1:1990 Acoustics, Hearing protectors, Part 1: Subjective method for the measurement of sound attenuation

ISO 4869-2:1994 Acoustics, Hearing protectors, Part 2: Estimation of effective A-weighted sound pressure levels when hearing protectors are worn

ISO/TR 4869-3:1989 Acoustics, Hearing protectors, Part 3: Simplified method for the measurement of insertion loss of ear-muff type protectors for quality inspection purposes

ISO/TR 4869-4:1998 Acoustics, Hearing protectors, Part 4: Measurement of effective sound pressure levels for level-dependent sound-restoration ear-muffs

ISO 6161:1981 Personal eye-protectors, Filters and eye-protectors against laser radiation

ISO 8194:1987 Radiation protection, Clothing for protection against radioactive contamination, Design, selection, testing and use

American Conference of Governmental Industrial Hygienists

Guidelines for Selection of Chemical Protective Clothing, 1987

A Guide for Control of Laser Hazards, 1990

National Fire Protection Association

NFPA 70E Standard for electrical safety requirements for employee workplace

NFPA 2112 Standard on flame-resistant garments for protection of industrial personnel against flash fire