Information Circular 8742

Underground Mine Communications

(In Four Parts)

1. Mine Telephone Systems

Compiled by Staff–Mining Research

UNITED STATES DEPARTMENT OF THE INTERIOR
Cecil D. Andrus, Secretary

BUREAU OF MINES

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UNDERGROUND MINE COMMUNICATIONS

(In Four Parts)

1. Mine Telephone Systems

Compiled by Staff–Mining Research

ABSTRACT

This Bureau of Mines report is devoted to descriptions of systems that provide in-mine wired telephone service. Although they may incorporate other features, each system described functions to allow one telephone to selectively access another telephone. Except for the paper on Conventional Telephone Equipment, the equipment described is newly developed and specifically designed to satisfy the requirements of underground mine communications.

INTRODUCTION

The Coal Mine Health and Safety Act of 1969 authorized the Bureau of Mines to undertake research for the development of new or improved means and methods of communications from the surface to the underground area of a coal mine. Bureau-sponsored studies of operating mines showed that though the average mine had a single-channel system, typical coal mines had requirements for equipment that would provide 6- to 20-channel capacity.

In some mines, particularly noncoal mines, conventional telephone equipment is utilized to provide multichannel communication links. A paper on the conventional telephone system contains a description for a hypothetical conventional phone system for coal mines and describes some of the equipment available that could be used to implement a system. The paper also briefly discusses the planning and economics of installing and operating a multipair cable phone system.

The three remaining papers describe systems and equipment that various communication companies have evolved from their commercial- and industrial-grade equipment. The evolved pieces of equipment were designed to satisfy many of the mine communication requirements and typical specifications for equipment and systems as set forth in Bureau-sponsored research. Each system was specifically designed for intrinsic safety.

The Mine Dial-Page Telephone paper describes a system that combines the best features of a conventional telephone system and the existing mine pager-phone system. A multipair cable is used to provide a separate pair of lines for private phones.

The Coaxial Cable Telephone paper gives an account of a Bureau-sponsored development at Collins Radio that has combined voice and data in a communication system for underground mines. The system operation is controlled by a dedicated minicomputer, and the individual messages are frequently multiplexed on a coaxial cable. This allows for several hundred private channels without having a separate wire pair for each channel.

Another paper, An Industrial Communications System, explains a system developed by the Bell Telephone Laboratories. Bell Laboratories has redesigned its basic phone service that is used in our everyday lines to meet requirements delineated by Bureau of Mines-sponsored research.

All papers emphasize the functional operation of the equipment from the user's point of view, its usefulness in mining operations, and the appearance of the hardware. Descriptions of the technical details, such as circuits, operating voltages, and frequencies are kept to a minimum.

Use of company names is for identification purposes only and does not imply endorsement by the Bureau of Mines.

CONVENTIONAL TELEPHONE EQUIPMENT

by

Howard E. Parkinson[1] and John D. Foulkes[2]

ABSTRACT

This paper is concerned with the application of conventional telephone equipment, particularly cable transmission equipment, in underground mines. It emphasizes the economic incentives for proper planning, outlines the basic considerations that enter the planning process, and describes the tools and hardware available for the installation and maintenance of single-pair and multiple-pair (called multipair) cabling. It includes a brief description and discussion of available multiplex equipment which, in special circumstances, can be used as a substitute for multipair cable.

INTRODUCTION

A large and increasing number of noncoal mines use conventional, multipair telephone equipment for voice communications. In most cases underground telephones are dial-access extensions of a surface PABX. With the advent of intrinsically safe dial telephones, we expect to see this practice adopted in some coal mines. In addition to carrying voice traffic, multipair cable is often used to implement monitoring and control systems.

PLANNING AND COST FACTORS

Telephone transmission is made over wires, and those wires represent a considerable fraction of the cost of a telephone system. Figure 1 shows three broad categories of equipments in which telephone companies invest. The "transmission" category represents not only wires, of course, but it also includes multiplex systems, microwave systems, and other wire substitutes. Since transmission equipment accounts for about half of plant investment, the telephone companies put considerable effort into planning the layout and the growth of their transmission facilities.

It is interesting to see how these cost factors affect a mine. For example, a hypothetical, moderate-size mine has the following principal characteristics:

1. Less than 2 years old.

2. Total area of 6 square miles.

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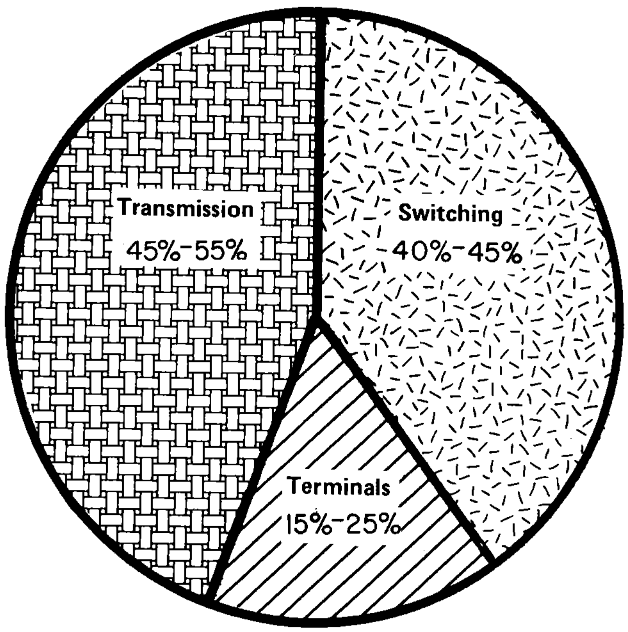

FIGURE 1. - Telephone company investment.

3. Main haulageway of 3.5 miles.

4. Average submain length of 0.8 mile.

5. Average working section size of 300 feet by 400 feet.

6. Average panel size of 800 feet by 2,100 feet.

7. Five working sections per shift.

8. A maximum of six active working sections.

It is a young mine and uses continuous-mining techniques at its six working sections, as shown on the mine map (fig. 2).

Single-Pair Cable Installations

Figure 3 shows the main haulageway, the operational submains, and the working sections and illustrates how a single-pair pager-phone system would be wired. The solid black line represents the single pair, and the dotted line represents the aboveground loopback. The black squares represent splicing points, and the circles represent the telephones. Telephones can be seen along the main haulageways, one at each butt entry and one near each working section, and a twisted pair is shown running to the pager phone at each working section. When a panel is worked out, the wire is usually discarded. But this is expensive. For example, consider the following installation costs:

1. Using 14 AWG neoprene and not reusing any cable (a common practice). $59,800

2. Using 14 AWG neoprene cable, and reusing section cable as needed. $17,200

3. Using 14 AWG for all mains, 18 AWG for sections and not reusing cable. $25,100

If the section cable is not reused, the cost of the twisted pair and the hardware needed to mount it (exclusive of installation costs) is about $60,000. This does not include the cost of telephones. It may be impractical to assume that all section cable could be recovered and reused, but if this were done, cable costs could be reduced by $17,000. If 18-gage wire is used for the sections and then abandoned, replacement costs would be about $25,000.

Figure 4 shows the relative investment in wire and pager phones of the system previously described, and the breakdown for a multipair system installed in the same mine. The point is that the mines must face the same financial reality that the local telephone company faces; that is, the bulk of equipment costs are in the transmission plant. Hence, it is worthwhile to plan the network and to revise the plan on a scheduled basis.

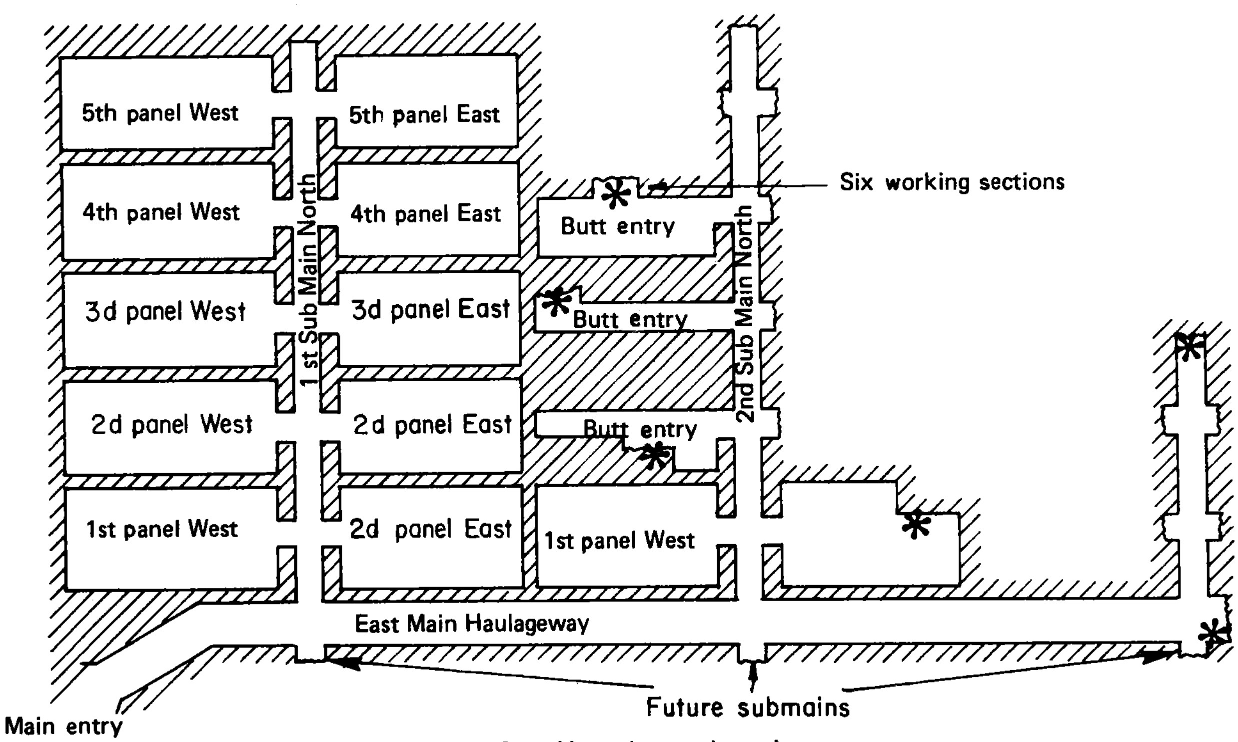

FIGURE 2. - Hypothetical coal mine.

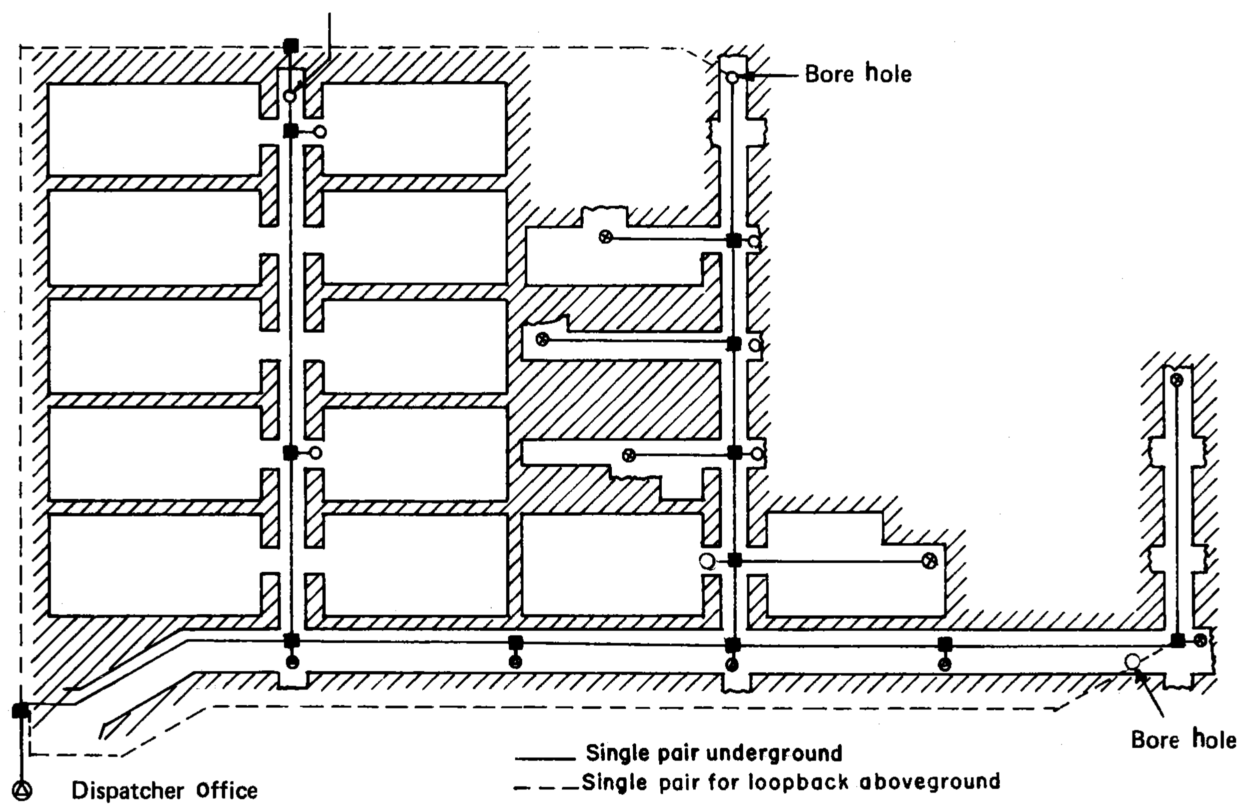

FIGURE 3. - Single-pair pager-phone installation.

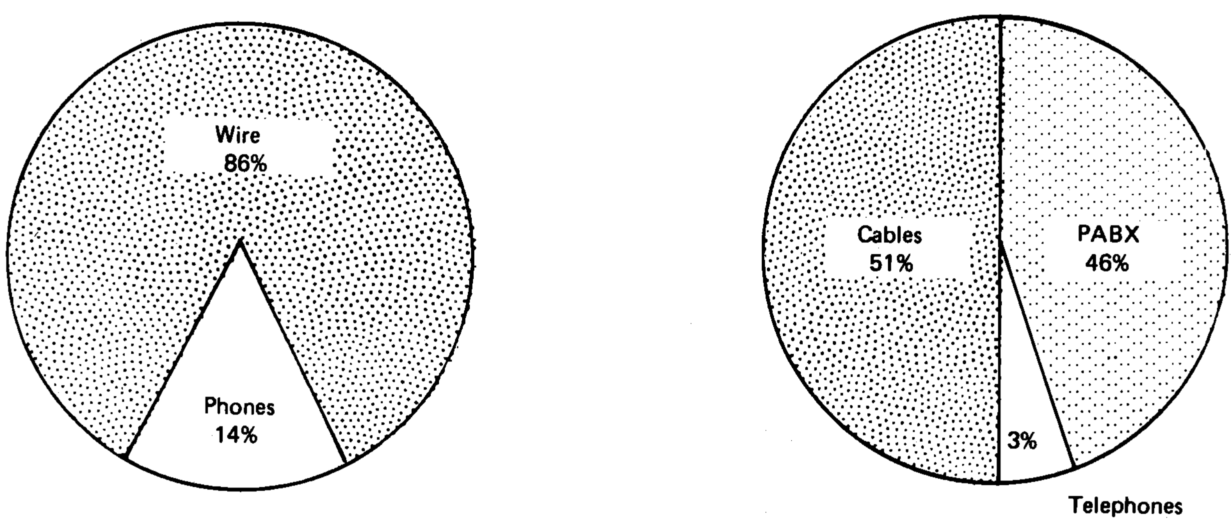

FIGURE 4. - Equipment costs for hypothetical mine.

The breakdowns of figure 4 do not include installation costs. If they did, the percentage investment in wire would be even larger than that shown. Hence, this simple picture is unrealistic.

Another objection to these cost breakdowns is that they are predicated on the assumption that the mine is a static entity, with no allowance made in the wiring for growth. A mine is not static; its architecture or layout changes (fig. 5), but fortunately these changes are usually known well in advance. As far as changes are concerned, the telephones fall into three basic categories:

1. Telephones in the main haulageway, opposite each submain, would rarely, if ever, be moved (permanent).

2. Telephones opposite each butt entry would remain in place for about 1 year or so until more panels in the submain have been developed (semipermanent).

3. Telephones at the working sections, however, according to mine safety regulations, require that a communication link must be established within 500 feet of the working face; hence, these telephones are required to be moved perhaps once a week (frequently moved).

When dealing with a single-pair system, additional lengths of wire could simply be spliced on as the mine was extended.

Multipair Cable Installations

For a multipair access installation (fig. 6), planning becomes important. The figure shows an example of how a multipair system may have grown in our hypothetical mine, which has four working sections (A, B, C, and D). In this example, when the system was installed, working section A did not exist, so three-pair cable was used to give sections B, C, and D private lines. (It was assumed that it was all right to make the telephone at the working face an extension of the butt entry phone, which may not be reasonable in low coal.) When section A came into operation, either more cable had to be installed or more telephones had to be converted into extensions without private lines. Figure 6 shows that six-pair cable was run along the main haulageway, so that at this stage of development, several telephones were forced to share a pair. There were 16 telephones in use.

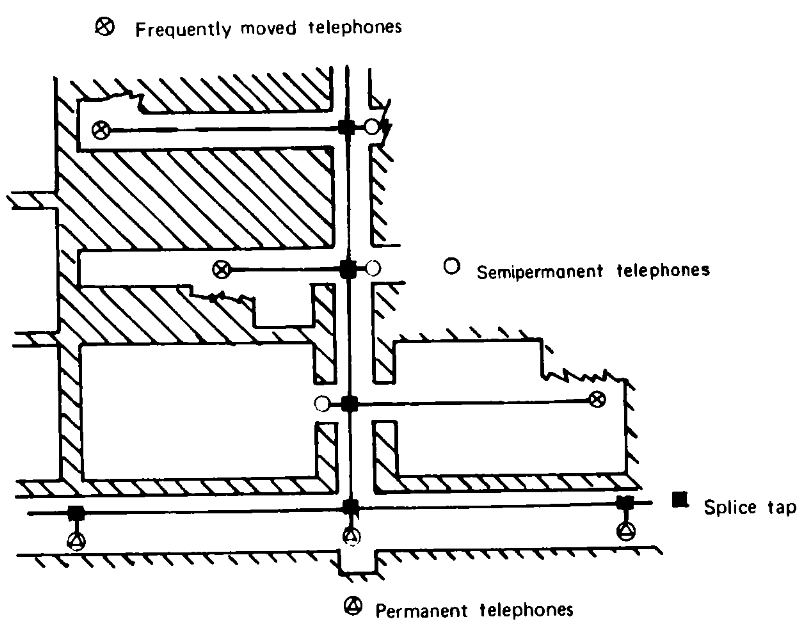

FIGURE 5. - Detail of a single pair.

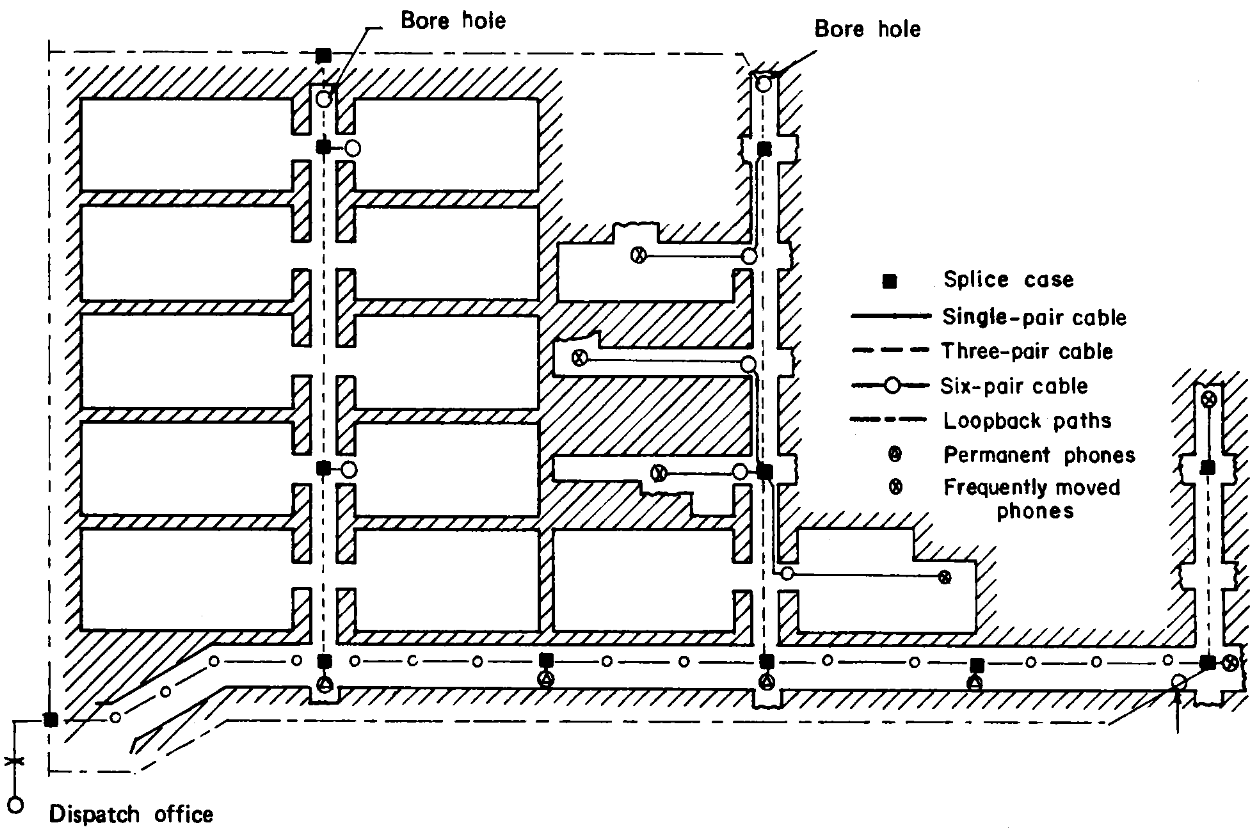

FIGURE 6. - Multipair installation.

The installation, as it stands, is fairly inexpensive (1975 prices):

Reusing section cable.. $12,158

No reuse of cable.. $18,584

The six-pair cable costs were calculated on the same basis as those for the single pair. The costs of the six-pair system are lower than those of the single-pair system because 18-gage, rather than 14-gage, wire was used, since far fewer telephones hang across each pair. Several telephones are extensions, and as long as that is a satisfactory condition, costs are manageable. However, if the objective is to provide every telephone with its own pair (which really is the point of a multipair dial access system), the additional cables have to be run down the main haulageway. Figure 7 shows the cable and hardware costs of equipment in the main haulageway relative to the six-pair cable. If another 12-pair cable is run down the main haulageway, total equipment costs increase to section A. If a 25-pair cable had been installed down the main haulageway in the first place, a considerable sum in installation costs probably could have been saved. The lesson, of course, is to keep future needs in mind when planning cable layouts, particularly in areas like main haulageways and maintenance areas where telephone locations are unlikely to change for many years.

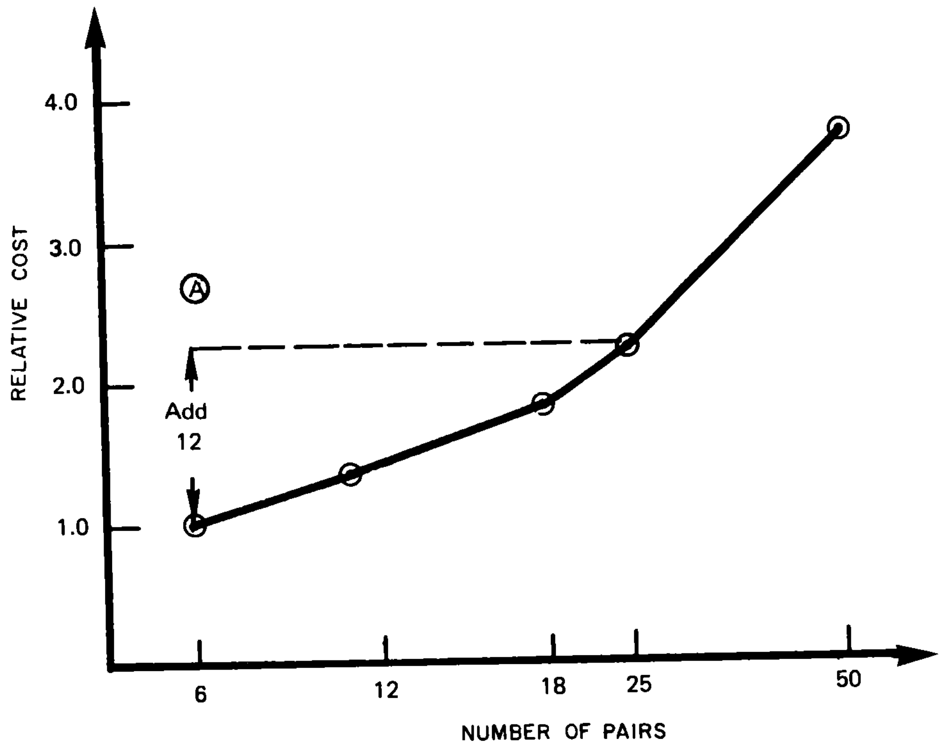

FIGURE 7. - Main haulageway costs.

Figure 8 shows details of the multipair system and, once again, the three categories of telephones--permanent, semipermanent, and frequently moved telephones--can be seen. To reduce future maintenance costs, some thought should be given to how these three types of telephones should be mounted. Housing the permanent telephones in a rugged enclosure, which would give them long-term protection against the environment and wear-and-tear,

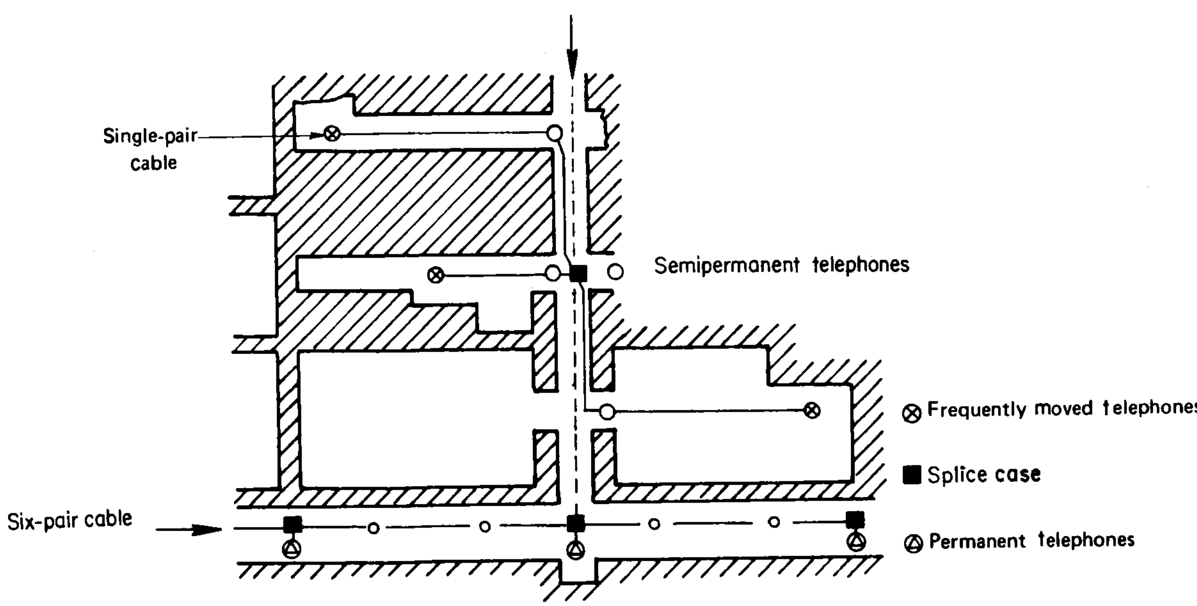

FIGURE 8. - Detail of multipair.

is one way. Semipermanent telephones should be ruggedly mounted, but they do not necessarily require an elaborate housing. Frequently moved telephones (discussed in other papers) require protective mounts, which are easily moved.

To summarize, in planning mine communication, the pairs that will be needed in the future and mobility of the telephones involved should be kept in mind. In addition, pairs that will be needed for purposes other than for telephones (telemetry, remote monitoring, etc.), which incidentally may exceed voice communication needs, should also be taken into account.

MULTIPAIR CABLE HARDWARE

Figure 9 shows the type of multipair cable that has been discussed and the standard mounting position. The pairs are supported by a stranded steel messenger cable and are linked to them by a polyethylene jacket (hence, the name "figure 8" cable). The pairs can be distinguished by a standard color coding and are protected by a core tape and aluminum shield. Several tools and techniques have been developed for splicing and dressing multipair cable in the mine environment using relatively unskilled labor. For example, figure 10 (upper left) shows the small plastic part used to splice wires together without having to strip the insulation. The tool shown in the upper right corner is used to hold these plastic parts in much the same way that a stapler holds its staples. Actually, the splicing operation is about as easy as stapling two pieces of paper together. Another type of connector used for splicing is shown in the lower portion of the illustration.

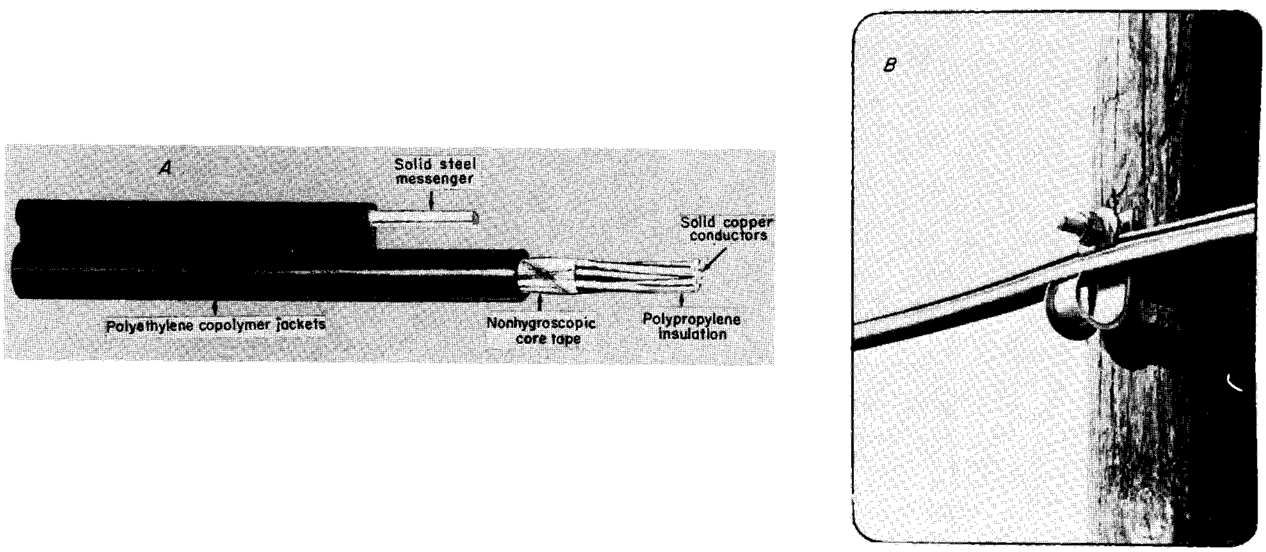

FIGURE 9. - Type of multipair cable. *A*, Cutaway diagram; *B*, standard mounting position.

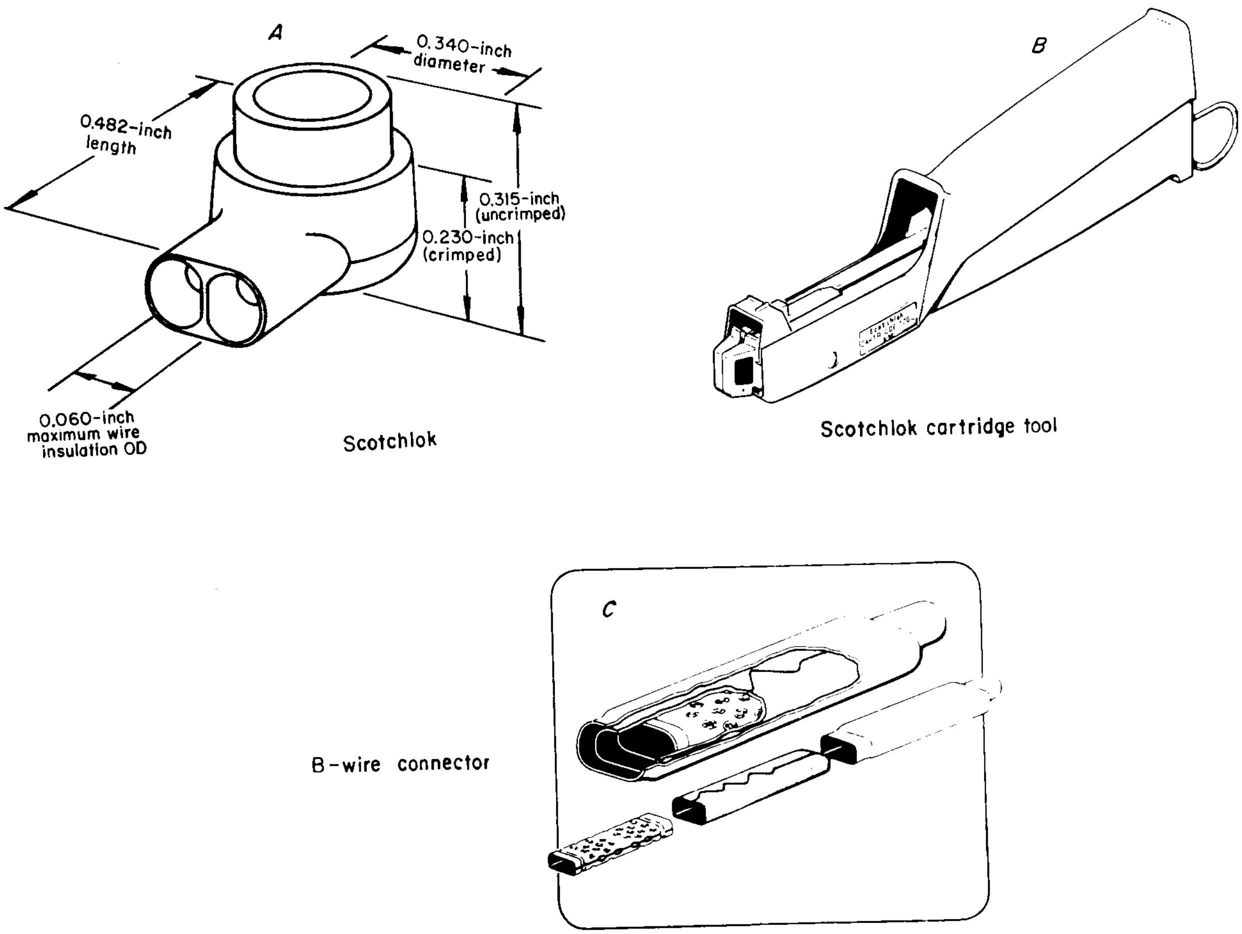

FIGURE 10. - Examples of crimp-type splice connectors. *A*, Scotchlok; *B*, Scotchlok cartridge tool; *C*, B-wire connector.

As for dressing the cable, figure 11 shows a splice that is readily available. These cases can also house terminal blocks of the type shown on the upper left of the figure; they are used at junction points to tap off one or several pairs of a larger cable.

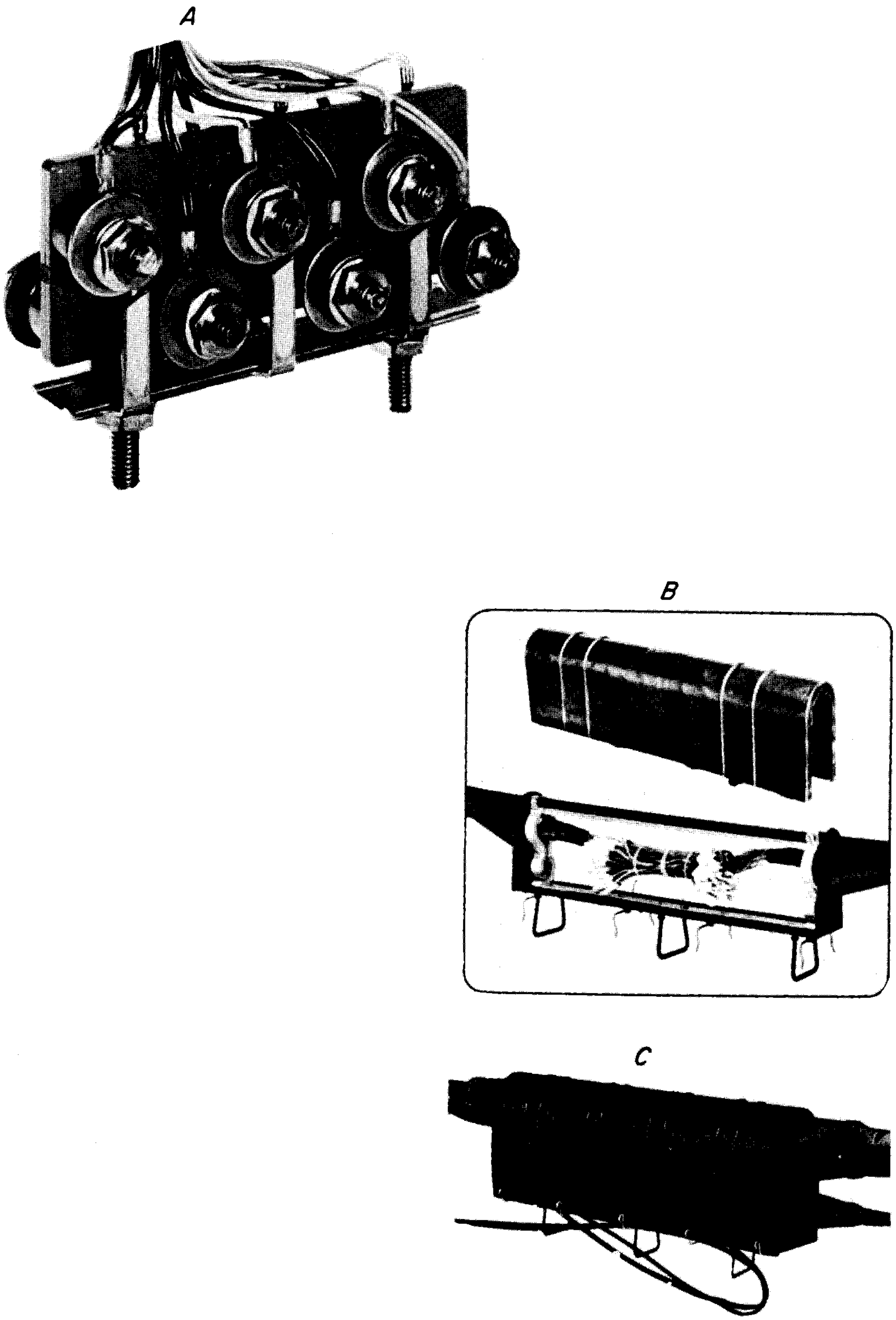

FIGURE 11. - Typical splice cases. *A*, Terminal block; *B*, interior view of figure-8 splice case; *C*, exterior view of figure-8 splice case.

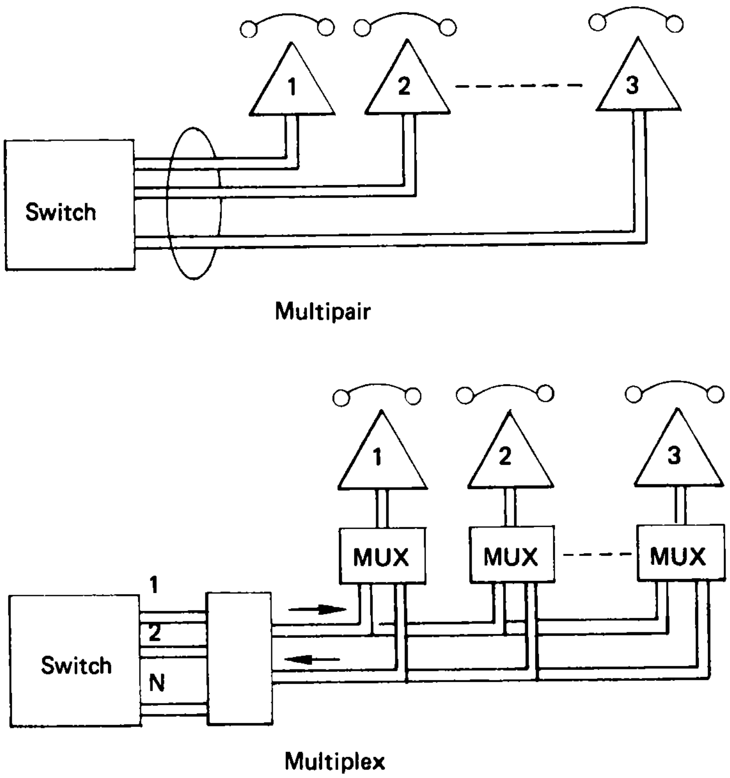

FIGURE 12. - Principle involved in multiplexing equipment. *A*, Multipair system; *B*, multiplex system.

MULTIPLEXING EQUIPMENT

Figure 12 illustrates the principle involved in multiplexing equipment.

In the multipair system, individual pairs are used to connect the telephones to a switch, such as a PABX. A multiplex system provides a substitute for copper pairs. Associated with each telephone is a MODEM (modulator-demodulator), labeled "Mux" in the diagram, which enables all the telephone conversations to be carried (typically) on two pairs to the switch. At the switch, another box of electronics sorts out the channels into separate pairs for the switch. Many manufacturers offer multiplex telephone carrier systems and some are employed in underground mines. At the Sunshine mine, for example, a special situation arose in which the number of pairs in the shaft was limited, and a multiplex system manufactured by Anaconda was used.

Figure 13 shows the remote unit that houses the multiplex equipment associated with a single telephone. Figure 14 shows a telephone of the type used at the Sunshine mine. Multiplex equipment is simply a substitute for copper wires and this, in many cases, offers equipment savings.

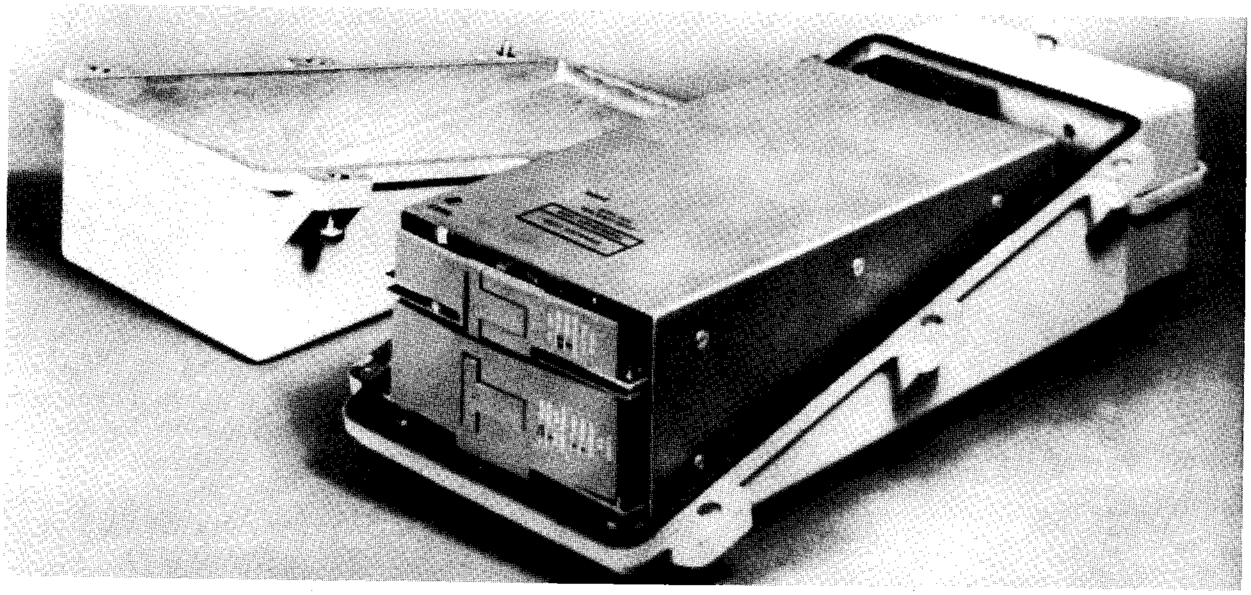

FIGURE 13. - Anaconda S6A single-subscriber terminal.

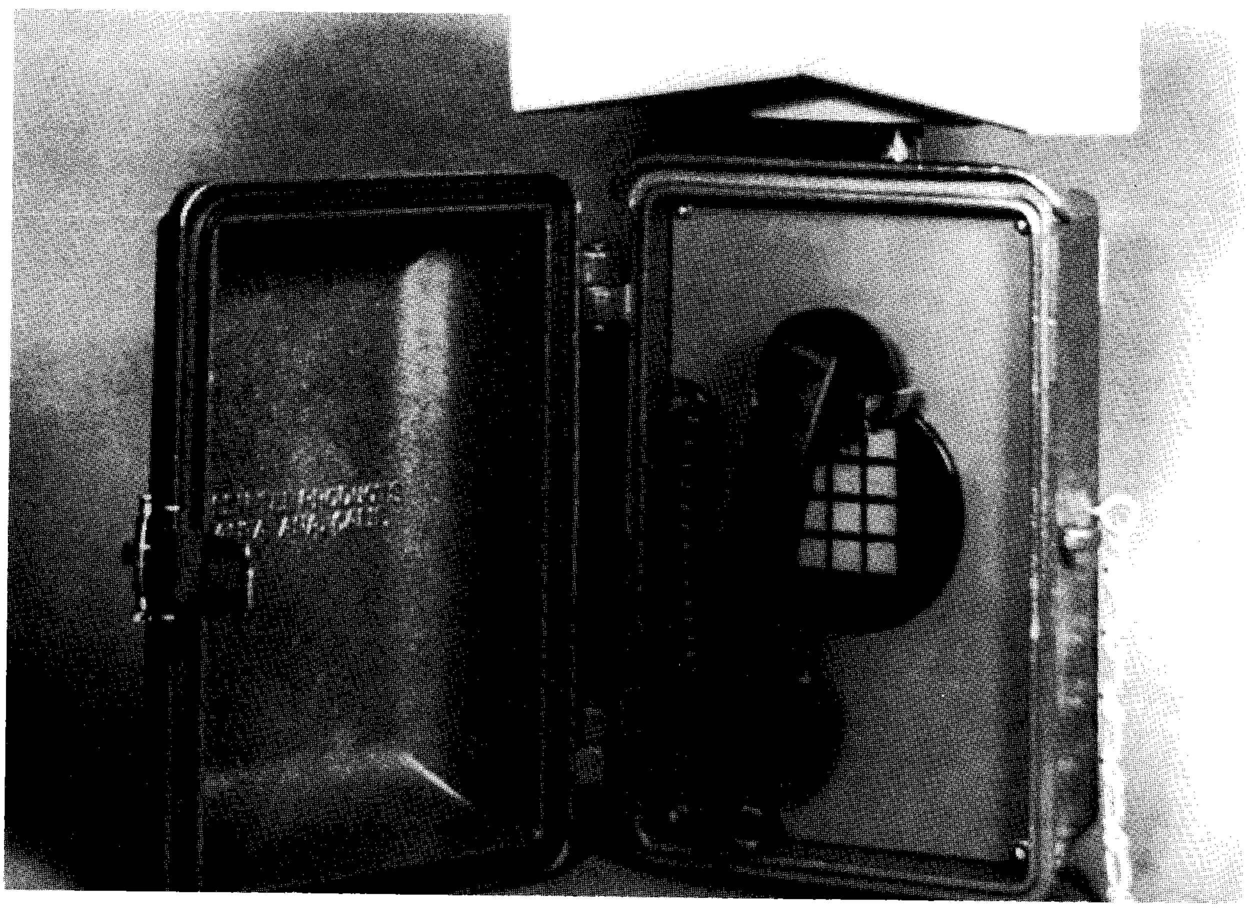

FIGURE 14. - Sunshine mine underground telephone.

COST SUMMARY

Table 1 summarizes cost of the equipment discussed so far. Looking along the bottom line, one can see that if section cable is reused, the cost of a single pair in the hypothetical mine would be $17,200, multipair implementation would be about $12,000, and the employment of a multiplex system would cost about the same as multipair. In many mines, however, the employment of multiplex equipment would be impractical.

TABLE 1. - Summary of equipment costs[1]

Reuse section cable?	Single-pair 14 AWG Neoprene	Multipair 19 AWG Alpeth 8	Multiplex 19 AWG Dedicated
No	$59,800	$18,584	-
Yes	17,200	12,158	$12,110

[1] 1975 prices, exclusive of the telephones.

In a typical coal mine, for example, electromagnetic interference caused by the trolley phone would probably make two of the channels of the Anaconda system unusable (as shown in fig. 15). In addition, because of the way the system is presently powered, the equipment would not be permissible.

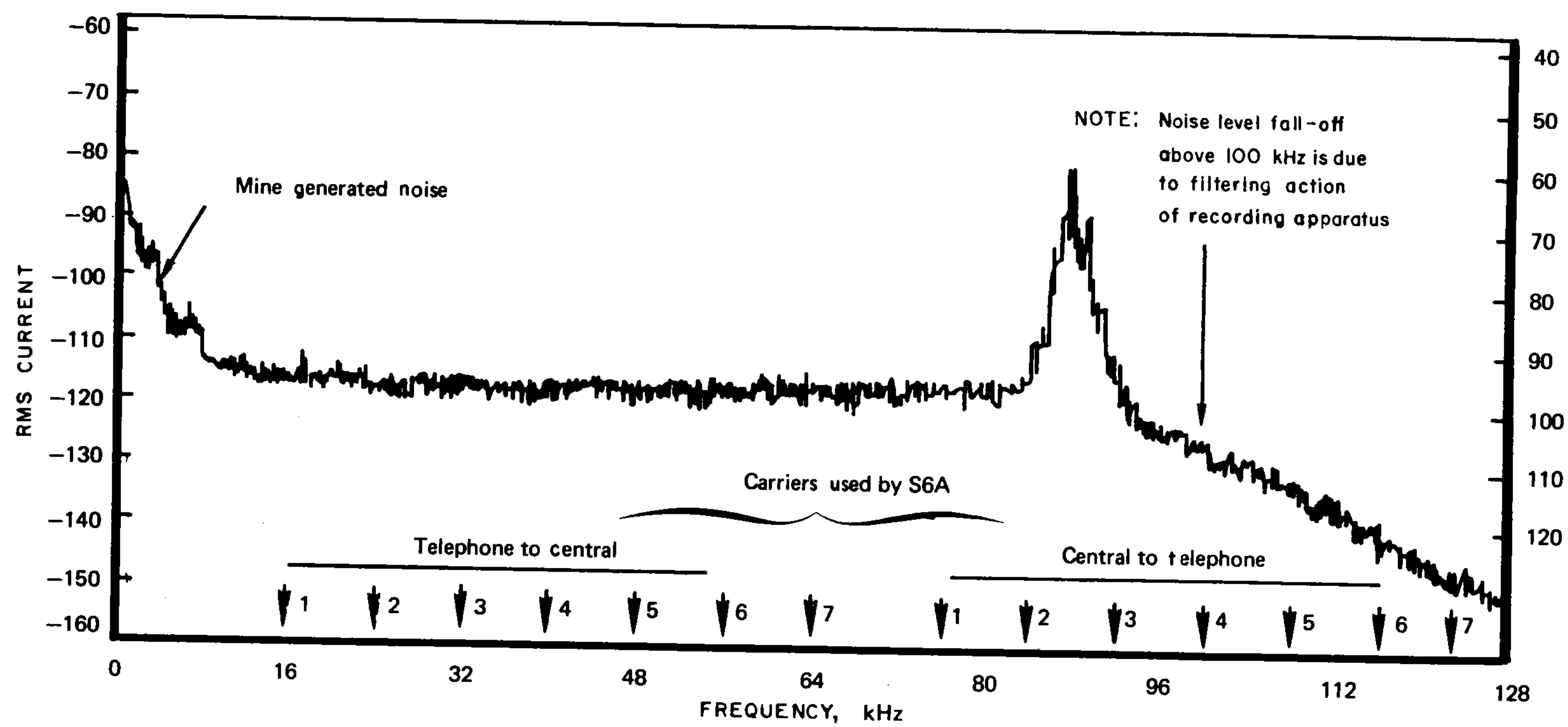

FIGURE 15. - Spectrum of current in one phone wire, 1 kHz to 100 kHz, Robena No. 4 mine, underground, 11:42 a.m., December 7, 1972; spectral resolution is 125 Hz.

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A DIAL-AND-PAGE TELEPHONE SYSTEM

by

James E. Alton[1]

ABSTRACT

In 1973, the GAI-Tronics Corp. (GTC), at the request of the American Electric Power (AEP) Service Co. for Southern Ohio Coal Co. Division, developed a mine dial-and-page phone to fill a gap in mine communication. During the course of the development, coordination and cooperation was maintained with Howard Parkinson of the Federal Bureau of Mines and the Mining Enforcement and Safety Administration (MESA), leading to MESA approval (9B-43) of the current product. Until then, only the pager phone, trolley phone, and conventional (nonpermissible) dial telephone were available for overall mine communication. Emergency communication was difficult to handle because of the heavy traffic carried on all mine communication equipment. Permissibility was also a prime factor behind the development of the dial-and-page phone, since conventional telephones could not be used in a methane atmosphere. The decision was made to provide a permissible product that would combine the best features of the conventional telephone and the existing mine pager at a reasonable cost. This goal has been achieved by the mine dial-and-page phone.

INTRODUCTION

The mine dial-and-page telephone has the appearance of a pager phone equipped with a dial. It is connected to a PABX, or manual switch board, and provides private-line dial access to all other telephones connected to the PABX. This makes it more efficient to communicate during peak hours of mine operation (such as the startup and end of a shift) and also provides a private line for use during emergency or breakdown conditions.

Besides not being permissible, conventional telephones present other problems in mines. For example, most underground telephones are not directly associated with a particular person or group of people; for example, telephones in the main haulageways. When these phones ring, it is a nuisance to answer the call and find that the called party is not in the area. The dial-and-page phone solves the problem in the following way. Instead of a bell, the dial-and-page phone emits a distinctive tone, called a "birdie tone," to alert the called party. This tone lasts for 4 seconds, and then the calling party is automatically put through to a paging mode. In this paging mode, the calling party can announce whom he wants.

Another disadvantage of conventional telephones is that if power should fail at the PABX or switchboard, all communication is lost. In such circumstances, a dial-and-page system automatically reverts to the mode of

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operation of a conventional pager-phone system using the batteries associated with each telephone.

By combining the dial feature with the pager phone, the miner does not have to learn new communication habits that might tend to confuse him in an emergency since he is already quite familiar with both the telephone and the pager. Flexible communications among all telephones associated with a mine can have substantial advantages in terms of productivity. In a recent case in Southern Ohio Coal Co.'s Meigs No. 2 mine, a conveyor broke down. Using the mine dial-and-page phone, the maintenance man was able to describe the actual trouble to the maintenance foreman without incident. As a result, the proper repair parts were quickly delivered to the location and the conveyor was back in operation in less than 1 hour, considerably faster than if workers were forced to travel back and forth several times to handle the problem.

On another occasion, the mine superintendent, who was underground at the time, received an urgent call from his New York headquarters. He was able to take the call immediately without having to relay any messages or go aboveground to his office. These are just two of many examples of the advantages attributable to the mine dial-and-page phone system.

DESCRIPTION OF SYSTEM

Hardware

The basic mine dial-and-page phone system (fig. 1) consists of an interface cabinet, with provisions for handling up to 80 lines, and the associated electronics for operation, the interface cards (one for each phone), and two or more mine dial-and-page phones. The interface cabinet is located as close to the mine entry as possible. Often this is the same room in which the mine PABX equipment is located. In keeping with MESA regulations, at least one mine dial-and-page phone is required outside the mine.

The GTC mine dial-and-page phone system obviously requires the use of an automatic telephone switchboard--either that of a central office system, centrex system, or a private automatic branch exchange (PABX). Such a switchboard can be provided by a telephone company as part of the telephone service, or it can be sold or leased from one of the many interconnect companies now in operation. The GTC mine dial-and-page phone system has been designed for direct connection to any switchboard that can accommodate conventional two-wire bridged ringing. No additional interface circuitry is required for function or safety protection.

The GTC mine dial-and-page phone system utilizes an automatic rotary dial telephone exchange line for each independent telephone. In most situations, a PABX provides this function at the coal mine site. There are no special requirements for this PABX, thus conventional telephones at aboveground locations can also be used with a dial-and-page system.

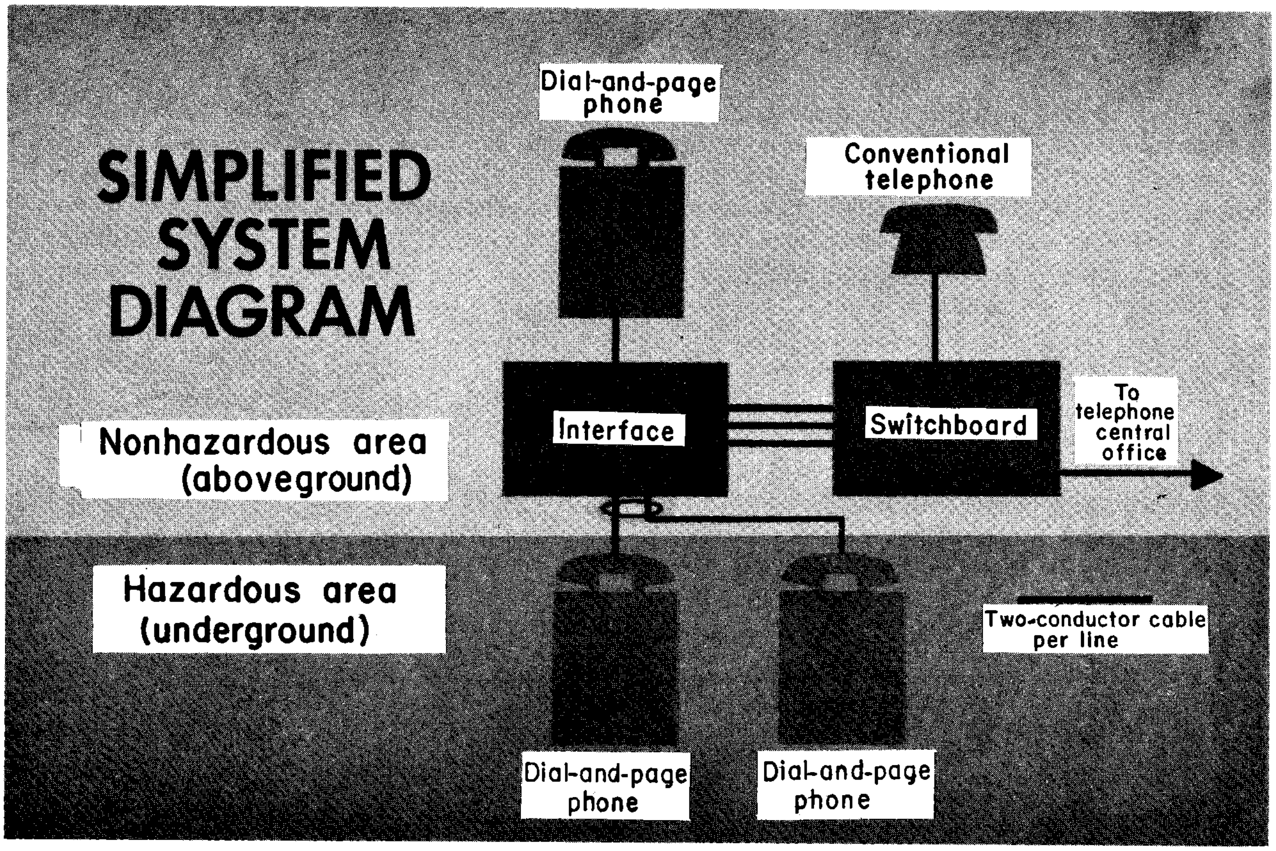

FIGURE 1. - Basic mine dial-and-page phone system.

In addition to a two-wire line for each telephone station leading from the PABX to the interface cabinet, three additional lines (wire pairs) are required to provide these system functions:

1. Monitor (one pair): The monitor line supplies approximately 20 milliamperes of direct current to a relay in the interface cabinet. When interrupted, the relay switches the system into a merged operation. The nominal 48 volts of direct current available in most switchboards can be used. Up to 1,600 ohms of series resistance can be tolerated. An adjustable resistor in the interface cabinet, in series with the relay, can be set to limit the current if 48 volts of direct current is used. An unused station line can also be used to supply this function.

2. All-call (two-pair): The all-call (two-pair) line is taken from the paging facility built into, or provided optionally by, the switchboard. One pair provides an "A" relay contact (normally open) and the other provides an audio signal at normal telephone line level. The "A" contact has to switch the positive leg of the monitor voltage into an electronic relay circuit. Maximum current through the contact is 30 milliamperes of direct current.

The switchboard supplier should install cable(s) for the station lines, and these special lines should be connected to a termination panel adjacent to the interface cabinet. The supplier should also install lightning arresters and line-loading coils where required, according to recommended telephone installation practices. Preferably, the PABX switchboard should be equipped with standby batteries in the event of an alternating-current power outage. However, this is not a requirement.

Figure 2 illustrates a typical mine dial-and-page phone system installation. Generally, the interface cabinet for such a system is located in a communications room along with the PABX equipment. In a typical installation, a multipair cable consisting of up to 100 pairs of 19-gage conductors and a steel messenger (fig. 3) is run from the interface cabinet to the first phone, generally at the bottom of the shaft. At this point, the cable is frequently split into two 50-pair cables, and it is threaded throughout the mine, often splitting at junctions to 25-pair, 18-pair, 12-pair, 6-pair, and, finally, a 1-pair for the phone at the face or last crosscut. The cable is most generally suspended from the roof by J-hooks located on one side of the tunnel. Figure 4 shows a typical mine dial-and-page telephone installed in a mine.

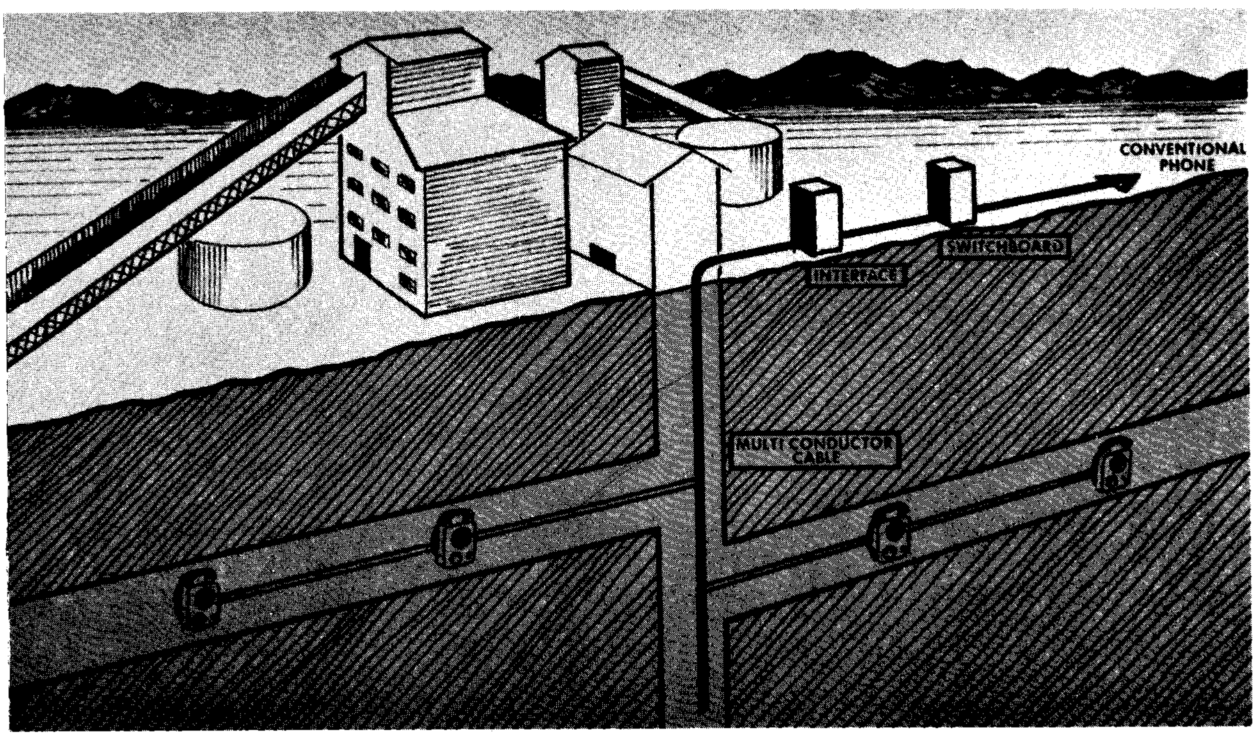

FIGURE 2. - Typical mine dial-and-page phone system installation.

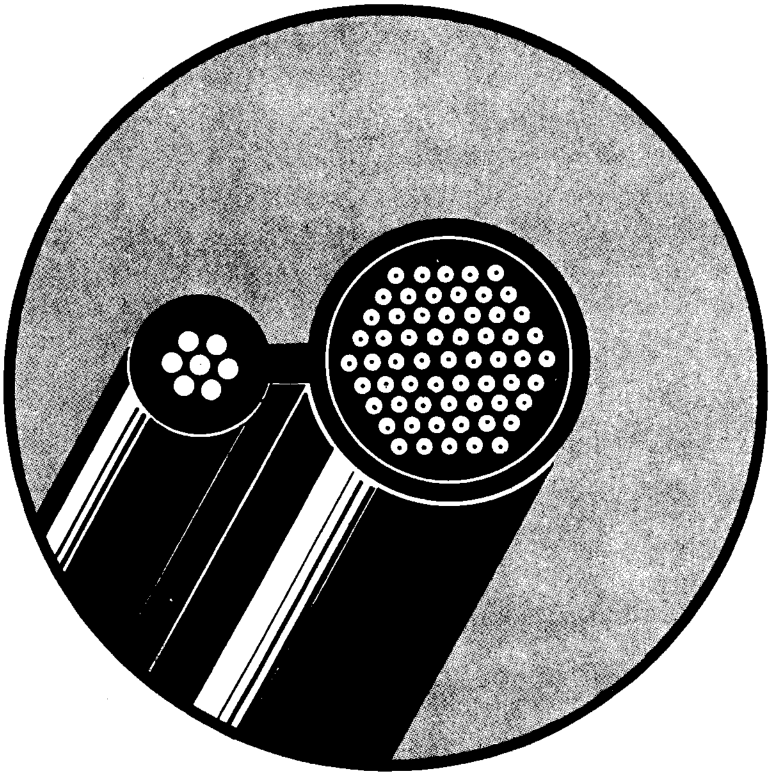

FIGURE 3. - Cutaway view of multipair messenger cable.

Phone Operation

Many mines begin operation with as few as 10 to 15 phones on their communication systems, and simply by adding interface cards and phones, they can be expanded to the full 80-phone capability of a single interface cabinet. If more than 80 phones are needed, a second interface cabinet and cabling can be added and connected to the same PABX.

In operating (fig. 5), the called party is notified of a call by means of an electronic "birdie" tone. (As an optional feature, a high-intensity flashing light is mounted on the front of the phone and flashes in conjunction with the "birdie tone.") To answer the call, the party merely picks up the handset of the phone and presses the handset switch to listen and talk. Releasing the handset switch returns the phone to on-hook status.

To make a call from any of the phones, the caller removes the handset from its holder, depresses the press bar in the handset, and listens for the familiar dial tone (fig. 6). The call can then be made as with any conventional dial phone, except that after dialing the extension wanted, the caller will hear the "birdie," which rings for about 4 seconds. He then has 36 seconds to page the particular individual in that area. When the called party answers, the page circuit is released and conversation takes place in the normal manner.

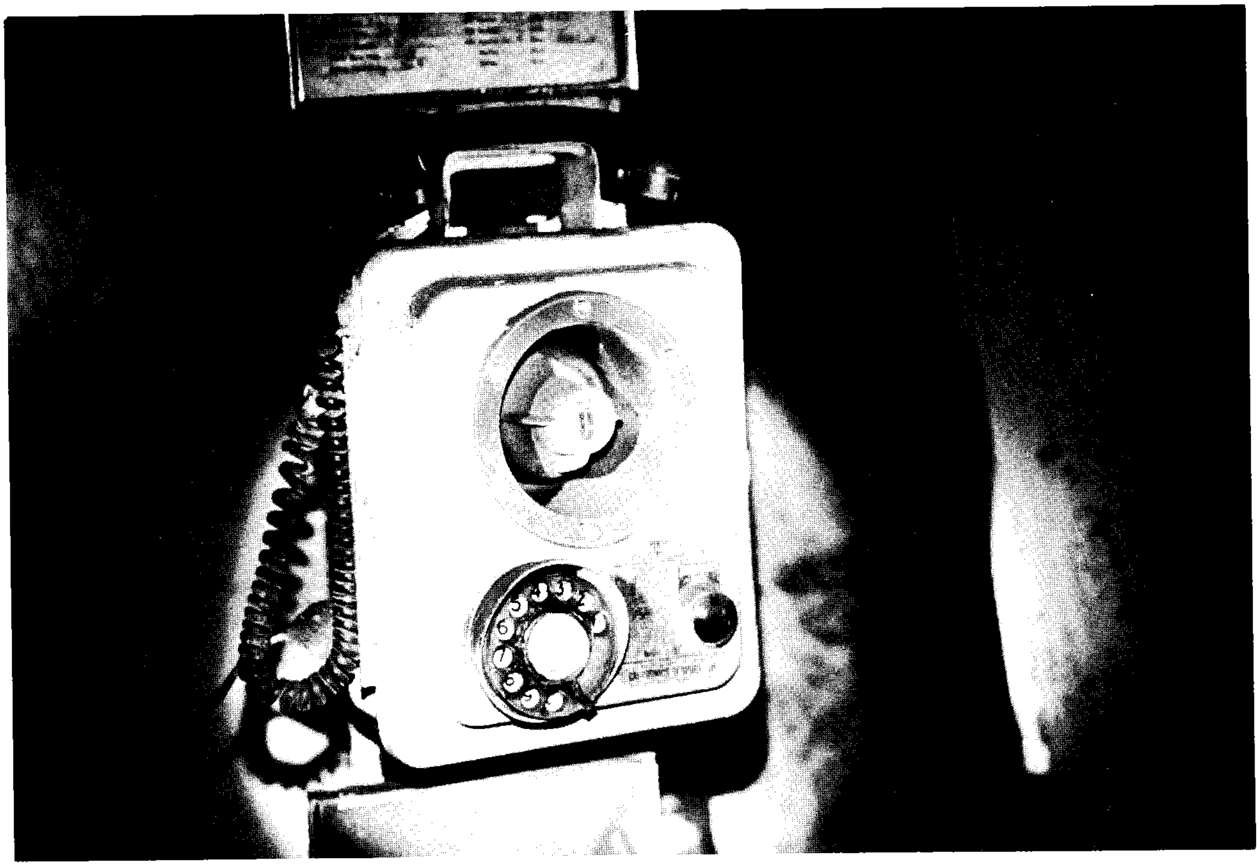

FIGURE 4. - Typical mine dial-and-page telephone installed in a mine.

Call-and-Merge Mode

The system automatically transfers to the merge mode in the event of a switchboard failure. To operate under this mode, the caller does the following:

1. Squeezes and holds handset bar (no dial tone will be heard).

2. Pushes and holds "emergency page" button.

3. Pages desired person(s).

4. Releases button and waits for answer (conversations are not private since any number of persons may use the party line simultaneously in the same conversation).

5. Releases handset bar to terminate call.

FIGURE 5. - System notifies called party by "birdie" tone signal (optional flashing light also indicated).

FIGURE 6. - Miner initiating a call on a dial-and-page phone.

PROGRESS TO DATE

Since the first mine dial-and-page phone was placed in operation in 1974, GTC has experienced a singular lack of difficulty in both installation and operation. As with any new product, we worked very closely with the personnel at each mine as a system was installed. Proper installation is critical to the successful operation of the system. Although GTC does not install the equipment, its company engineers are present at the jobsite for startup and checkout. On one occasion, the engineers found that two-conductor untwisted pairs were used for several phones and where these wires ran past rectifier banks and other noise-producing mining equipment, hum was introduced into the line. Shielded twisted pairs at these trouble spots corrected the problem.

In another instance, lightning arresters were not installed aboveground between the interface cabinet and the portal, resulting in several phones in the system being out of order for about 6 hours. This was also corrected, and no failures have occurred in this manner since that time.

Three systems have been in operation for over 2 years, and five systems for over 1 year. In each case, the manufacturer has conducted training programs for the mining personnel and has given assistance in the checkout prior to startup. These systems are located in Ohio, Pennsylvania, West Virginia, Illinois, Colorado, and Wyoming. Most are in coal mines, but a few are used in mineral mines, especially in the Western States.

One problem encountered early in the program was overcoming the need for an interface to the switchboard. GTC recognized the need to provide protection to the switchboard and made provisions for this in the design concept. After the details of the system were explained to the telephone company, its personnel determined that an interface was not necessary, and were willing to complete installation to the interface cabinet.

Even where intrinsic safety is not required, the versatility of the system was found to be highly desirable over conventional mine communications.

GTC is in the process of building its 10th system now and anticipates delivery by June. The company has several systems in proposal as well. Since this type is used in relatively large mines, continued acceptance is anticipated over the next several years as the demand for coal continues to grow.

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AN INDUSTRIAL COMMUNICATIONS SYSTEM

by

James L. Drake[1] and John M. Sticklen[2]

ABSTRACT

In the fall of 1972, the Ohio Valley Division of Consolidation Coal Co. asked the Chesapeake & Potomac Telephone Co. (C & P Telephone Co.) to extend aboveground telephone communications to its underground operations in three mines. A telephone system was designed, built, and installed for day-to-day operations and emergency use. From its inception, this installation was kept simple, providing only basic communication service needs. This initial installation and subsequent modifications to the telephone equipment did not meet intrinsic safety requirements. However, in March 1977, Bell Telephone Laboratories, Western Electric, and C & P Telephone of West Virginia completed a telephone system design that is believed to be intrinsically safe. This system has been installed and is undergoing service evaluation. An application has been submitted to the Mining Enforcement and Safety Administration (MESA) for approval and certification. This paper describes the service and its features.

INTRODUCTION

The telephone company believes that with the technology now available, the extension of communication services to underground mine environments is a natural continuation of aboveground capabilities. Moreover, encouragement in this endeavor was given by the mine operations people.

West Virginia telephone company has been on the scene for quite some time. For example, figure 1 is a picture of a miner using a Western Electric standard telephone set for underground mines in 1913. The picture comes from a 1913 telephone company newspaper article, "The Telephone's Place in West Virginia Coal Mining," which tells the story succinctly on page 3 of the article:

> "The instruments for use in coal mines are substantially the same as those used elsewhere, except that they are enclosed in compact, cast-iron boxes, 10 inches wide, 10-3/4 inches high, and 8-1/4 inches deep, coated with a finish that is proof against moisture, acid fumes, and gases. A hood on the top of the box protects the large, rust-proof ringer gongs and has an opening at the bottom wide enough to allow the sound waves to escape freely. A lever

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THE TELEPHONE'S PLACE IN WEST VIRGINIA COAL MINING.

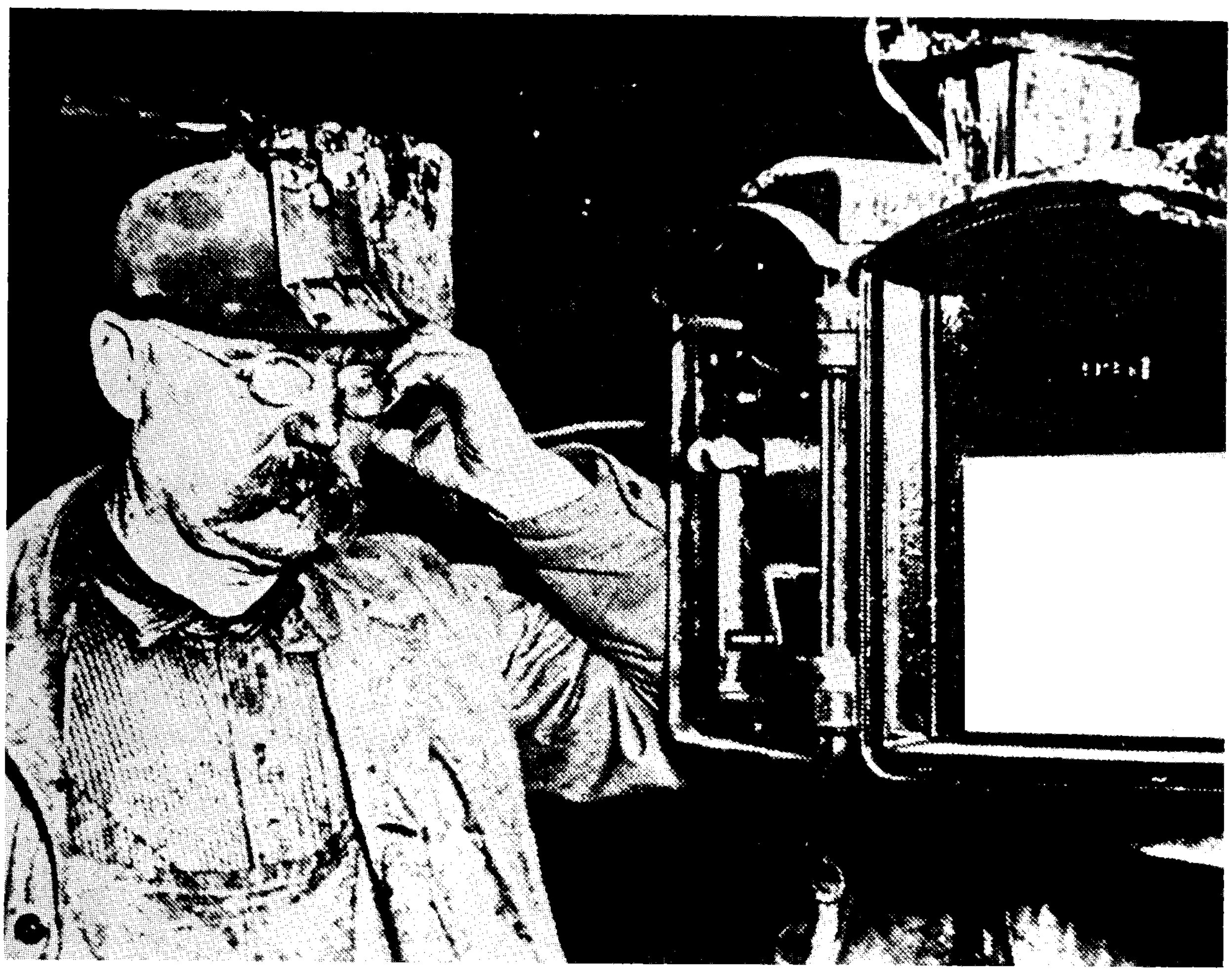

FIGURE 1. - Coal miner talking on a Western Electric standard underground telephone in 1913.

fastened by a pin or spring lock shuts the door, which has a wide overlap and is provided with a watertight gasket. All openings through the inner case for the ringer cores and the generator crank are sealed by gaskets and felt washers. The terminal box at the bottom is threaded to receive an iron pipe for bringing the line wires from the ground to the telephone. Opening the door exposes the receiver, generator crank and transmitter mouthpiece.

"No. 14 gauge copper telephone wire, rubber covered, double impregnated braiding is used underground. Lead covered cable is also used in some cases. The most approved plan of installation provides a circuit for the telephones entirely independent of the signal-bell circuit, and a means of ringing the signal bells in all or any part of the mine, as desired. Hand generators are used in the model installation, so as not to be dependent on power circuits, which are of no service when the engine stops or the fuses blow out. Polarized bells that have no contacts to get dirty and spark are also used."

In the 1950's, C & P Telephone of West Virginia introduced a telephone set for use in explosive atmospheres that was designed around the philosophy of explosion containment. To contain an explosion within the telephone set required a 39-pound casing, which greatly limited portability. By this time, it will be noticed that a common thread prevalent in the first 40 years of design and development is that the primary effort was placed on the telephone set. Both of these telephone sets require "pipe" or conduit; not a very practical item for a 100-mile-square coal mine.

In the early 1970's, as work began on the design of a communications <u>system</u> for use in underground mine environments, the following requirements were established:

1. <u>Must meet intrinsic safety standards</u>--This applies not only to coal mines, but to other explosive environments.

2. <u>Must be compatible with the environment</u>--Consideration is given to the dust, moisture, and corrosive conditions.

3. <u>Must be rugged in structure</u>--The system must withstand 10-inch pliers and 4-pound hammer-type maintenance, as well as "bounce" a piece of roof.

4. <u>Must be size-flexible</u>--Whatever is built must be sized for the small operator as well as the large companies.

5. <u>Must be a system in design</u>--The system has to be intrinsically safe: cable, power supply, station set.

6. <u>Must work with present telephone system</u>--It should be as an addendum to services already marketed; such a system should not be the single cause of change in aboveground communications.

7. Value-added pricing--The system should be provided on an economical scale so that savings created by the introduction of the system will more than offset the installation cost.

8. Full-service full-support concept--The service offering must provide for maintenance, training (initial and continuing), route design, and transmission engineering.

The system undergoing field evaluation has been designed to meet all of these criteria.

THE INDUSTRIAL COMMUNICATIONS SYSTEM (ICS)

An important feature of the Industrial Communications System (ICS) is that it is superimposed on the current telephone system provided by the telephone company. The underground telephone presents a compatible interface to other telephone equipment, such as a PABX, a key telephone system, or the C & P Telephone Co.'s central office. The system does not impose any special requirements on the overall telephone-planning process.

Conventional dial telephone service is provided between the underground station and the standard administrative telephones above ground to aid in the day-to-day efficient operation of the mine. These connections can be made directly, or via a control console if the mine is a large operation, or if conference calls between several stations are required (fig. 2).

A "line circuit" is installed in the same roon that houses the mine's existing telephone equipment. The primary purpose of the line circuit is to convert intrinsically unsafe signaling voltages to voltage levels required for safe mine operations, whether fans are on or off. This line circuit is also used to provide line continuity and control signals if a control console, used in larger installations, is required.

The telephone line is extended by wire or cable to an apparatus case near the mine portal. In this situation, equipment is installed to interface with the line circuit equipment, again with an intrinsically safe voltage level maintained to this point. The "mine portal circuit" also provides the necessary lightning protection. Figure 3 illustrates this portion of the system.

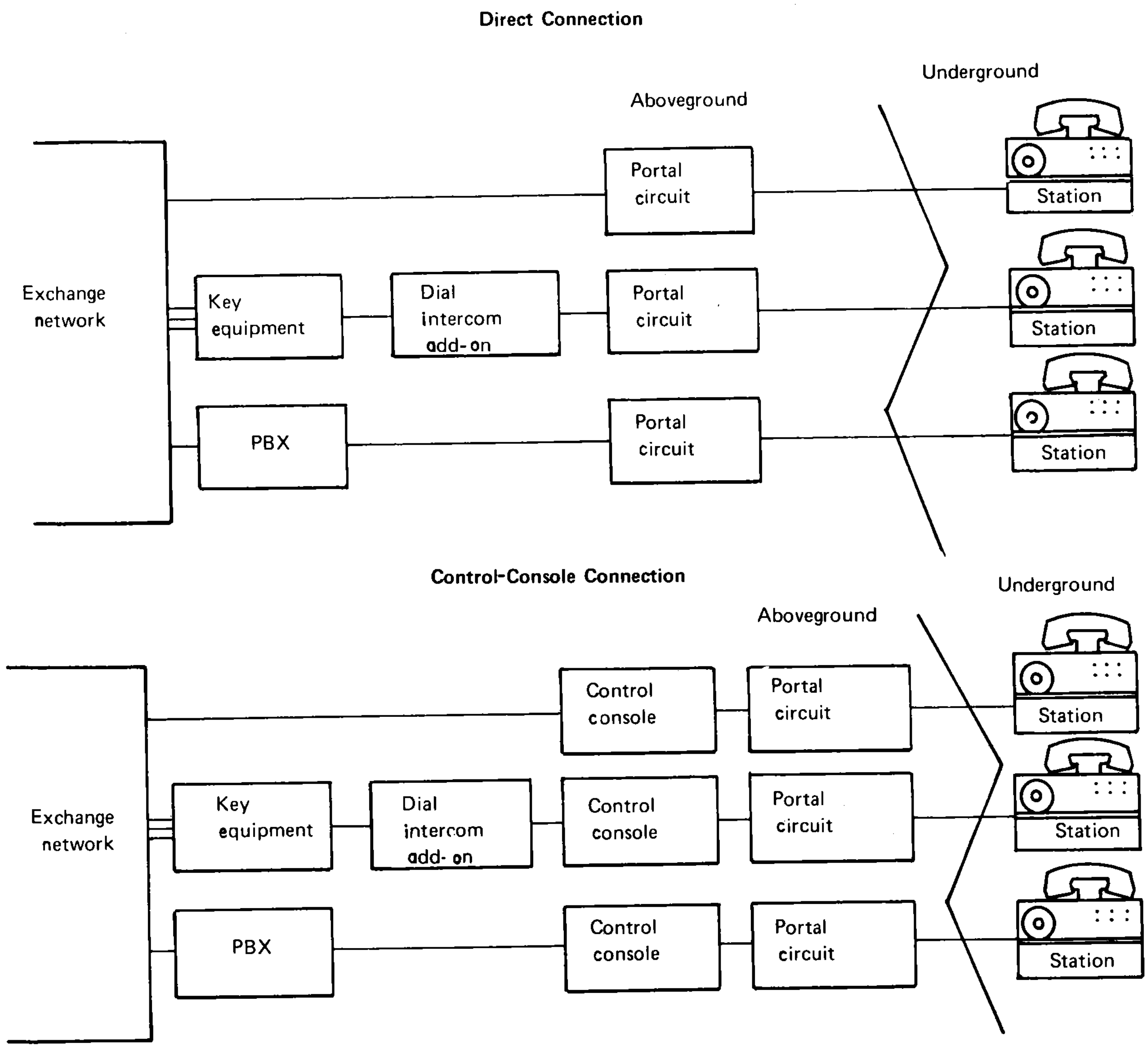

FIGURE 2. - Types of talking paths provided.

From the mine portal, telephone lines are distributed through the mine via wires or cable. (A 19-gage self-supporting cable is recommended.) In most conventional telephone systems, it is necessary to install loading coils (fig. 4) at specified intervals to maintain a clear talk path. The ICS does not require loading, as a general rule, for distances up to 10 miles beyond the portal or other point of entry. Eliminating the use of loading coils in the mine greatly simplifies cable installation.

Telephone Station Set

For the service evaluation installation, station sets were designed to be intrinsically safe. To withstand the severe environmental conditions of a

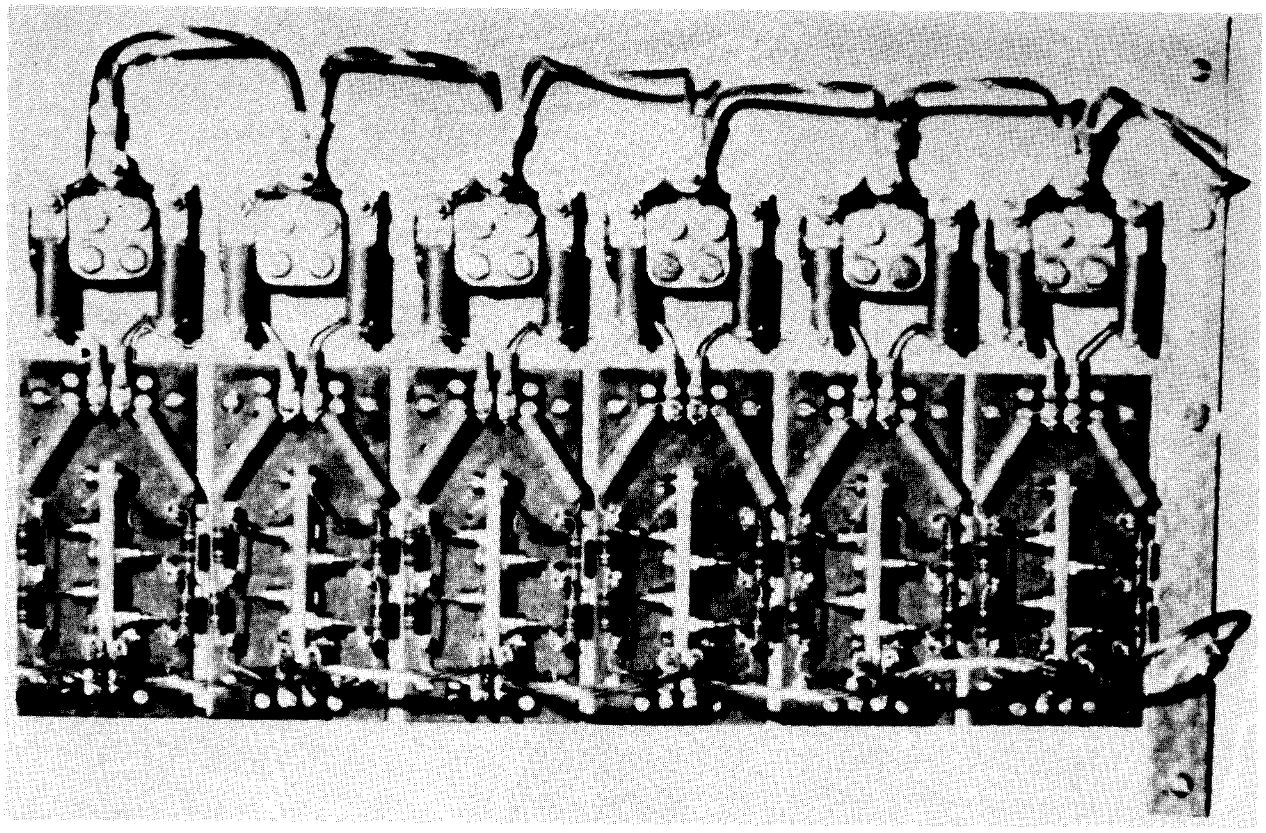

FIGURE 3. - Mine portal circuit equipment (six circuits).

coal mine, two types of casings were used--fiberglass and aluminum--to house the station set. Both of these materials provide light weight and portability features as well as ruggedness. Weight requirements have been held to about 12 pounds, three times less than the present explosive atmosphere set, and half the weight of the Black & Decker "Work Mate" advertised widely as an easily portable work bench (fig. 5). It is too early to say what casing will be used for the product on-line model, but plastic-type materials will be considered before any decision is made.

A number of characteristics contribute to making our station set intrinsically safe and environmentally sound. These have been incorporated as standard features:

1. <u>Dial phones--rotary or touch-tone</u>--The dialing mechanism and switch-hook contacts are completely enclosed in the sealed station housing.

2. <u>Handset with push-to-talk switch</u>--Ambient noise on the line is kept to a minimum.

3. <u>Transmit and receive amplifiers</u>--Associated with the handset, these amplifiers permit elimination of cable loading coils previously mentioned.

In order to maintain transmission, the inductance and capacitance on a circuit must be equal. In a standard cable pair there is more capacitance than inductance. To overcome this imbalance, Load (induction) coils are wired into the circuit at proper intervals. This added inductance tends to make the capacitance and inductance appear equal in relation to the voice currents.

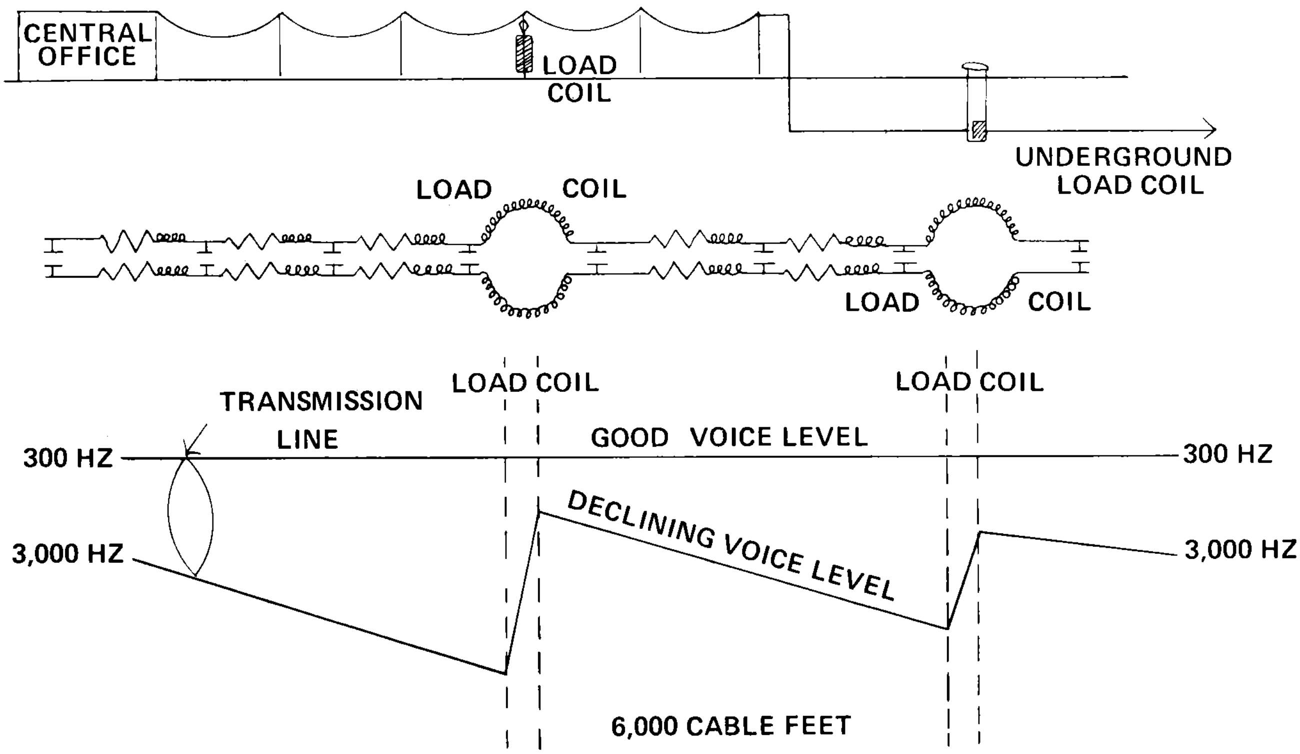

FIGURE 4. - Loading coil and its function in conventional telephone installations.

4. Weatherproof loudspeaker with power amplifier--This feature provides a high output level for an efficient audible tone signal and voice paging.

5. Improve-hearing button--When depressed, the gain of the receiver amplifier in the handset is increased (for very noisy locations).

6. Sealed enclosure--The casing is designed to allow the station set to operate in 4 inches of water. Damp-air and dust-particle penetration is held to a minimum by use of a pressure-release valve.

7. Battery test button--The battery condition can be checked without opening the station set. When depressed, an associated lamp will light if battery is in good condition.

8. Call waiting lamp--This lamp remains on for 5 minutes to alert a passing employee that a call was placed to the station.

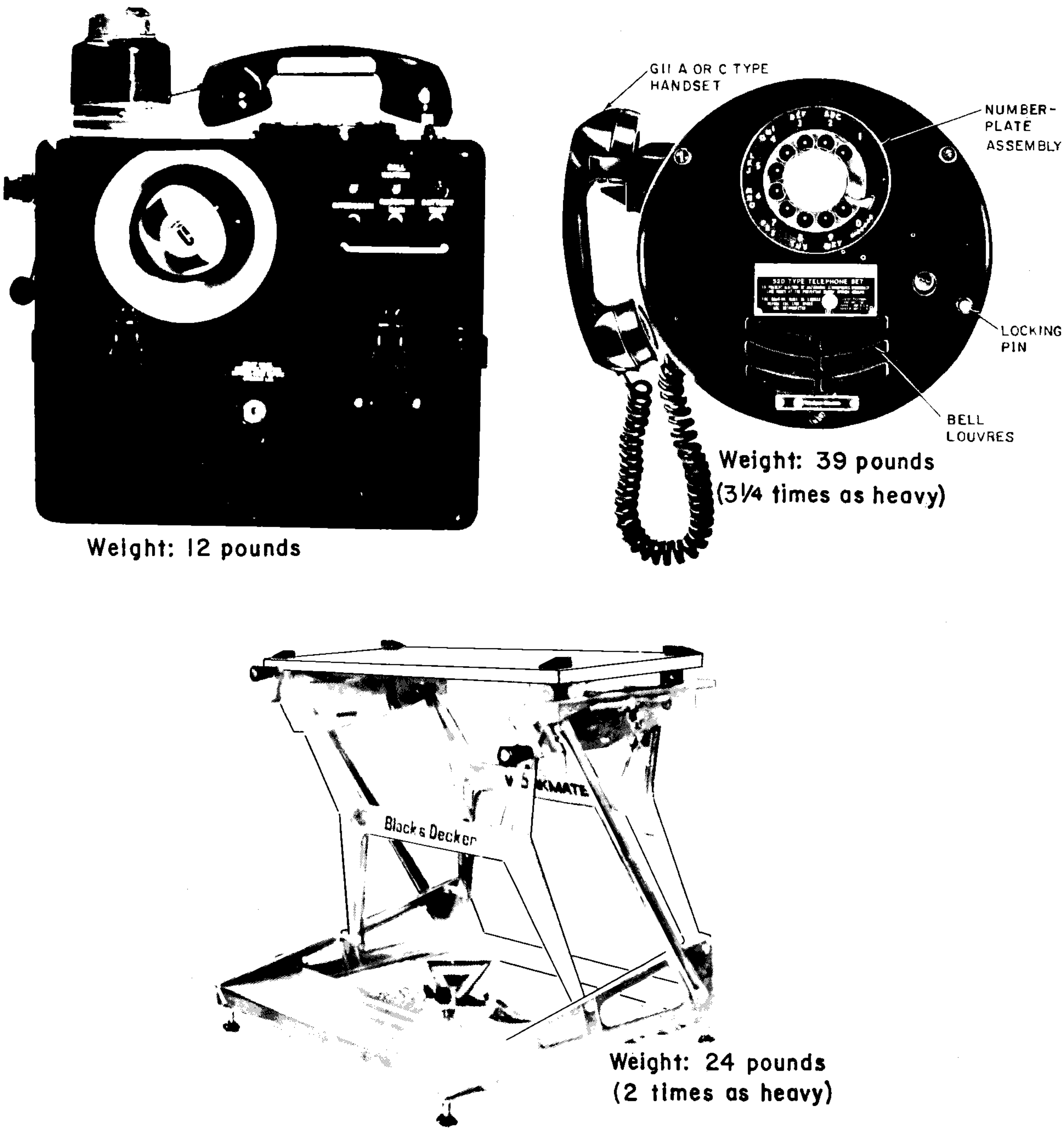

FIGURE 5. - Size and weight of ICS underground telephone compared with those of a 520B explosionproof telephone and a portable work bench.

Of course, the indicator lamps mentioned are light-emitting diodes (LED's), which help conserve the drain on the 12-volt battery. These features are presented in figure 6.

In addition to these standard features, options have been provided for use where the need exists. This permits the mine operator to control costs by not having to bear the burden of features he does not need or would seldom use. The more significant options are as follows:

Strobe alert lamp--A flashing strobe lamp, designed for intrinsic safety, may be extended up to 800 feet from the station--plug end connected. It permits the visual signal to be located as close as practical to the working face.

Intercom arrangement--This option permits two station sets on the same line to talk independently of the normal talk path.

Narrow-band telemetry--A noninterfering shared use of the telephone line provides narrow-band data transmission above the normal upper voice range of 2,600 hertz. (This is an economical shared use of that expensive cable pair for monitoring devices, etc.)

Terminals for wireless transmitters--Terminals will be available to connect signaling leads to trigger a wireless transmitter when the station set receives a call.

Automatic loop transfer--Equipment can be provided to permit automatic changeover to a redundant wire or cable pair if the wire or pair in use fails.

These features are depicted in figure 7.

Control Console

Part of the communications requirements included in our first system design for Consolidation Coal was a control console placed in the communications center. This console permits an attendant to conference station lines, seize communications in an emergency and, most importantly, maintain increased control and tracking of communications traffic and personnel below ground.

The telephone company soon concluded that this portion of the service had to be packaged sufficiently small that more than just a few mines could utilize its benefits and features. The console has been designed to accommodate up to 30 station lines (a maximum of 90 station sets). Actually a console for more than 30 station lines can be built, but it is believed that the upper limit of what a person can reasonably control would be no more than 30 lines.

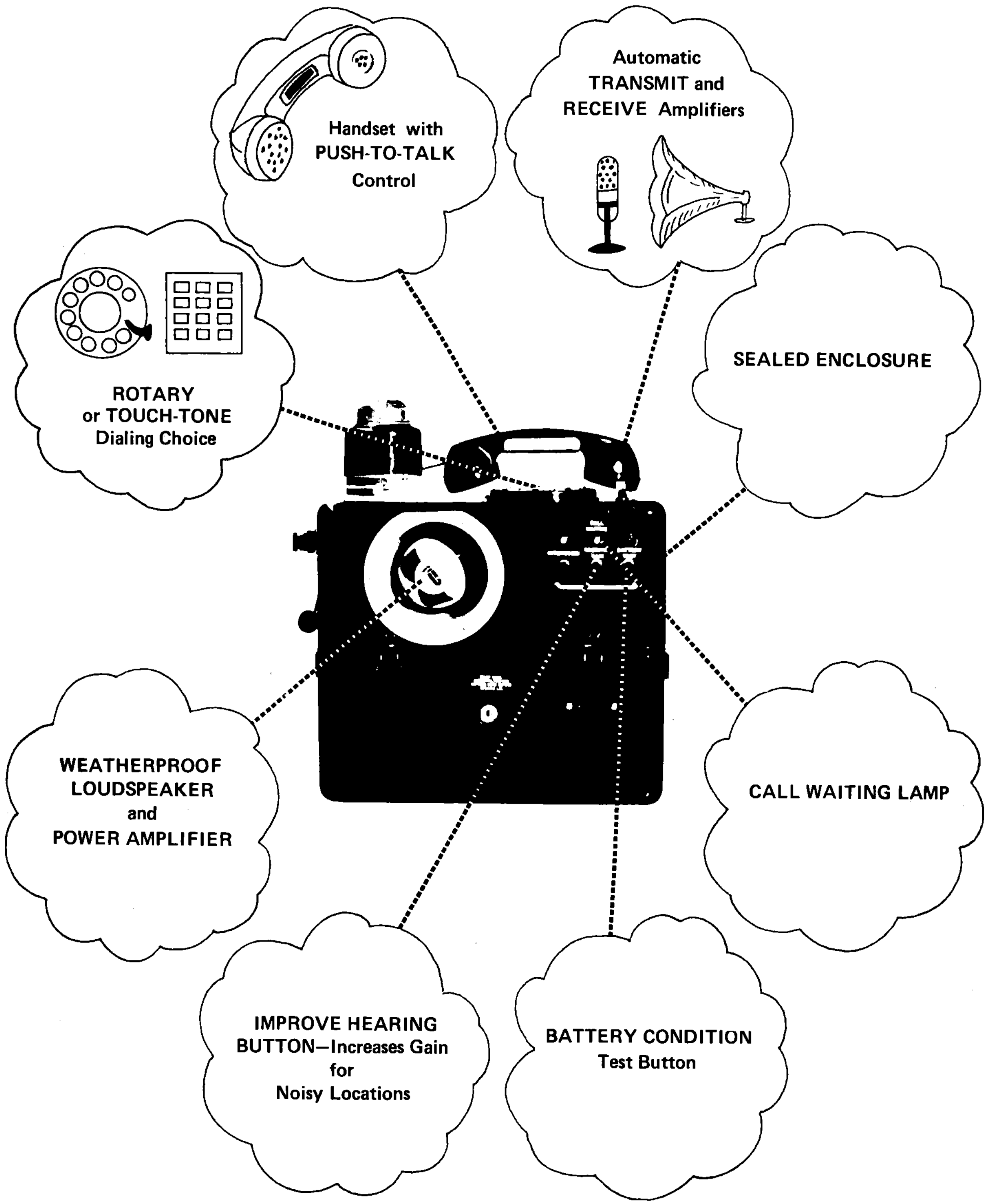

FIGURE 6. - ICS underground telephone—standard features.

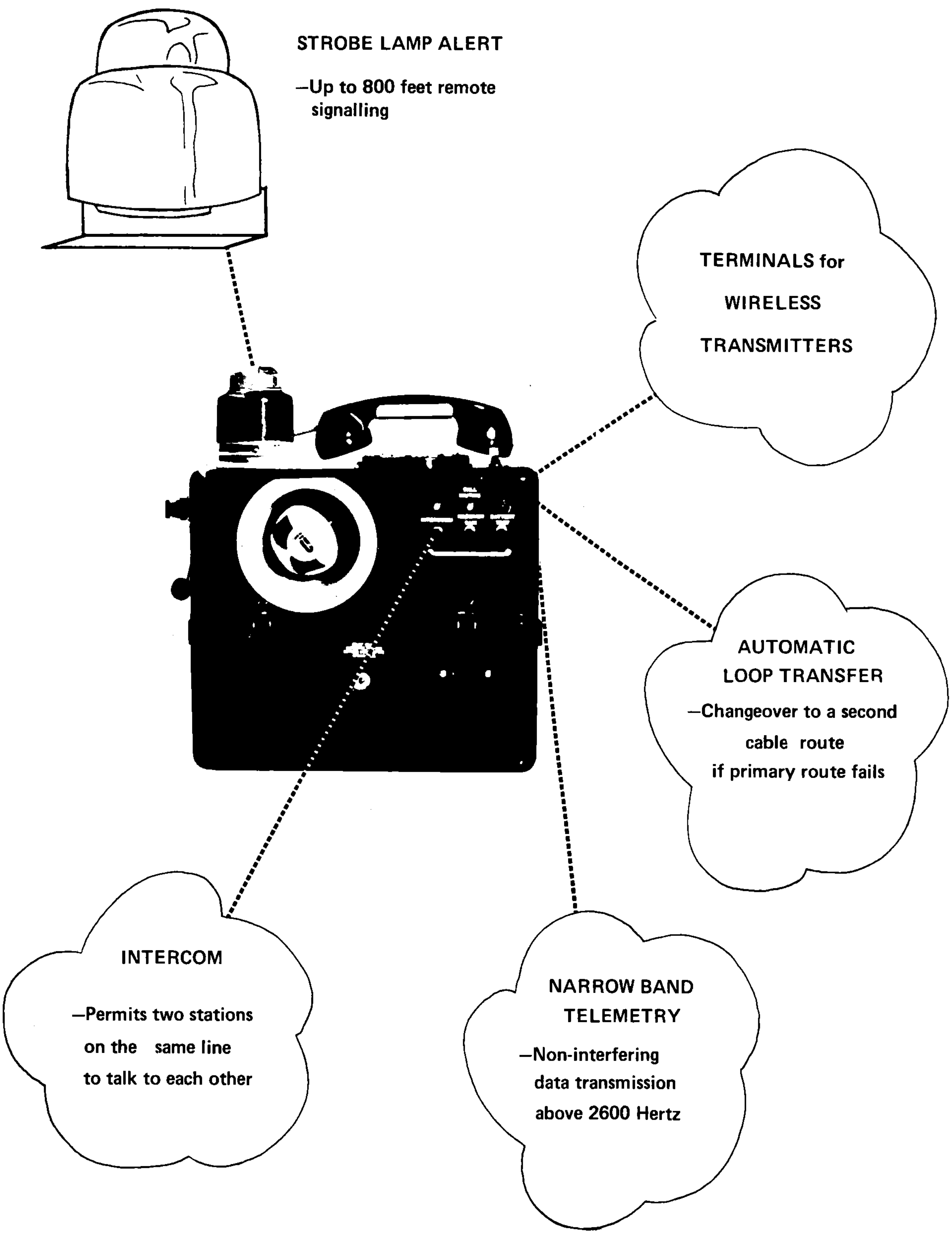

FIGURE 7. - ICS underground telephone—optional features.

The attendant of the console will find the following standard features available for use in "normal mode":

1. Busy lamp per line--The lamp emits a steady light, indicating a station set on that line has gone "off-hook."

2. Continuity indication--The busy lamp will flash and an alarm will sound when there is a continuity failure of the line.

3. Attendant override--The attendant may override a call in progress by depressing a key associated with the line-busy lamp. The busy lamp will flutter while this is taking place.

4. Attendant paging--Associated with each line is a conference key. When this key is depressed, the attendant can page the station sets on that line.

5. Attendant conference--Depressing several line conference keys at the same time permits the attendant and the answering station sets on those lines to conduct a conference.

6. Group conference--Operation time is reduced by grouping together preselected station lines to be called (by depressing one key). Up to five group-conference arrangements are available.

7. Loudspeaker--A small loudspeaker is mounted in the control console for those instances where a third party present in the control center would like to monitor the conversations taking place between the attendant and the station lines.

When the "emergency conference" key is depressed, the console is placed in the "emergency mode" so that the following emergency conference functions can take place:

1. Any desired line may be seized by depressing the line conference key. This line is now preempted and no other line--PBX, central office, or intercom--can call the line.

2. Group conference lines can be seized in the same manner as individual lines.

3. Lines off-hook and in conversation when this feature is activated are seized by the control console.

4. Station sets on lines seized will receive a continuous alert tone. Station strobe lamps, where provided, flash continuously.

5. Station sets answering are automatically connected to conference and the alert tone ceases.

6. On the consoles, the lamps associated with each conferenced line flash until the alerted station set answers.

7. The line-busy lamp lights when the station set answers, and the conference lamp associated with each station line flutters, identifying what lines are connected to conference.

The loudspeaker is automatically connected when the emergency conference feature is activated. The attendant can leave the all-conference situation in effect and conduct a private conversation with any station line by depressing the busy-override key associated with the line.

All emergency conference calls can be recorded automatically on a cassette recorder. As an option, a second recorder can be connected to the console to record normal conversation.

Should a group of people be required to confer with parties underground, a remote connection activated from the console has been provided. Items such as the 50A conference set are ideal in a situation like this. All of the console features are illustrated in figures 8 through 10.

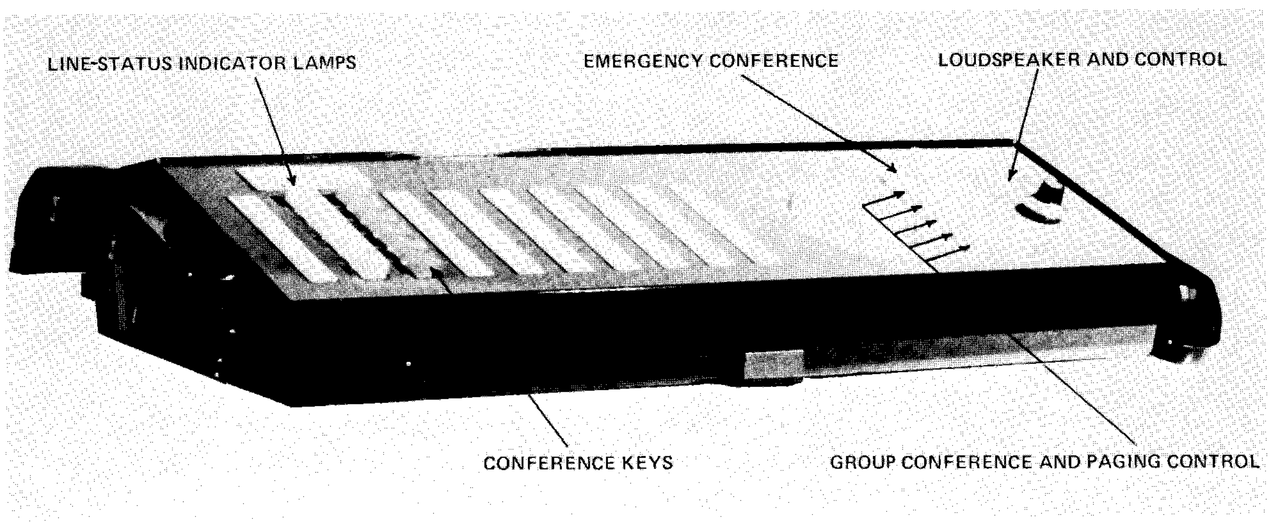

FIGURE 8. - Control console with overview of features.

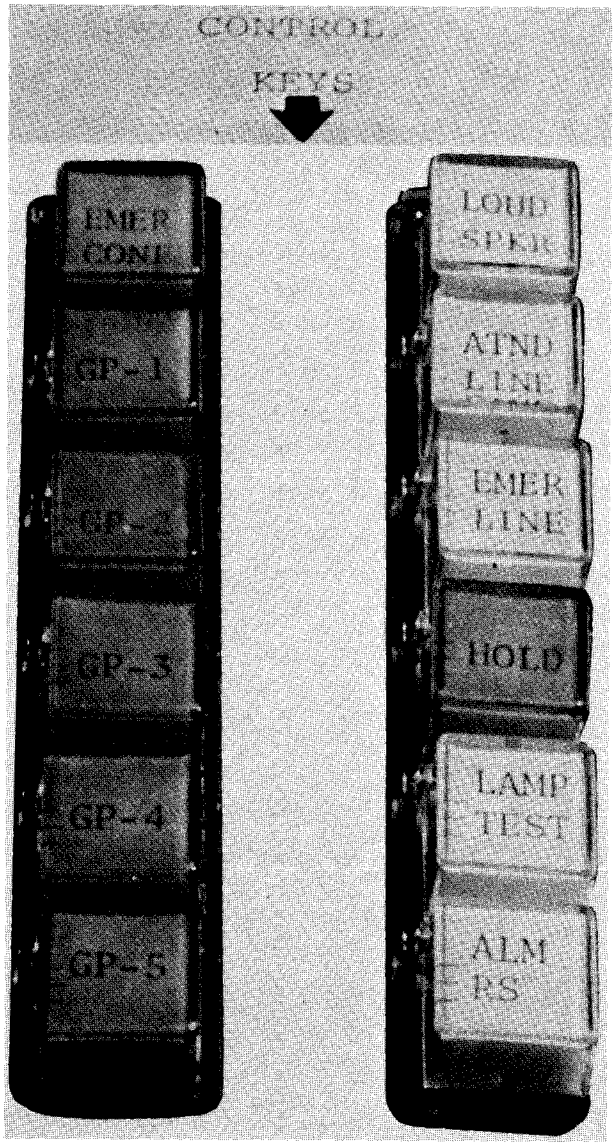

FIGURE 9. - Control console showing detail of attendant control keys.

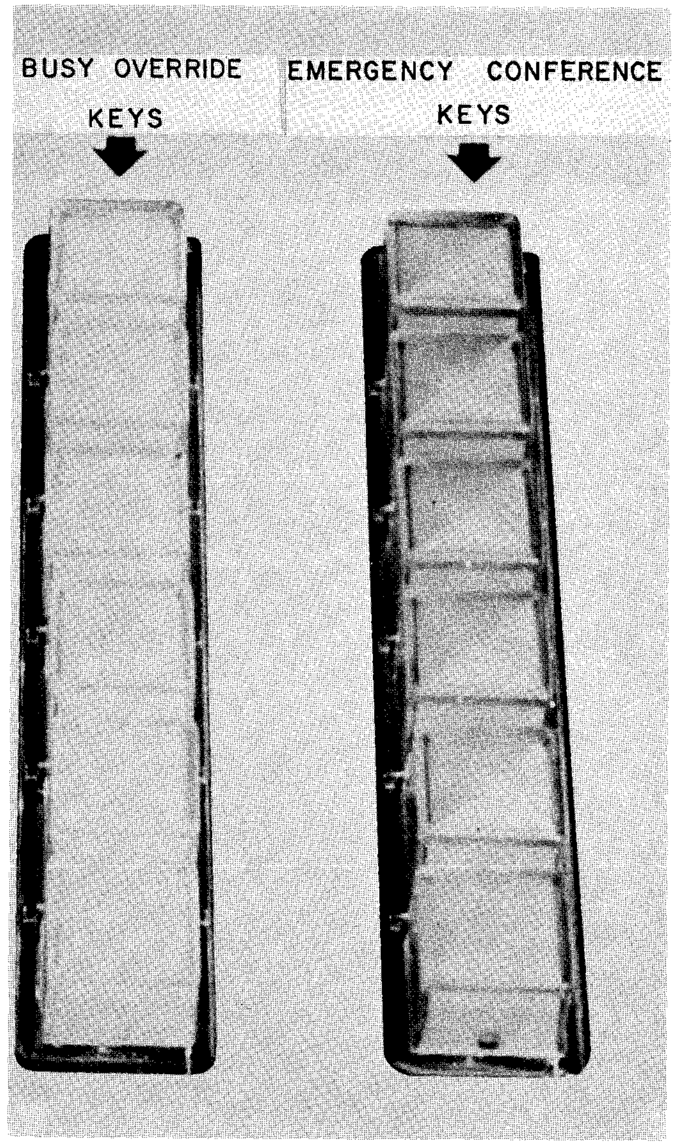

FIGURE 10. - Control console showing detail of busy override and conference keys.

EARLY SERVICE-EVALUATION RESULTS

Prototype installations are made to determine flaws in design and construction. The telephone company fully expects Consolidation Coal Co. personnel to be critical of the installation. Early findings indicate that Consolidation Coal is living up to its obligation to constructively evaluate the system. The following station set modifications are being considered:

1. Brighter strobe light.

2. Continuous strobe light signal during ringing cycle.

3. Loudspeaker volume control.

4. Connectors for line circuit, intercom, telemetry, and strobe light that do not protrude from the side of the set.

5. Eliminate solder terminations in connectors by using screw-type "Hubbell" connectors.

6. Longer handset cord.

7. Larger and brighter LED's.

8. Locate LED's and buttons nearly flush with housing.

9. Mount dial on front of set.

10. Bright paint.

Additional information on the service evaluation installation of the Industrial Communications System may be obtained by writing to

J. M. Sticklen, District Engineering Manager
C & P Telephone Co. of West Virginia
1500 MacCorkle Ave.
Charleston, W. Va. 25314

A COAXIAL-CABLE TELEPHONE SYSTEM

by

Harry Dobroski, Jr.[1]

ABSTRACT

An integrated mine communication and monitoring (MCM) system has been developed by the Bureau of Mines for underground mines. It allows private telephone channels, environmental monitoring, and control of underground equipment, all on a single coaxial cable. All system operations are under the direct control of a dedicated minicomputer. Many advanced features are incorporated into the system, such as paging to roving personnel, two-way section wireless, through-the-earth emergency communication, and others. This system is presently installed in United States Steel Corp.'s Robena mine complex near Uniontown, Pa. A similar system was recently installed in Eastern Associated Coal Co.'s Federal No. 2 mine, and the Bureau of Mines has a small system in its Bruceton Safety Research mine.

INTRODUCTION

Three types of communication systems have become very popular in U.S. coal mines: loudspeaking page phones, carrier current phones, and magneto ringing phones. Basically, all three are simply single-channel party-line systems.

Although these systems are quite reliable, the single channel creates a variety of problems. For example--

1. Since no call is confidential, messages are sometimes purposely made vague, especially if accidents or safety topics are being discussed.

2. A potential user must literally "wait on the line" until the channel becomes clear for his use; thus, when foremen have to wait to call in reports or supply requests, this single channel creates a serious productivity bottleneck.

3. In many large mines, there are independent branch lines that must be tied together by a dispatcher, adding further delays to the system.

To solve these problems, some mines have installed other phone systems--mostly commercial dial phones in industrial enclosures that offer extra channel capacity and private-line features; others have installed a system that combines both dial-phone and page-phone features in a single unit.

[1]Electrical engineer, Industrial Hazards and Communications, Pittsburgh Mining and Safety Research Center, Bureau of Mines, Pittsburgh, Pa.

Although these do represent improvements, they do not truly solve the overall problems that face modern coal mines. Besides extra channels, a communication system should have many other features to enhance productivity and safety.

1. A means of paging a roving miner to alert him that he is wanted on the phone.

2. Wireless-to-wired system interconnects by which a miner can talk on the wired phone system by using a remote portable radio.

3. Monitors that alert personnel that there is a toxic or explosive gas buildup.

4. Control interfaces that allow remote control of fans, pumps, or other devices.

5. Through-the-earth transmitters and receivers that can serve as emergency links, and also be used to switch monitors on and off.

6. Loopback that allows an alternate path of communications if the main path is cut.

All these features, and others, should be possible on a single transmission cable.

DISCUSSION OF SYSTEM

Overview

The capabilities stated have been met by a new integrated mine communication and monitoring system (MCM) developed by Collins Radio Group of Rockwell International under a Bureau of Mines contract. The functional block diagram of this system is shown in figure 1.

A single coaxial cable is installed throughout the mine with various branches for distribution. This cable carries both radio-frequency (RF) and direct-current power. Cable splices are made with a special splice connector shown in figure 2. The radio frequency is a frequency division multiplex (FDM) signal that carries the communication, monitoring, and control signals to the in-mine devices that are connected to the cable by a special tap (fig. 3). On-line RF amplifiers are used to overcome line losses. The direct current, which is provided by several surface power supplies, is used to charge batteries in all the underground devices. These batteries assure that the system will remain operational, even if the main power is lost.

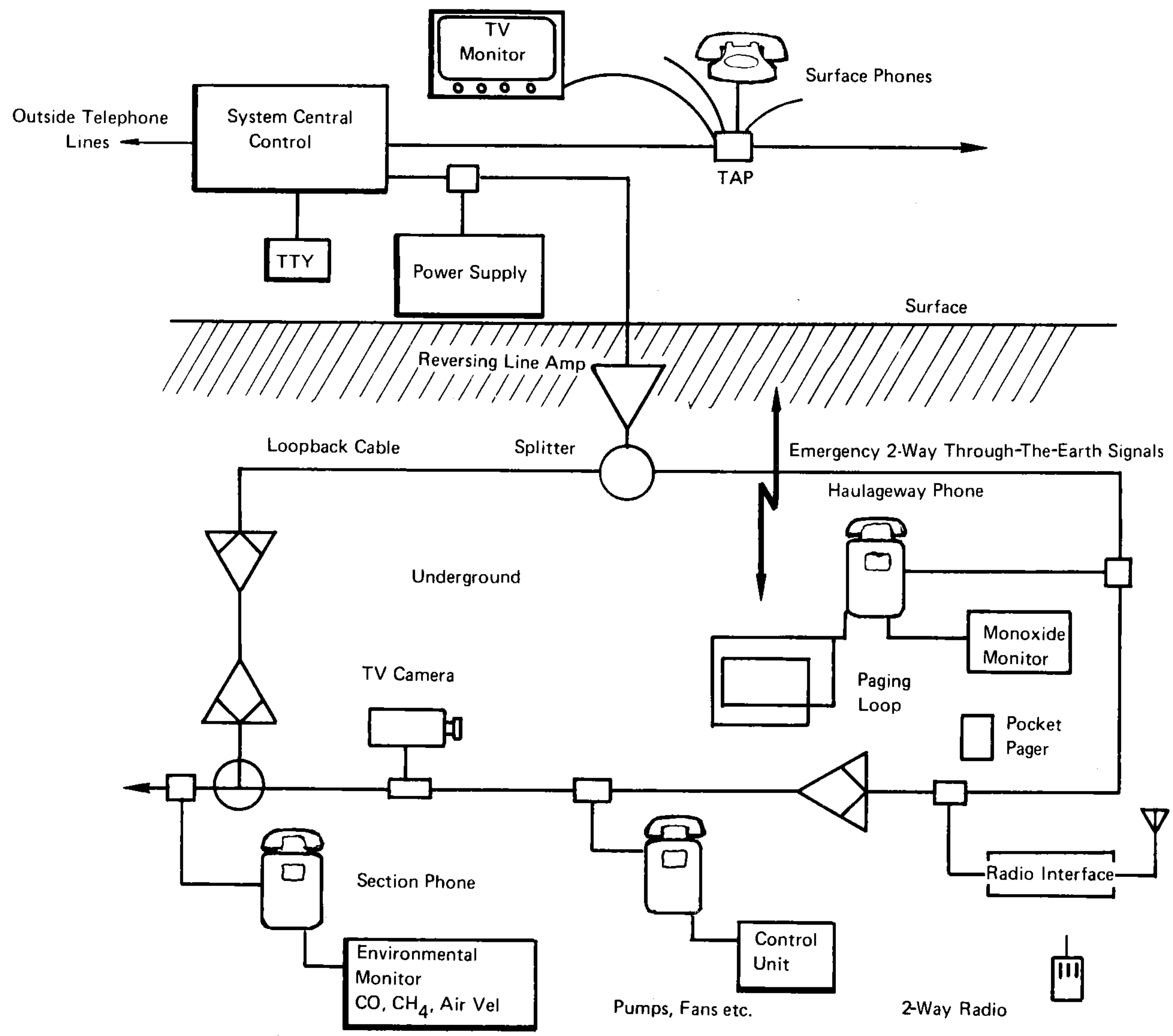

FIGURE 1. - Functional block diagram of whole mine communication and monitoring system.

The heart of the system, the system center (fig. 4), is located on the surface. It consists of a dedicated minicomputer, various interface and control circuits, power supplies, a teletypewriter (TTY), and a monitor display matrix.

Telephone Service

The minicomputer is programed to operate the system on an FDM basis. The frequency division multiplex allows many independent channels on the single coaxial cable without interference. Each telephone is a complete single sideband transmitter and receiver, the operating frequency of which is assigned by the system center. This assignment occurs whenever a phone goes off-hook. Each phone is continually kept in contact with the system center on dedicated

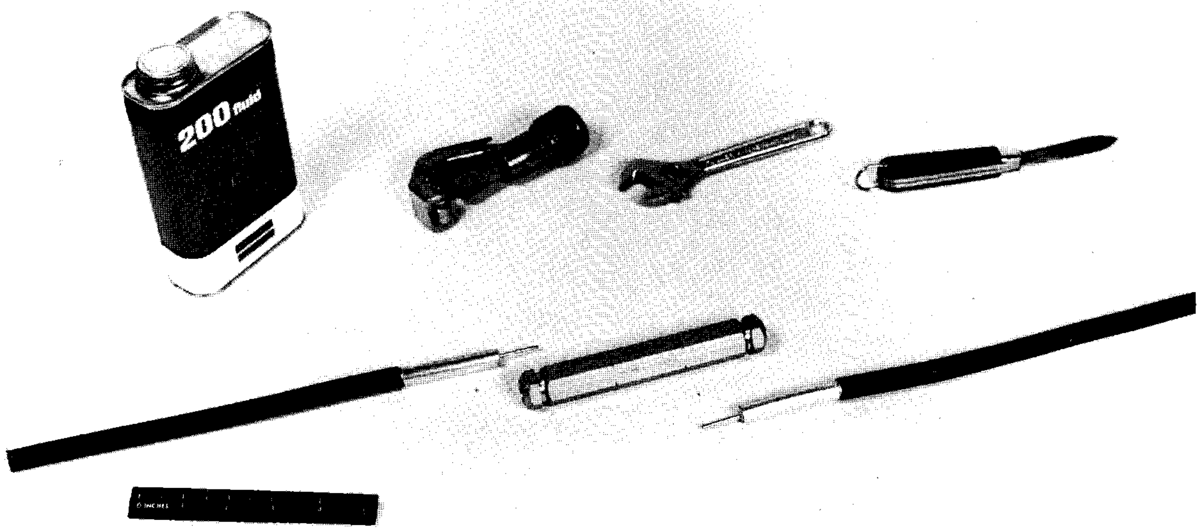

FIGURE 2. - Equipment and tools for cable splicing.

FIGURE 3. - Workman making underground phone taps.

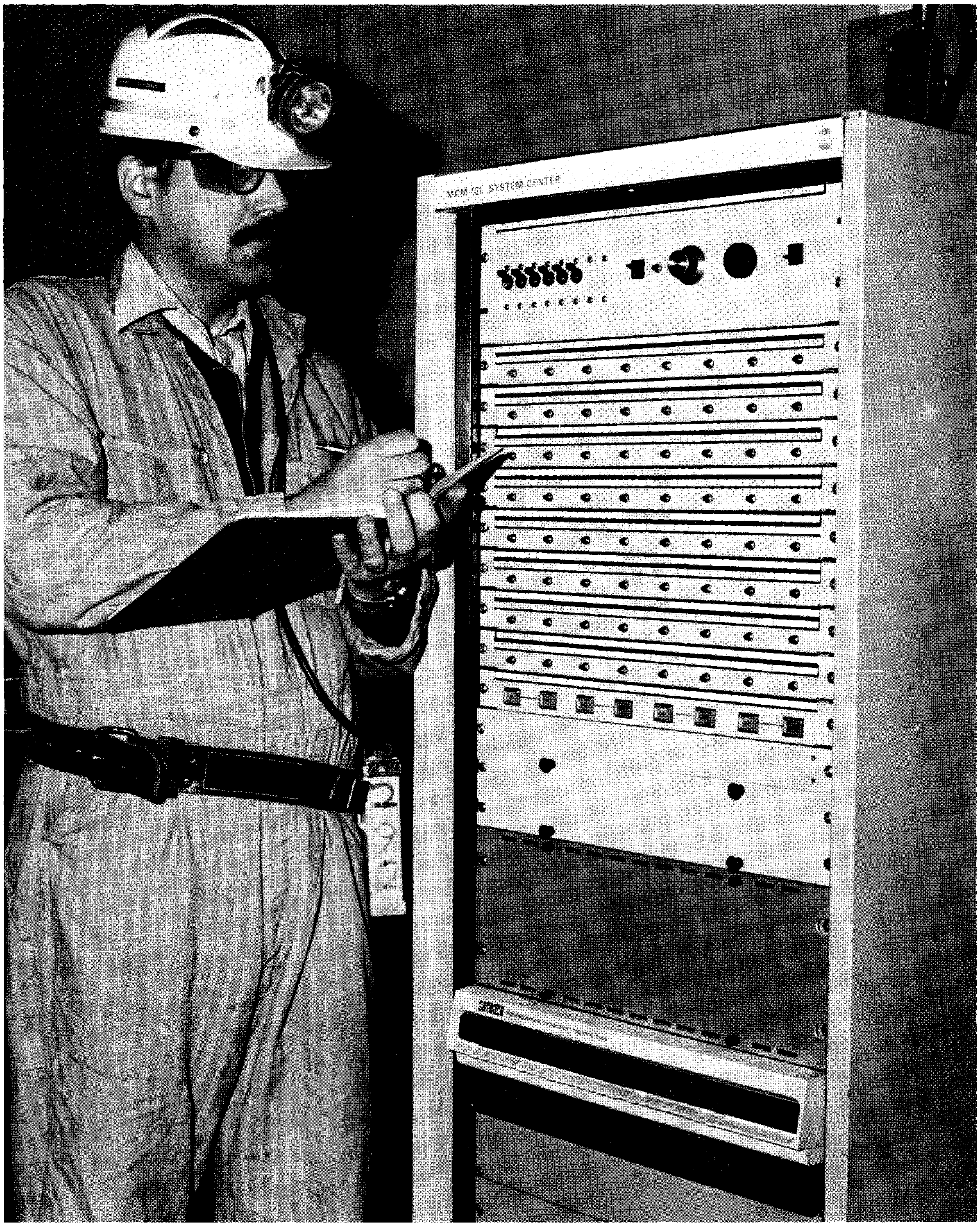

FIGURE 4. - System center equipped with dedicated minicomputer, interface and control circuits, power supplies, a teletypewriter, and a monitor display matrix.

FDM channels by digital means. A digital channel assigns the "called" phone and the "calling" phone proper frequencies, which allows full duplex operation. Other phones can be added to the conversation, if desired, for three-way (or more) conversations. Otherwise, the system center assigns different frequencies to other phones to achieve the private-line feature. Several hundred frequency channels are possible.

Besides the private-line capability, the system offers many other phone features:

1. Interfaces with telephone company lines.

2. Priority override that allows certain phones to join existing phone conversations.

3. Restricted access, which allows certain phones to call only certain other phones.

4. Call transfer.

5. Hold.

6. Call forwarding, which transfers the ring from one phone to another.

These features can be assigned to any phone by simple software inputs.

The system uses two types of telephones: Surface phones and underground phones. The surface phones resemble standard, desk-type, touch-pad telephones. The underground phones (fig. 5) are rugged versions of the surface phones, but they have extra operational capabilities. The underground phones are the basic building blocks that allow flexible expansion of system capabilities. Besides being telephones, these phones can be equipped with a low-frequency transmitter for paging roving miners and can also be interfaced with monitors, control circuits, or escapeway receivers.

Monitoring and Control

There are two types of environmental monitors that can be connected to any underground phone to create a monitoring station. An air-split monitor checks for methane, air velocity, and carbon monoxide (fig. 6). The air-split monitor is intended for use on the section where these three parameters are most inportant. A haulageway monitor checks for carbon monoxide only. The haulageway monitor is intended for rail or belt haulage where it could detect potential fires. In either case, if a particular monitor senses an alarm condition, this condition is displayed on the associated phone by a blinking lamp. At the same time, the monitor information is sent to the system center via the digital FDM channel. Here, a corresponding lamp on a lighted monitor display matrix is activated, alerting the surface to the problem and its location. In addition, the TTY prints out the time of day, location, and nature of alarm for future reference. Besides the environmental

FIGURE 5. - Underground telephone.

monitors, there is an equipment monitor to check fans, pumps, and circuit breakers.

A control interface is also provided to go between the phone and the device to be controlled. This interface connects to the phone in the same manner as the monitors and communicates with the system center by the FDM digital channels. Therefore, remotely located pieces of equipment, such as pumps and fans, can be controlled from the surface, if desired. Associated sensors or equipment monitors complete the loopback circuit. For example, if a fan has been remotely turned off, the nearby air sensors associated with other phones would detect the low airflow and send the information to the surface monitor matrix. Hence, the operator is assured that the desired control has taken place.

Pocket Paging

A low-frequency transmitter that is an integral part of every underground phone allows roving personnel to be paged throughout the mine. To operate, the caller simply goes to any phone and dials the paging number of the desired individual. The system center then instructs each ultralow-frequency transmitter in each underground phone to transmit a code associated with the proper pager. These pagers are small receivers carried on the pocket (fig. 7). The code being transmitted turns on the desired receiver, alerting the

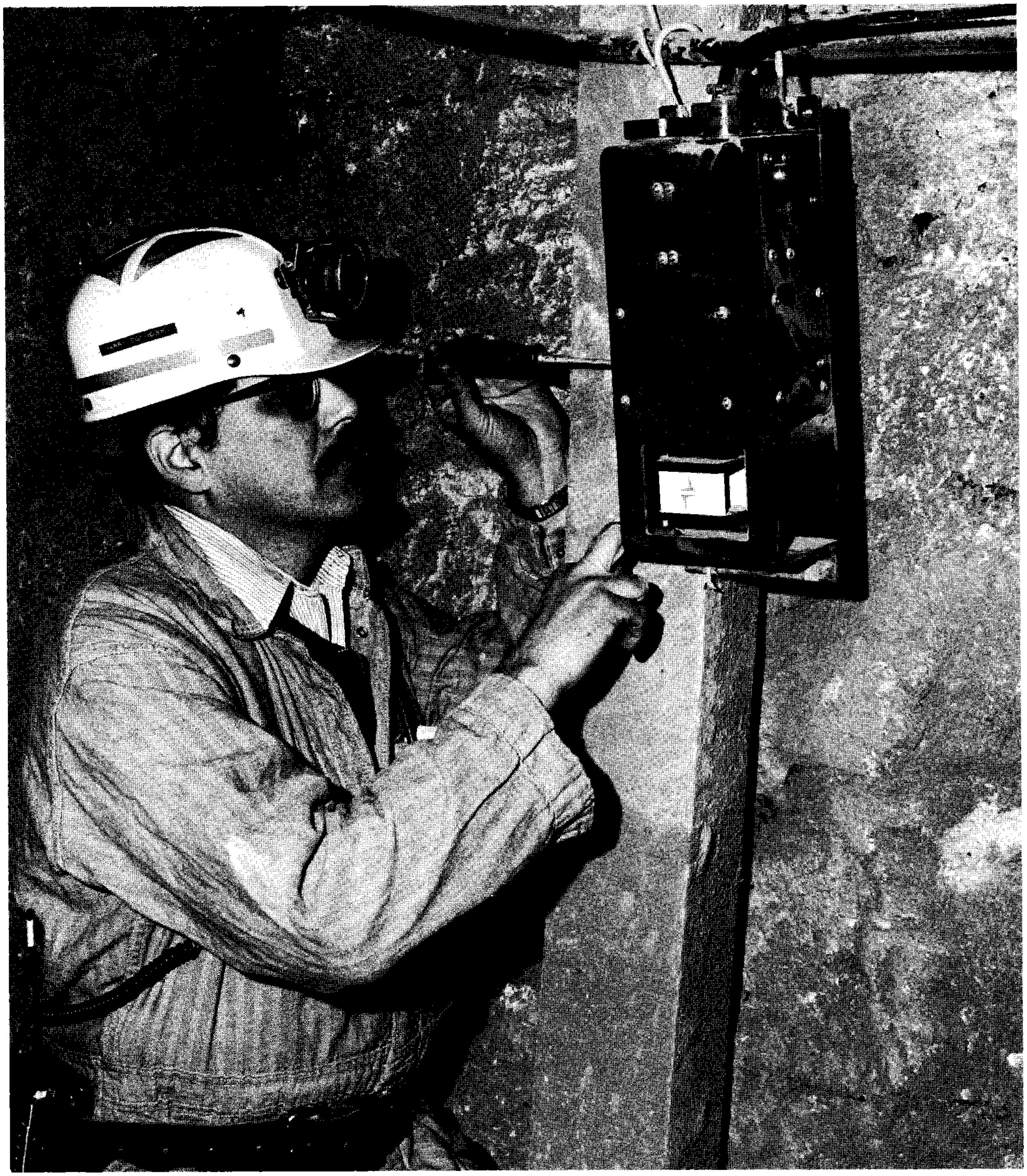

FIGURE 6. - Workman attending air-quality monitor.

individual, via a buzzer and lamp, that he is being paged on the phone. When the person goes to the nearest phone and dials a special number, the system center automatically connects him to the caller.

FIGURE 7. - Call-alert pocket paging receiver.

Telephone to Radio Interconnect

In addition to paging, the system offers a two-way radio option (fig. 8). In this feature, a radio interface-and-dialer unit is attached to the cable, and the roving personnel are equipped with two-way radios. If within range, these roving personnel can communicate directly with each other in the usual two-way radio fashion. However, if they wish to call on the telephone system with the portable radios, they may do so. Simple on-off coding of the radio activates the interface, which automatically dials a distant phone. In like manner, any telephone can contact any portable radio by dialing the interface. The radios used, which are small, operate in the UHF band of the radio spectrum where the operating range is about 400 feet when operating around corners.

Loopback

The system also contains a loopback feature. A coaxial cable is deployed in the mine to form a complete loop onto itself, but it is not located in the same entries as the main cable. In case of a cable break due to roof fall or explosion, communications will not be lost. This loopback technique is recommended for any phone system to assure communications under emergency conditions.

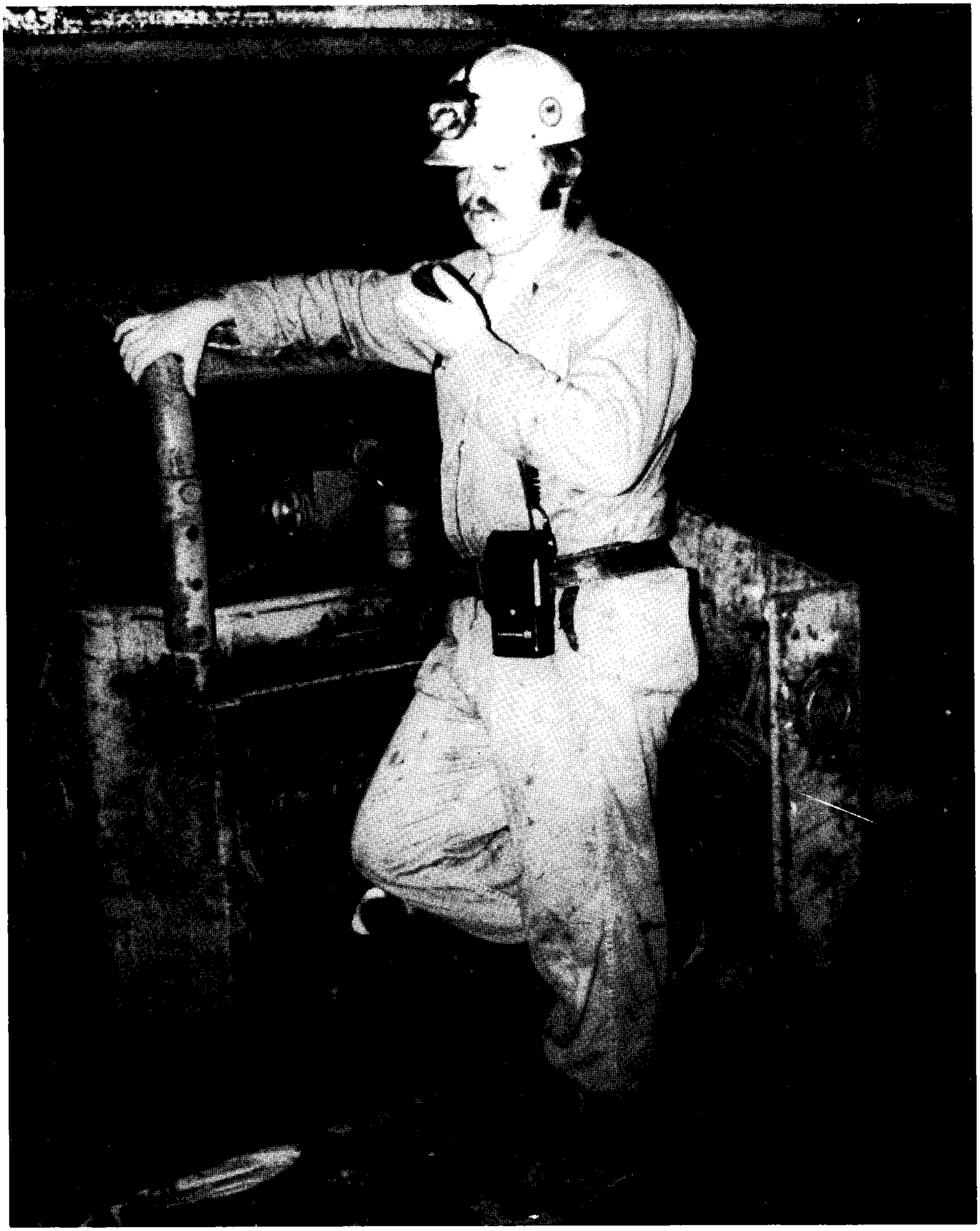

FIGURE 8. - Two-way UHF radio.

On the MCM system at Robena, it was not possible to get every phone on the loopback because of the mine layout. However, if a phone communication is lost because of any failure or cable break, this fact is printed out on the TTY, and immediate action can be taken. In this way, the problem is automatically isolated, and the proper maintenance personnel can be dispatched to the problem area to ascertain the difficulty.

Through-the-Earth Signaling

Bureau of Mines research has shown that ultralow-frequency (ULF) radio signals can penetrate the earth a few thousand feet, and have developed a small waveform generator to produce these signals. This device is so small that it can be built into the miner's cap lamp battery, or it can be carried on his belt as a small accessory (fig. 9). When the signal generator is activated and an antenna is deployed, a code signal is transmitted through

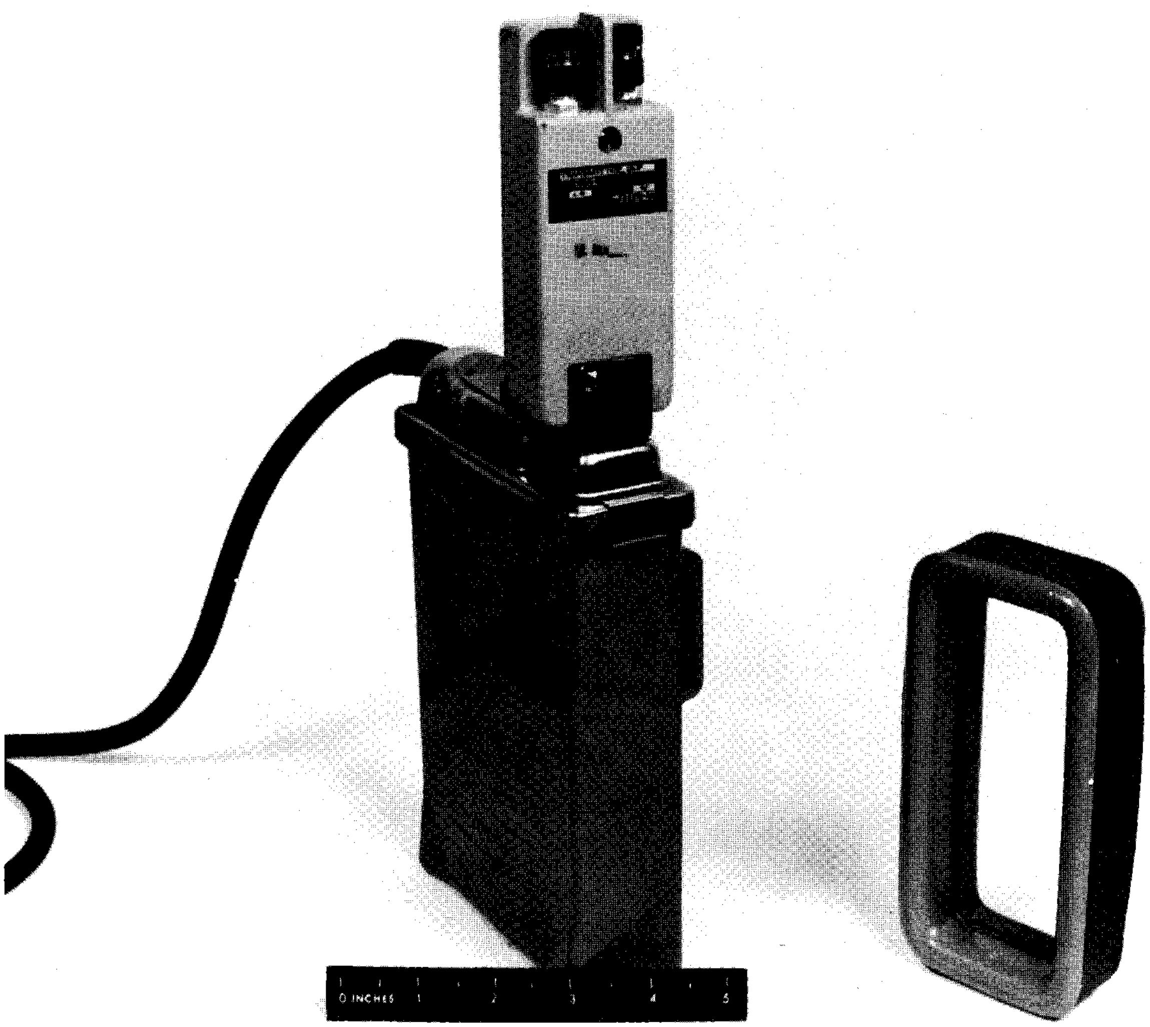

FIGURE 9. - Belt-carried through-the-earth ULF radio transmitter attached to cap-lamp battery. (Spool of antenna wire on right.)

the earth that can be received by special helicopter receivers and portable ground receivers (figs. 10-11). These receivers can accurately determine location of the underground signals. A power amplifier can now be deployed with an antenna on the surface to transmit voice down to the wave-form signal generator which also contains a voice receiver. The trapped miner can reply by code-keying his signal generator. Hence, a true two-way communication system is established entirely through the earth.

Each underground telephone in the system has the same ability and can operate the same way. The ULF radio signals are generated by the same circuit and antenna that produces the paging signals described earlier. If a voice receiver is connected to the phone in place of the monitor or interface device, voice transmissions from the surface can be heard. The phones installed in the escapeways have voice receivers already in place for emergency use (fig. 12). Therefore, in case of a mine disaster, communication can be maintained with the surface even though all mine wiring has been destroyed. Certain escapeway phones have special monitors attached (fig. 13) in addition to voice receivers. These phones can, upon command from the surface, transmit the status of the local mine environment through the earth to receiving (figs. 10-11) and signaling equipment used on the surface for locating and communicating with trapped miners. Specifically, indications are transmitted of whether preset threshold levels of carbon monoxide, methane, and temperature have been exceeded and whether the airflow has dropped below its threshold level. In this way, underground personnel can ultimately be warned during a mine emergency to avoid certain dangerous areas.

Maintenance

System maintenance is simplified by the automatic interrogation polling feature of the system center that requests device status. Since the system center continually interrogates each device via the digital FDM channels, the status of all equipment is always known. If a certain piece of hardware, such as a phone, becomes faulty or switches to internal battery power, these conditions are printed out on the TTY, giving the time of day and identification of equipment that is operating abnormally.

A small test set further simplifies system maintenance (fig. 14). The test set permits maintenance personnel to make an operational check on individual phones. Tests can be made of the radio-frequency input to the phone, radio-frequency output, coax-line voltage at that site, battery condition under load, and microphone quality. This is shown on a simple go/no-go meter readout.

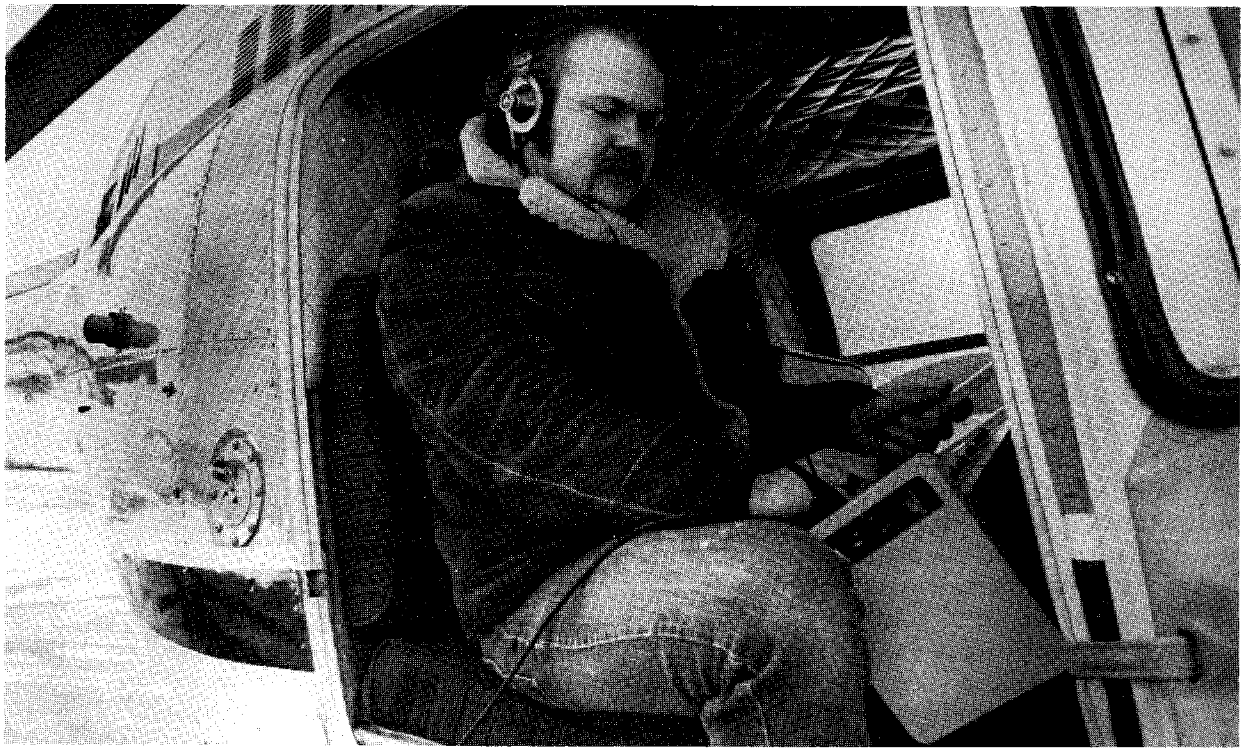

FIGURE 10. - Special helicopter receiver.

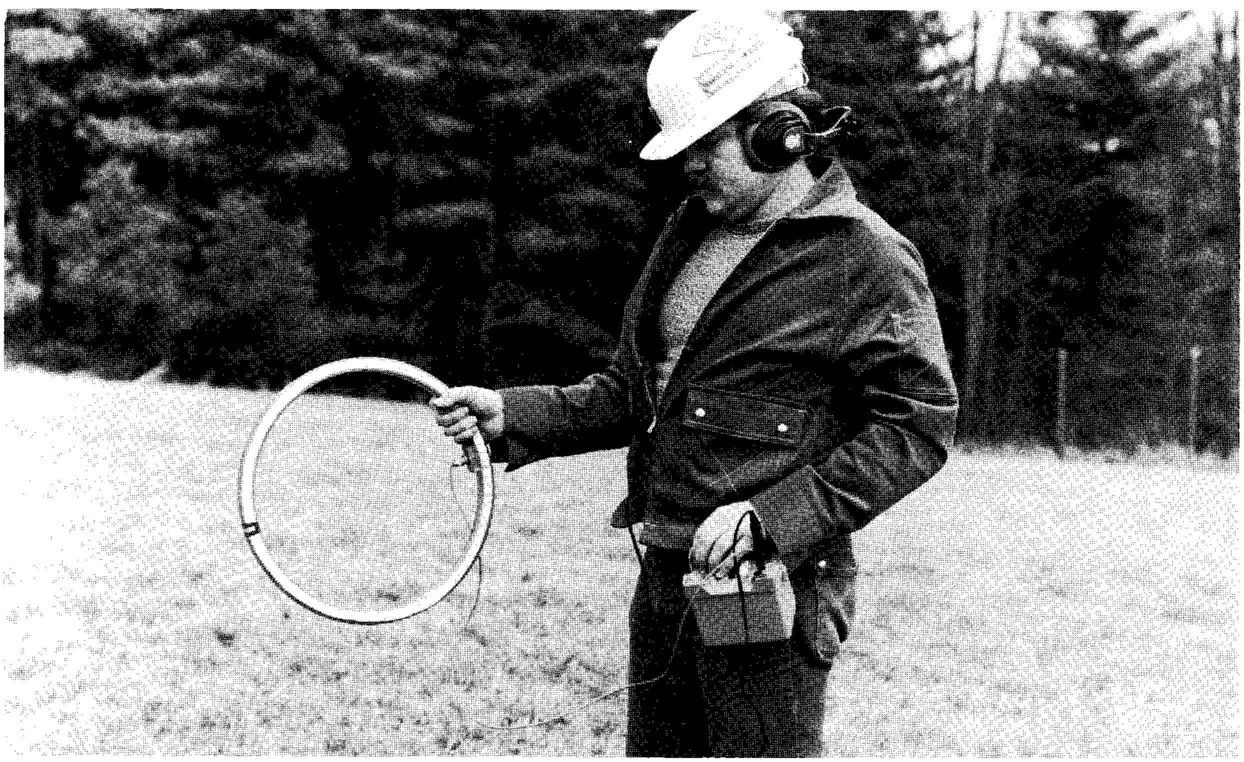

FIGURE 11. - Portable ground receiver.

FIGURE 12. - Emergency voice receiver installed to right of escapeway phone. Miner shown activating ULF radio transmitter in phone.

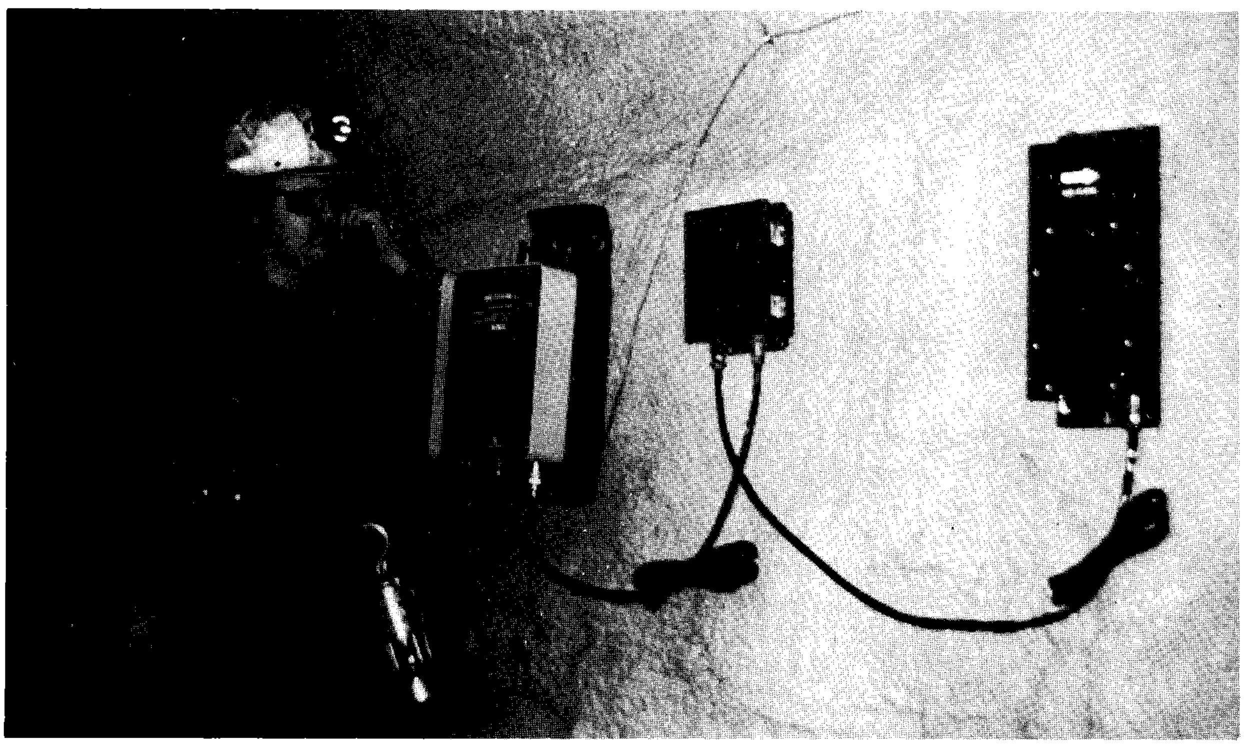

FIGURE 13. - Escapeway phone with through-the-earth monitoring hardware.

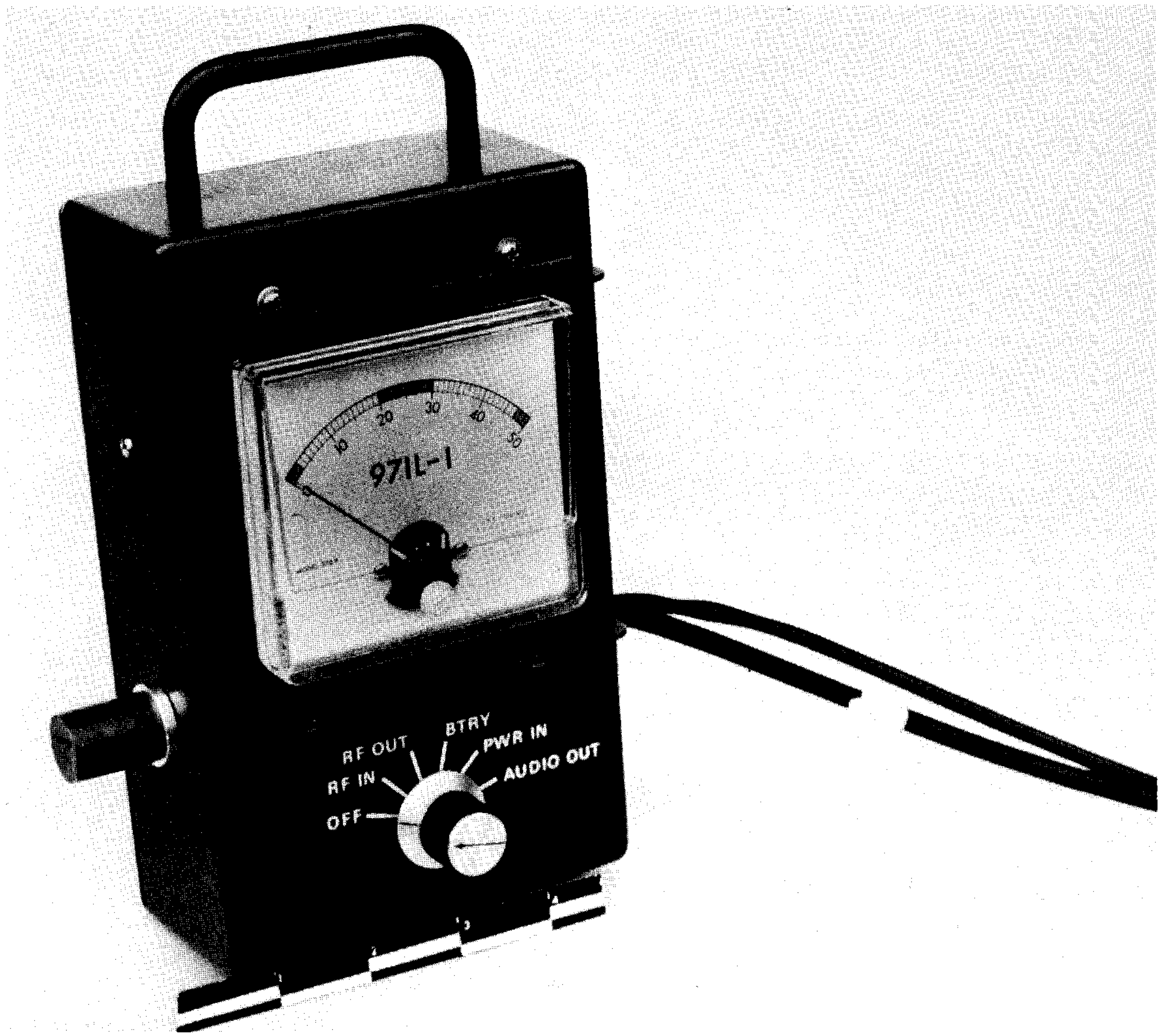

FIGURE 14. - Test set for system maintenance.

PROGRESS TO DATE

The system has proved itself to be flexibly designed, having provided whole mine voice communications, monitoring, and control over a single coaxial cable by FDM techniques. It has operated successfully in the United States Steel Corp.'s Robena mine complex in Pennsylvania for 2 years. Other systems have been, or are being, installed in Eastern Associated Coal's Federal No. 2 mine in West Virginia, the United States Steel Corp.'s Lynch No. 37 mine in Kentucky, and the Island Creek Coal Co.'s Pocahontas No. 3 mine in Virginia.

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5. Westinghouse Electric Corp. Trapped Miner Location and Communications System Development Program, Final Report. V. I. 1973, 181 pp. (Bureau of Mines Contract H0220073); available from National Technical Information Service, Springfield, Va., PB 235 605/AS.

6. _____. Trapped Miner Location and Communications System Development Program, Final Report. V. IV. 1973, 52 pp. (Bureau of Mines Contract H0220073); available from National Technical Information Service, Springfield, Va., PB 235 608/AS.

APPENDIX.--COMMUNICATION REPORTS

The following is a list of reports available in the area of communications. These reports may be obtained from the National Technical Information Service (NTIS), U.S. Department of Commerce, Springfield, Va. 22161. Microfiche copies are $2.25 each, and paper copies are available at the prices indicated.

Company name	NTIS No.	NTIS price	Title
Westinghouse			Coal Mine Rescue and Survival
	PB 208 266	$5.50	V. 1--Survival Subsystem
	PB 208 267	9.00	V. 2--Communications/Location Subsystem
	PB 208 268	9.00	V. 3--Rescue Subsystem
J. H. Crary	PB 213 204	9.00	Determination of the Electromagnetic Environment
A. D. Little	PB 218 688	4.00	A Field Program and Instrumentation System for EM Noise Measurements
A. D. Little	PB 218 658	4.50	Assessment of EM Noise Measurements Taken by Bureau of Mines Contractors
Westinghouse Georesearch	PB 226 600/AS	5.50	EM Location System Prototype and Communication Station Modification
West Virginia University	PB 225 862/AS	6.00	Analysis of Communication Systems
National Bureau of Standards	PB 226 773/AS	4.00	Survey Report of the USBM EM Noise Measurement Program
National Bureau of Standards	PB 226 781/AS	3.50	Applicability of Speech Bandwidth Compression Techniques in Mine EM Communications
Colorado School of Mines	PB 231 154/AS	7.75	Thru-the-Earth Electromagnetics Workshop
Mine Safety Appliances			Develop, Assemble, and Install a Permissible Surveillance and Communication System in the Bureau of Mines Mining and Safety Research Center Coal Mine, at Bruceton, Pa.
	PB 231 574	4.00	V. 1--System Description
	PB 231 575	4.50	V. 2--Circuit and Installation

Company name	NTIS No.	NTIS price	Title
Westinghouse Georesearch	PB 232 880/AS	$4.50	Electromagnetic Location Experiments in a Deep Hardrock Mine
Continental Oil Co.	PB 232 887/AS	5.50	Siesmic Miner Detection and Location System; Phase I--Final Report
A. D. Little			Survey of EM and Seismic Noise Related to Mine Rescue Communications
	PB 235 069/AS	6.00	V. 1--Emergency and Operational Mine Communications
	PB 235 070/AS	10.50	V. 2--Seismic Detection and Location of Isolated Miners
Westinghouse	PB 235 604 (set)	21.50	Trapped Miner Location and Communication System Development Program
	PB 235 605/AS	7.50	V. 1--Development and Testing of an EM Location System
	PB 235 606/AS	4.50	V. 2--Detection and Location of Entrapped Miners by Seismic Means (by Dr. S. J. Duda)
	PB 235 607/AS	5.00	V. 3--Monitoring, Locating, and Communication System for Normal Mine Operation and Post-Disaster Rescue Operations
	PB 235 608/AS	4.50	V. 4--Performance Test and Evaluation of a Full Wave Location Transmitter
Collins Radio	PB 237 218/AS	4.00	System Study of Coal Mine Communications
Colorado School of Mines	PB 237 852/AS	5.50	Research on the Transmission of EM Signals Between Mine Workings and the Surface
A. D. Little	PB 240 552/AS	4.50	Investigation of Communication Standards as Related to Coal Mines
Collins Radio	PB 240 481/AS	3.50	Waveform Generator for EM Location of Trapped Miners
National Bureau of Standards	COM 741 1688/AS	4.00	Surface Magnetic Field Noise Measurements of Geneva Mine
National Bureau of Standards	COM 741 1687/AS	6.00	Electromagnetic Noise in Grace Mine

Company name	NTIS No.	NTIS price	Title
National Bureau of Standards	COM 741 1717/AS	$6.75	Electromagnetic Noise in McElroy Mine
National Bureau of Standards	COM 741 1718/AS	5.50	Electromagnetic Noise in Itmann Mine
National Bureau of Standards	COM 741 1450/AS	4.50	Time and Amplitude Statistics for Electromagnetic Noise in Mines
National Bureau of Standards	COM 751 0258	6.00	Electromagnetic Noise in Lucky Friday Mine
Continental Oil Co.	PB 243 068/AS	5.00	Seismic Mine Monitor System--Phase IV report
Continental Oil Co.	PB 241 504/AS	4.00	Seismic Mine Monitor System--Phase II report
A. D. Little			Technical Services for Mine Communications Research
	PB 249 829/AS	5.00	Task D--Applicability of Available Frequency Multiplexed Carrier Equipment
	PB 249 830/AS	5.00	Task B--Applicability of State-of-the-Art Repeaters for Wireless Mine Communications
	PB 249 831/AS	5.00	Task A--Applicability of State-of-the-Art Voice Bandwidth Compression Techniques for Wireless Mine Communications
Collins Radio	PB 244 896/AS (set)	20.00	Research and Development Contract for Coal Mine Communication Systems
	PB 244 897/AS	4.50	V. 1--Summary and Results of System Study
	PB 244 898/AS	5.50	V. 2--Mine Visits
	PB 244 899/AS	7.50	V. 3--Theoretical Data Base
	PB 244 900/AS	4.50	V. 4--Environmental Measurements
Continental Oil Co.	PB 251 705/AS	4.00	Seismic Mine Monitor System

The following publications are available without charge from the Publications Department, U.S. Bureau of Mines, 4800 Forbes Avenue, Pittsburgh, Pa. 15213:

Lamonica, J. A., R. L. Mundell, and T. L. Muldoon. Noise in Underground Coal Mines. BuMines RI 7550, 1971, 11 pp.

Lee, F. R. Permissible Mine Equipment Approved by the Bureau of Mines During 1967-68. A Supplement to Bulletin 543 and Information Circulars 8220, 8299, and 8372. BuMines IC 8463, 1970, 25 pp.

Lepper, C. M., and J. H. Scott. An Improved Electrical Resistivity Field System for Shallow Earth Measurements. BuMines RI 7942, 1974, 20 pp.

Parkinson, H. E. Mine Pager to Public Telephone Interconnect System. BuMines RI 7976, 1974, 14 pp.

U.S. Bureau of Mines (Staff--Mining Research). Mine Communications. Proceedings: Bureau of Mines Technology Transfer Seminar, Bruceton, Pa., Mar. 21-22, 1973. BuMines IC 8635, 1974, 86 pp.

In addition, Preprint No. 76-F-133, entitled "A Review of Research on Underground Mining Communications," by John N. Murphy and Howard E. Parkinson is available from the Society of Mining Engineers of AIME, 540 Arapeen Drive, Salt Lake City, Utah 84108.

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