U.S. BUREAU OF MINES NEW DEVELOPMENTS

IN MINE COMMUNICATIONS

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ABSTRACT

A brief description is given of various Bureau of Mines research activities that have begun since July 1974 and are not being reported on by others at the Third West Virginia University (WVU) Conference on Coal Mine Electrotechnology.

An essential feature of the various projects is that they are pragmatic. The projects are applied research and are carried out both by the Bureau in-house research group and by other research groups through contract research.

Projects have been directed toward wired-type communications with a special effort to modify the wired systems so as to be more effectively used. The projects are in three groups: Pager phone systems, trolley line phone systems, and guided-wire wireless communications. Also, a brief sketch is given of research that is essential for further developments in mine communications.

From the early results of these various projects, the Bureau has good reason to project that there will be improved performance of existing communication systems and that communications will be extended to other individuals working in areas that are excluded from present mine communication systems.

INTRODUCTION

Certainly the winds of change that will bring about lasting communication improvements in many mines have been set in motion. Two years ago, at our Second WVU Conference on Coal Mine Electrotechnology, our conference chairman took a poll of the attendees and over 82 percent expressed themselves as feeling that, for both the near and long term, it would be necessary to have improvements in mine communications. The communication session this morning provides the opportunity for highlighting two approaches that will

improve phone systems: (1) Providing private line voice communications to any phone in the mine and (2) a direct connection of the under ground phones with the above ground phones. About 60 percent of our second conference conferees felt that both these features were desirable.

A second area highlighted at this morning session is the two-way radio. Although only about 20 percent of the previous conferees expressed the feeling that this was desirable, there is a need for radio as the usage of trolleyless and also trackless haulage increases. The Bureau has new developments since the second conference, in both phone systems and wireless radio. These will be presented by others at this conference.

The new developments that I shall be talking about are to improve existing telephones and trolley phone systems and to provide a new type of communications in face areas. I shall also discuss the developments required for future improvements in mine communications, supervisory control, and automation.

MINE PAGING TELEPHONES

Paging telephones are the most widely used mine communications system. A particular limitation of this system is the inability to alert a person,who is somewhat removed from the location of the phone that he has been paged. Paging or call alert has been singled out for improvement. The Bureau has selected means for improvement that permit a call alert while keeping the telephone system intact and without undesirable interference with the phone operation.

A visual page display has been developed. The prototype of the visual system allows for 16 call displays. The display is controlled by the dispatcher who controls two basic functions: Post or clear, and identification. He first makes a selection of post or clear by depressing the post or clear button. The depressing of one of these buttons will actuate a switch that supplies 12-volt dc to the phone line and illuminates the switch button to indicate that 12 volts is applied to the phone line. Simultaneously with the applying of the dc voltage, there is a short-duration, multiple-frequency tone code that distinguishes a post operation from a clear. A post or clear selection must be followed by an identification selection from one of the 16 symbols, which are associated with particular individuals. Depressing an identification button causes transmission of a multiple frequency tone. This tone burst is also transmitted simultaneously with the dc voltage. If a post function was initiated, the depressed symbol button will light, indicating that posting has been accomplished. If a clear was initiated, the lighted symbol button is extinguished, indicating the clear is completed. The post or clear light is extinguished when the dc is removed from the phone line. This is accomplished after an identification button has been depressed or by the runout of an 11-second timer

that begins running when either the post or clear function button is depressed. The symbol button illumination is a reminder to the dispatcher of the pages posted and their status. A flashing symbol key indicates that the page has been posted for more than 10 minutes.

The display units, which will be located throughout the mine, consist of a 16-disc display module, a protective NEMA-type 12 enclosure, and a lamp assembly. The overall size is 14 inches by 12 inches wide by 6 inches deep, with top and bottom flanges for wall mounting. In the prototype, there is a second box housing a rechargeable battery, a charger with 115-volt ac line connector, a tone receiver and decoder, a solid state relay, and display driver electronics. The unit can be powered from 12-volt lantern batteries, and battery life is comparable to the pager phone battery life.

The 16 discs are in a 4 x 4 matrix. Each disc is free to rotate on a horizontal axis through the center and in the same plane as the disc. The disc is 2-1/4 inches in diameter; one side is phosphorescent green, and the other has a retroreflective red symbol. Mounted on one edge of the disc is a permanent magnet that is alined with an electromagnet mounted behind the disc. The pole piece of the electromagnet is magnetized by a pulse in the coil. The remnant magnetism in the pole piece rotates the permanent magnet which is affixed to the disc, thus causing either the blank side or the symbol side to be seen. The disc is magnetically held in the desired position by the permanent magnet. Thus, no power is required to hold the disc for viewing. The background is caused to glow either by a blinking strobe or by the rays from an approaching cap lamp. The entire background of the display glows a faint green, thus enabling the approaching viewer to detect the presence of the display. The display is periodically flashed by the blinking strobe. The phosphorescent surface will first glow brightly, and in about 1/2 hour, 80 percent of the brightness will be dissipated. In the absence of any light, the display can be read, depending upon the viewer's eye-dark adaptation, up to 1/2 hour after a light flash. Also, because of the red-green contrast, the symbols can be read in bright light.

There is also a call alert pocket page version that utilizes a loop in place of the visual display box and emanates an electromagnetic signal that is received in a small pocket receiver carried by the miner. Each system provides a means of selectively calling attention to an incoming call. All call alert replies are directed to the dispatcher, who forwards a message.

TROLLEYWIRE PHONE

There are two backbone mine communications systems, the paging phones and the trolleywire phone. The trolleywire phone is a carrier current communications system for the dispatch and control

of track haulage vehicles. The problems encountered are more severe than those of the paging phone. The equipment must operate from the adverse environment of a mine haulage locomotive and over a transmission line intended for dc power distribution. Despite frequent instances of performance deficiencies such as dead spots, garbled transmissions, and damaged equipment, especially microphones, the carrier communications are used because there is not presently available a satisfactory alternative. Hopefully, from the radio developments being discussed at this conference, there will come a viable alternative to the trolleywire phone. Because the carrier phone is in extensive use in the mining operations, the Bureau has initiated a program to eliminate present performance deficiencies and to improve the overall capability of a trolleyline communications system.

Dr. James R. Wait and his associates at the Institute for Telecommunication Sciences, Office of Telecommunications, have analyzed the utilization of the trolley wire and its rail-ground return as a radiofrequency transmission system. The results of the analysis, which took into consideration the rock conductivity, the mine geometry, the position and size of the trolleywire, and frequency variation from 50 KHz to 800 KHz, show that the trolleywire-rail system represents a low-loss transmission line and should provide communications over very long ranges, like 100 miles, for typical equipment now in use.

Richard Spencer, Arthur D. Little, Inc., has been actively pursuing a trolley phone improvement program. Dick has completed his study and has identified particular deficiencies, has singled out the restraints that inhibit the obtaining of a 100-mile range, and has proposed some means of overcoming these deficiencies and restraints.

For this talk, I have singled out just two problems--(1) dead spots and (2) the restricted space aboard locomotives and jeeps.

Dead spots, places where signal level is beneath the threshold of the receiver, result from the shunting and mismatch conditions caused by various noncommunication devices connected to the trolleywire. A large number of devices have been identified as low-impedance loads at the frequency of the phones, 88 KHz or 100 KHz. Of these devices, two are most important, the rectifiers feeding the dc to the trolleywire and the lights on the vehicle. These problems can be solved by isolating the low impedance loads from the carrier frequencies. Fortunately, this can be accomplished by inserting a tuned circuit between the low impedance device and the trolleywire. For the lights, which have small dc currents and low rf impedance, the solution is practical. The inserted tuned circuit comprises a coil and a capacitor in a parallel arrangement; this allows the dc current to flow uninhibited and blocks the carrier from being shunted by the low-impedance device.

Westinghouse Research Laboratory, Pittsburgh, Pa., has developed, under Bureau contract, an active impedance multiplier that can be used for elevating the carrier frequency impedance of a locomotive. It is relatively small and can be used at the input of a locomotive. This causes the trolleywire to look more like a 200-ohm carrier transmission line. However, impedance multipliers are rather costly and are not yet commercially available.

The more severe problem is the rectifier. The approach of the solution is the same as that for isolating the locomotive headlight, but the wire in the coil must be of the same size as the feeder conductor. The large wire is difficult to arrange in a coil that will have a high reactance to the carrier frequency, and thus a rather inefficient large-value capacitor is required to form a parallel resonant circuit. Experiments with the low-quality resonant circuit have resulted in doubling of the carrier voltage. This is not much of an improvement. However, a Bureau-developed hoist phone has a super sensitive receiver, i.e. about 1,000 times more sensitive than the present trolleywire phone, and works very effectively from a small pickup loop. By separating the transmitter and receiver portion of the phone, it is possible to directly connect the transmitter to the trolleywire and inductively couple the receiver to the signal field near the loop. Because of the high sensitivity of the new equipment, it might be possible to develop a new trolleyline phone that would work better where there are low-impedance devices on the trolley. This has been tried, and field measurements showed as much as an 8-db improvement in signal-to-noise ratio for a loop-received signal. It might be necessary to have input both from a loop and from direct contact. This would require selecting the better signal.

Sometimes, everything begins to fall in place. The other big problem with carrier phones is the restricted space for mounting microphone, speaker, trolleyphone, and voltage-adjusting devices upon, in and on the locomotive. New electronic chip-type components, some of which are used in the Bureau-developed hoist phone, allow the designer to do away with the bulky passive tune circuits. If we exercise a little ingenuity, a trolleywire phone could probably be miniaturized to the point where it would fit into the extra space in the housings of some of the heavy duty speakers. The Bureau is seeking a cost-sharing agreement with an equipment builder to develop an improved unit. The improved phone sensitivity might allow for a good reduction in the transmitter power; if this happened, the unit could operate from a small, sealed 12-volt battery with a generator somewhat like a present car generator. Then, at long last, we would have removed from the trolley, except for the signal connection, all of the communications equipment that has been bedeviled by the 300- or 600-volt dc on the trolley.

FACE AREA COMMUNICATIONS

The Bureau, in the Inherently Safe Mining System program, has developed a face communications system for both a shuttle car haulage and an extensible belt face haulage. These systems combine radio, carrier, and telephone to permit communications between the roving face boss and his crew and between the roving face boss and the top-side office. There is some fallout from these programs that looks practical for longwall sections and bridge conveyor sections.

Wireless, or radio as it is better known, is seldom totally wireless in mine communications. Radio wave propagation is very poor in the pit. The British have developed the leaky feeder cable with inserted repeaters in their attempt to get minewide wireless communications. But it isn't wire LESS--it has a helper wire called a leaky feeder. The Bureau has been prodding the development of radio, not minewide, but at places in the mine where the miner's freedom to move about makes it essential that he have wireless communications.

There are three aspects to the wireless development. One is the work of the Motorola Co. which is now providing a portable repeater and a new line of handi-talkies that are half the size of the HT220 series used by the Bureau in the earlier experiments. This equipment has the MESA approval for intrinsically safe devices.

A second aspect is the applications--the longwall section and the beltway section are such that radio wave movement must be through openings that are restricted by machinery. These restrictions greatly reduce the already limited radio propagation in the mine openings. The restriction is so bad that it is impossible to establish communication without the aid of helping leaky cables. In these particular applications, one termination of the leaky feeder is an antenna that enhances the propagation into free space and the other is a repeater. The handi-talkies cannot communicate with each other without the repeater. They transmit on one frequency and receive on another frequency that is transmitted by the repeater. The repeater has been modified and can also double as a base station if required. To enhance the acceptance of the units by the miners, there is a battery charger on the section so the miners do not have to take the units in and out of the mine.

The third aspect of the problem is the microphone/speaker-to-miner interface. The Bureau has contracted with EPSCO Labs for a thorough study of the problem of communicating with a working miner who often does not have his hands free and is in an area where acoustic noise is very restrictive to hearing a speaker on portable radios. Thomas Giordano of EPSCO has well defined the problem and has made some excellent recommendations which the Bureau is implementing in a prototype system. The system uses a noise canceling airpath microphone that picks up

the speech signals at the miner's lips. The hearing device is an earphone-earcup combination. This arrangement also provides the added benefit of protecting the hearing of the wearer of the device. These devices are coupled to the helmet, and a small cord with plug connector allows for the separating of the microphone-speaker helmet set from the transreceiver, which is carried either on the belt or in a chest pack. A small switch, which may be clipped onto the coveralls, is used to key the transmitter. Of course, some miners do not need the special modifications for high-acoustic-noise areas, and they can utilize the microphone-speaker provided with the handi-talkie.

A fully wireless section radio system, coupled to a dial telephone, has been developed by the Bureau in conjunction with Collins Radio as an add-on feature to the coaxial cable telephone system, thus permitting the interface of wireless radio with the mine telephone. This will be more fully discussed by Harry Dobroski in his talk later this morning.

These developments of radio are attractive, and the Bureau has made arrangements with mine operators to thoroughly evaluate the systems and to measure their effectiveness.

An incidental benefit that most likely will develop from these face radio systems will be control and monitoring systems. Already there is talk of using the radio to remotely monitor the continuous-mining-machine methane reading outby at the section telephone. There is an active interest in remotely controlling a longwall shearer, and there is also talk about automatic control of the mobile bridge conveyors from the continuous-mining machines.

Next, we want to look at some of the work the Bureau is doing that is essential for further developments in mine communications, monitoring, and remote and automatic controls.

RESEARCH FOR FURTHER DEVELOPMENTS

The communications program is an ongoing program. The studies, the developments of hardware, the developments of systems, and the demonstrations of hardware and systems will enable us to better provide for the future needs of the mining industry. An extensive study was made of "The Applicability of State of the Art Voice Bandwidth Compression Techniques for Wireless Mine Communications." This study was undertaken with the hope that "now" might be the time to develop a real time bandwidth compression scheme that would enable equipment builders to come up with a portable radio unit that would consume 1/100 of the power of those developed by the South Africans for mine rescue teams. The conclusion is that "now" is not the time; the best that can be done with bandwidth compression will not greatly reduce the physical size of the unit or significantly reduce

the battery drain. However, from other advice in the report, we have moved ahead with refuge chamber communications wherein we are having developed a non-real-time, non-voice-type system that can be used for character transmission from the mine to the surface.

Another study, titled "Applicability of State of the Art Repeaters for Wireless Mine Communications," was initiated with the expectations that the mining industry might soon have a means of communicating with trackless and trolleyless vehicles without the expense of installing and maintaining a special leaky feeder cable. There is no available utopian F1/F1 repeater that can simplify the solution to our problem of high propagation loss that would require repeaters about every 2,500 feet. But all is not bleak, for it does appear that we can develop a F1/F2-F3 repeater system that will function in conjunction with the telephone system. With the combined systems it will be possible to communicate with vehicles about 1,350 feet from the phone line. This will require that telephones be established every 2,500 feet along the phone line and that they be interfaced to the radio.

Another study, titled "Applicability of Available Multiplex Carrier Equipment for Mine Telephone Systems," also turns out to have a discouraging conclusion for coal mines. However, we are also actively engaged in metal-nonmetal communications where we are not faced with the problem of permissibility and the problem of interfacing between carrier and pager phones. Very few metal-nonmetal mines use pager type telephones. The Bureau is cooperating with the Sunshine Mining Co. and we hope to derive about five additional phone channels over a single existing telephone pair. Generally, this concept is not economical for coal mines using the mine pager phone system.

There is a report titled "Propagation of Radio Waves in Coal Mines" that will interest designers who would like to know more about radio propagation in haulageways and shafts. There is an interesting finding for most of you who might want to communicate between the front and the rear of a 600-foot-long train in a haulage-way. The finding is that if you have 5 or 6 feet of clearance between the train and one sidewall and you use the 450-MHz frequency, you can do it without any helping cable. Also, for those of you who never asked but always wished you knew how a hoist phone really worked, there is a good theoretical analysis of deep shaft communication.

Another study is entitled "Data Flow Requirements for Remote Supervisory Control of Continuous Mining Machines." The purpose of this investigation was to get a feel for the magnitude of data that must be transmitted if indeed a supervisor was to monitor and control a mining section from a point outby the working

face. In order to restrict communication channels to bandwidths that are practical for mining, it was decided that some machines would have their own small computers and that only video and voice signals would be transmitted in analog form. All other information would be transmitted as a synchronous bit stream over digital channels. The conclusion is that for short distances like 2,000 feet there would be no difficulty in transmitting 40,000 bits of information per second, and that if necessary it could be done over a single twisted pair. This is encouraging because the Bureau is looking into the possibility of developing a remote supervisor's station from which the mine section foreman might be able to monitor and control an entire mining section.

There are other Bureau studies, hardware projects, systems developments, and demonstrations that I have not mentioned. These are covered in a summary way by John Murphy's paper entitled "Overview of U.S. Bureau of Mines Research in Electrotechnology." This paper will be published in the proceedings of the Third WVU Conference on Coal Mine Electrotechnology.

CONCLUSIONS

The Bureau has started a number of development projects, some of which have already reached the mining industry and have begun to provide improvements in mine communications. Others will be reaching the mining industry in the next two years. The Bureau and others in the mining industry are accepting the challenge to improve mine communications as needed to communicate with both voice and data.