COLLINS

report

Collins Radio Company

Volume 1 Summary and Results of System Study

Research and Development Contract for Coal Mine Communication System

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Research and Development Contract for Coal Mine Communication System

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Introduction

This report is a compilation of all information obtained in accordance with the requirements of contracts S0122076 and H0232056. A series of eight coal mines were visited to determine their communications usage and requirements. Presently available equipment was surveyed and evaluated to determine its applicability to the needs of the mines. The equipment studied includes that made by the following companies:

Anaconda Telecommunications Division

Andrew Antenna

Bendix Communications Division

Collins Radio Group of Rockwell International

Executone Communication and Sound Systems

Gai-tronics

Mine Safety Appliances Company

Motorola Communications and Electronics, Inc

National Mine Service Company

Plessey Communications Systems Corp

Pye Electronics Limited

Reach Electronics

Set Com Corporation

Sonex Incorporated

Mine visits and in-depth interviews were made at the following sites:

Robena No. 4, Pennsylvania

Greenwich Colliery Mines, Pennsylvania

Somerset Coal Mine, Colorado

Keystone No. 1, West Virginia

Harris Mine No. 1, West Virginia

Baldwin Underground No. 1 Mine, Illinois

Lovilia No. 4 Coal Mine, Iowa

Orient No. 3 Coal Mine, Illinois

The study considered the possibility of using wireless communication underground. A data base defining equipment capabilities was needed so both analytical and experimental programs were formulated. The analytical program combined presently available information into an overall profile which predicted the underground communication capabilities using transmissions between 1,000 and 200,000 Hz. The tests in the experimental program checked these predictions and evaluated the use of the 150- to 1,000-MHz portion of the spectrum.

The requirements, as determined from the surveys, and the capabilities, as determined from analysis and experiments were summarized. These groups of data were then combined into a set of requirements for an integrated underground communications system. The requirements are contained herein as specifications for a fully integrated communications system. An additional subset of specifications describes the requirements for a minimal system for use in small mines or those with little remaining operating life.

At the conclusion of contract S0122076 a final report was written detailing the findings and recommendations to that point. Comparison of those recommendations and the ones contained herein reveals several differences. These are the result of additional information gained during the present contract. This information includes additional mine surveys and the low frequency propagation studies. Predictions of low frequency propagation were updated and were checked experimentally.

The four volumes comprising this report address separate major items.

Volume 1 summarizes the entire report and includes both a dissertation on the strengths and weaknesses of various available communication techniques and a set of requirements for several grades of comprehensive mine communication systems.

Volume 2 details the eight mine visits, along with the conclusions reached following each visit and the final conclusions reached when the requirements of all mines visited were considered.

Volume 3 contains all information used in predicting the performance of low frequency transmissions in through-the-earth systems, along with the predictions themselves for typical situations.

Volume 4 describes the propagation measurements made in selected mines during both contracts, along with the findings resulting from these measurements.

2.1 COMMUNICATION SYSTEM SPECIFICATION

In an ideal system an individual must be able to initiate and receive calls as necessary, regardless of his location within the mine. To accomplish this a group of semiautonomous subsystems are required. A basic fixed intramine phone system is used, along with vehicular, hoist, and (if necessary) longwall communication systems, and is integrated into a single functional system. System operation should be as familiar to the user as possible, with a goal of operating like the public phone system.

Studies of operating mines showed that the fixed intramine communications equipment requires a 6-to-20 channel capacity. The number of channels required in such a minimum system is related to size of mine, number of working sections, and desire to include vehicles and longwall sections as part of the overall system rather than as isolated elements. If an entire mine, including the surface complex, is integrated into a single system, more channels are required. The mine requires 6 to 10 of the operating voice channels, while the extent of the surface communications and data transmission determines the total number of channels necessary.

Operators of underground vehicles must be in constant communication with one another. Both production efficiency and safety are served by this constant contact. Production efficiency is further improved by selectively connecting vehicles with the fixed intramine system, permitting the mine management to be contacted while in transit.

Longwall sections present a unique situation and special effort is required to obtain acceptable communications. Personnel are dispersed over a large area, yet all need to be in constant contact. A radio system provided with voice operated transmit (VOX) is required for greatest operating efficiency and safety, yet VOX presents its own problems. The extreme noise levels at the face require an exceptional grade of noise canceling microphone or VOX will not work and, in fact, noise cancellation is required for any usable system. In the absence of a radio system, a series of stations mounted to the longwall machinery is usable but cannot be considered to be a good system. Both operating efficiency and personnel safety requires that the longwall installation selectively interconnect with the fixed intramine system. During normal section operation, interconnection is not desirable unless a call is specifically directed to the section. When the section is down, any men performing maintenance must be able to monitor and call on the main system as they move about the longwall.

A mine presents a uniquely harsh environment in many areas. Equipment will receive harsh treatment when in operation. Rock dust and/or coal dust will pack in and around all exposed surfaces and crevices. High humidity and dripping water will erode surfaces. The moisture may be corrosive. The equipment must be designed to operate under all these conditions.

2.2 COMMUNICATION SYSTEMS EVALUATION

Both wired and wireless communications have been evaluated during this program. Each has certain strong points; however, the best integrated system appears to be a mixture containing various elements of both types.

Wireless communication systems do not tie the user down to a specific location. There is no one "best" frequency to use, instead different segments of the radio spectrum have different strong points. In the uhf (300 to 3000 MHz) region equipment and antennas are small and lightweight. Power consumption of portable gear is low, with a resultant low battery weight for a given operating life. Straight line signal attenuation is low; however, to operate around corners, either high power or additional antenna structures are required. Operating range may also be extended with the added system complexity of repeaters.

By shifting to the vlf/lf region (3 to 300 kHz) problems involving signal loss in adjacent entry operation are eliminated. Transmission is directly through the earth and via existing wiring in the mine. With sufficient power and antenna structure, direct operation is possible between in-mine and surface stations. Necessary power level and antenna size are both significant factors at the low frequencies. Antennas for portable equipment are heavy and inefficient. The prime use for this frequency region within a mine appears to be in one-way paging operation where a fixed transmitting antenna can be a sizable wire structure.

Wired communication systems can be simpler than any other type. Some form of wired system is installed in every one of the mines studied during this program. Most of these installations consisted of a single party line system. Unfortunately, not one of the wired systems truly met the mine's needs.

A single line telephone system is inexpensive and simple, but provides neither adequate line capacity nor privacy. Multiple single-channel systems are limited in connectability and can become expensive since redundant equipment and cabling are required. A PBX system provides no paging capability and is complex to wire and maintain, but supplies the required privacy and channel capacity. A single-cable multiplex system meets all needs as long as the individual called is near a station. In addition to the preceding strengths and weaknesses, no wired system provides vehicular communication except in the incidental case wherein the vehicle is near a fixed station just as a paging call is made.

A mixed system, with both wired and wireless elements integrated into an operating unit, provides the best whole-mine communications. A multiplexed, wired system should be used to selectively interconnect the bulk of the mine. Wireless subsystems then extend communication to personnel moving about when they are away from fixed phone locations. Vehicles communicate on their own wired or wireless subsystem, which can be interconnected selectively with the wired system. With a properly designed mixed system no key man is ever out of touch.

2.3 IN-MINE DATA GATHERING

A working understanding of present coal mine communications equipment and its usage is an essential prerequisite to the determination of future communications systems needs. A field survey program was planned and implemented in order to gain this background. Eight mines were selected as locations for on-site interviews of those personnel responsible for installation and maintenance of communications equipment and for in-mine inspection of communications equipment and signal distribution networks. The mines selected were chosen to provide the greatest possible cross-sectional sampling of mine size, age, mining methods, and haulage means.

The performance characteristics of various communications systems were determined through listening to conversations (noting noise levels) and by talk testing from randomly selected stations throughout each mine. Management, maintenance personnel, and working miners were asked to make general comments on the communications systems and to note any specific difficulties experienced in their use. Observations were made of mining operations and usage of communications in addition to the interviews with mine management personnel (from superintendents to section foremen) to determine whether correlations existed between communications, productions, and safety.

The individual interviews and resulting reports were analyzed to identify communication system requirements for each mine. These requirements were examined additionally to determine those items common to all mines.

2.3.1 Telephone Systems

A comparison of the performance quality of the telephone systems in the eight mines studied shows that the mines with poorer system performance are usually the larger, older mines. This characteristic appears to result from the older equipment and lines found in the larger mines. Typically there are many more miles of line (increasing probability of noise pickup), many line splices, and many telephone units on each circuit. As a strong trend we found that the greater the number of telephones the poorer the performance quality.

New equipment providing more channels and private line operation should be compatible with the best of presently installed systems so that the two can operate together until the older equipment reaches the end of its economic life. A substantial cost savings is thus realized by a sharing of the older but adequate telephone lines by both the old and new equipment.

Tape recordings were made of phone system activity in some of the mines visited. Statistical analysis of these recordings and a knowledge of telephone industry channel capacity requirements indicate that a minimum of six channels are required to handle mine communications. Twelve to twenty channels are needed in the larger, more active mines to handle expected communications increases. Most channels may be party line but mine management personnel said they wanted at least one private line channel in any new system.

Rechargeable batteries should be used to power the phone system. These should be capable of being recharged from power on the telephone lines so a system goal of at least one year mean-time-between-servicing can be met.

2.3.2 Trolley Phone Systems

An evaluation of present day trolley phone systems shows that they work very well indeed - considering the physical, electronic, and acoustic abuse under which they must exist. The most severe problems with these systems seem to be physical, such as microphone cord breakage and switch failures.

Their most severe performance constraint is imposed by the impedance characteristics of the trolley wire transmission system. The impedance varies widely within a mine and from mine to mine. Operating into a poorly matched transmission system results in high distortion and low signal strengths (which results in poor signal-to-noise ratios) at randomly distributed points in the mine.

The existing systems are made usable only by using high-power transmitters and with receivers operating over a wide dynamic range. The high ambient acoustic noise levels that must be overcome also present design problems with the trolley phone system. Trolley phone usage seems to correlate very closely with yearly output for track haulage mines and is at the saturation point in many high output mines.

Physical ruggedness of future designs for vehicular mounted equipment should equal or exceed that of the more rugged present designs. Loudspeakers must be separable from trolley phone units and swivel mounted to accommodate the operator. Audio power output must be adequate to override the high ambient acoustic noise levels without distorting. Careful system design and impedance control is required as a means of overcoming the null patterns that plague present transmission systems. Trolley power distribution lines must be isolated from rectifiers and loads by high current line traps to minimize loading on the signal paths. Finally, an adequate inventory of portable test equipment sould be available for installing and maintaining the system.

2.3.3 Longwall Communications

The longwall communications system must aid in reducing maintenance downtime and aid in increasing productivity. The goal in a longwall system is the provision of hands-free operation between all maintenance and operating personnel on the section. Present systems consist of wired intercoms using loudspeakers and handsets in a push-to-talk configuration. These systems permit communication within the section but are difficult to hear since the loudspeakers are fixed while workers move around as necessary.

2.3.4 Communications Center Requirements

There are two fundamental requirements for a communications center. First, the center must be flexible and expandable to accommodate growth with the mine. Second, the communications center should be located outside with multiple signal paths to the inside. This location provides an environment more conducive to maximal output from both the center and its operator, which in the long run offsets the cost of an outside location. The communications center must be economically expandable from a simple monitoring operation by a lamp man or hoist operator to a complex data center having a full time operator as mine size increases. Besides serving as an information center, the communications center must be flexible enough to interconnect the various networks and to serve as a broadcast center for full coverage announcements to all mine personnel.

Interface requirements for alarm and monitor systems are simply that they be compatible with voice grade communication distribution systems. Economics dictate that alarm and monitor sensors utilize communications networks for the transfer of data to the monitoring centers.

2.4 THEORETICAL DATA BASE

The effective design of efficient communications systems for mining environments demands a thorough knowledge of wave propagation characteristics through the earth. A series of theoretical studies have been prepared to obtain a reliable basis from which accurate propagation predictions can be drawn. These studies predict the absolute signal levels to be expected versus antenna configuration, power level, and displacement.

Another series of studies have been made by the National Bureau of Standards. These studies resulted in a tabulation of the noise level versus frequency to be expected for various underground conditions. Integration of the National Bureau of Standards measurements with the predicted signal levels results in a series of predictions as to the signal-to-noise ratios that can be achieved with an underground communications system.

Signal-to-noise predictions have been made for several antenna configurations as a function of antenna size, depth, and lateral displacement. From an analysis of the signal-to-noise ratios as a function of frequency, predictions were drawn concerning optimum usable frequency versus maximum transmission displacement for the various antenna configurations. A number of conclusions can be drawn from the predictions.

Low frequency waves can be transmitted through overburdens ranging in thickness from 150 to 1,500 feet. The two most common methods of coupling energy through-the-earth are the loop or magnetic dipole and the line source, sometimes referred to as an earth probe (surface) or roof bolt (subsurface) antenna. Vertical magnetic dipole (VMD) antennas exhibit maximum coupling when their orientation is coplanar, while horizontal magnetic dipoles (HMD) exhibit nulls and maxima as the antennas are rotated. These nulls render the horizontal magnetic dipole an unattractive coupling device for mine communication.

Examinations of curves drawn from the general predictions permits a series of specific predictions to be made assuming a minimum of 37 dB S/No (noise in a 1-Hz bandwidth) ratio is required for adequate information transfer.

a. Loop (VMD) to loop (VMD) provides the highest S/No ratio.
b. For a 20-meter (66-ft) radius transmit loop a maximum of approximately 225 meters (738 ft) separation can be achieved with an optimum frequency of 10 to 20 kHz. At lesser separations, the 100- to 200-kHz range provides higher signal-to-noise ratios.
c. For a 0.2-meter (8-inch) diameter transmit loop, a maximum of approximately 80 meters (263 ft) separation can be achieved at an optimum frequency of 70 to 100 kHz.
d. For a 100-meter (328-ft) line source transmitter, a maximum of 200 meters (656 ft) can be achieved at a frequency of 10 kHz. At separations below 500 ft, however, the 100-kHz frequency range provides the highest S/No ratio.
e. For up-link and down-link propagation using a 13.6-meter (44.6-ft) radius loop, maximum transmission was 175 meters (574 ft) at a frequency of 10 kHz, and for the 100-meter line source antenna, maximum depth was 225 meters (738 ft) at a frequency of 10 kHz.

Predictions for transmission from a loop to a line source can not be made because reliable E-field noise data is not available for this mode of propagation.

It has been noted in recent in-mine tests that there appears to be a gap between the propagation predictions and the experimental results as frequencies increase beyond 50 kHz. Additional experiments need to be conducted to obtain reliable predictions for these higher frequencies, and to define the differences between pure through-the-earth propagation and that which is aided by the wiring running within the mine.

2.5 EXPERIMENTAL PROGRAMS

A series of radio measurements were conducted in a working coal mine to determine uhf and vlf propagation characteristics. Measurements included the effects of frequency, polarization, antenna type, and distance. The uhf tests included propagation along straight tunnels and around corners, and a comparison of results using passive reflectors at tunnel corners. The vlf tests evaluated the performance of roof-bolt and loop antennas. A number of results were obtained that have practical significance in the definition, design, and implementation of radio communications systems in mines.

2.5.1 UHF

At uhf, a strong dependence of signal attenuation on frequency and polarization was noted. Along a straight tunnel, attenuation rates varied from 15-25 dB/100 ft at 200 MHz to 2.5-4 dB/100 ft at 1 GHz. Minimum attenuation is expected at frequencies above 1 GHz. Horizontal polarization was found to yield significantly improved results compared to vertical or cross polarization. The attenuation of horizontally polarized signals averaged 40 dB less than vertically polarized signals at 415 MHz and 30 dB less at 1 GHz. Considerable attenuation was observed in radio signals propagated around tunnel corners. Signal attenuation was approximately 45 dB at a point 20 feet past the corner at 415 and 1000 MHz. The rate of attenuation past 20 feet averaged 30 dB/100 ft as opposed to the 3 to 6 dB/100 ft rate observed in the main tunnel at 415 and 1000 MHz. Complete signal depolarization was noted along the cross-tunnel as opposed to the strong horizontal polarization observed in the main tunnel. The use of a corner reflector raised the signal level from 20 to 30 dB at a point 65 feet past the corner. At 1 GHz, the reflector appeared to lower the attenuation rate along the cross-tunnel, resulting in even greater effective gains further away from the corner.

2.5.2 VLF

At vlf, minimum attenuation between two roof-bolt antennas occurred in the end-to-end configuration, but other combinations yielded only 10 to 15 dB more attenuation. Attenuation was relatively flat over the frequency range 1 to 50 kHz and exhibited an attenuation rate of approximately 5 dB/100 ft for all frequencies and orientations. The communications radius of a 25-watt, roof-bolt voice radio system is predicted to be 1,200 and 1,400 feet.

Minimum attenuation for a roof-bolt-to-loop antenna system occurred along the axis of the roof-bolt antenna with the loop magnetic axis oriented vertically. The field strength produced by the roof-bolt antenna was relatively independent of frequency over the range 1 to 50 kHz. The attenuation rate averaged 4 dB/100 feet over all frequencies and orientations with individual measurements deviating only slightly from the average.

Three basic types of communication systems have been examined during this program. Two of these are pure radio systems, operating in the 300- to 3000-MHz (uhf) and 30- to 300-kHz (lf) portions of the rf spectrum. The third system type includes all forms of wired communications. This includes both the baseband-type telephone systems of which the pagers are a prime example, and the various carrier systems such as the trolley phones. While the following paragraphs discuss each type of system as an entity, it must be remembered that the best overall system in a given situation may well be some composite form.

3.1 UHF SYSTEMS

The primary strong points of a uhf system are the small size and light weight of the system components, plus low signal attenuation along a given entry. These advantages are in addition to the basic advantage of any rf system in that the user can be in constant communication as he moves about. Uhf is today's most desirable portion of the spectrum to use in implementing a 2-way system.

The physical size of uhf antennas is such that horizontal, vertical, or circular polarization may be chosen for a system. Tests in an operating mine have shown that horizontal polarization propagates much better than vertical. A study undertaken to explain the results of those tests predicted that the polarization should be in the direction of the greater linear dimension of the tunnel for least attenuation. Measurements have not been made to determine the degree of signal loss along passages in the presence of vehicular traffic; however, there are indications that this may exceed 10 dB. Circular polarization may be helpful in this case.

Since antennas are so small in this region, there is a good possibility that high gain units may be installed at all base stations. The effective power and range are thereby increased.

The tests that have been run show that uhf signals suffer very high attenuation when the signal path includes one or more corners. In negotiating these corners, the rf becomes depolarized, losing the advantage of horizontal polarization present in the signal as transmitted. Simple reflectors may be used to reradiate signals around corners, extending the coverage area greatly. These reflectors are small and light, but still cannot be considered to be desirable items. They occupy space that can be at a premium, especially if vehicles must negotiate the corner where they are installed. Unless they are rugged and mounted in a very secure manner they will be dislodged or damaged shortly after installation. In addition, if they are not properly aligned they will not accomplish their purpose, and they are one more item that must be installed when developing a section, then removed when retreating.

For the user of transportable equipment, operation in the uhf region is a great advantage. The small size and light weight of this end of the link, especially the antenna portion, is advantageous. Good communication can be provided within a small area such as a working section. Vertical polarization is easier to implement in personal portable equipment (with the use of a simple monopole antenna), however the use of horizontal signals presents no great difficulty. One form of horizontal omnidirectional antenna which can be readily carried consists of a crossed pair of dipoles, or turnstile, molded into the surface of the miners protective cap.

There are alternatives to the use of direct radiation from base stations which may be used in the uhf region. A form of "leaky" coaxial cable may be run along entries. Booster stations, similar to the base stations listed above, are required to periodically regenerate the signal on the cable for transmission and reception. There are two primary problems with this type of system. Signal loss along the cable at uhf is similar to that of a directly radiated signal, so approximately the same number of boosters are required in a cable system as base stations in a radiating system and the cost of the cable must be added in. Additionally, the radiation range of the cable is much shorter than that of transmitted rf from a base, so there is greater difficulty in coupling signals into adjacent entries. In the cable's favor, operation is not disrupted by the passage of the vehicles or machinery.

3.2 LF SYSTEMS

The primary advantage in using lf in a wireless system lies in the ability of the radiation to propagate through the mine and overburden in all directions. Communications between user and base may therefore be maintained as the user moves throughout various entries and crosscuts. Besides providing intramine communications, an lf system can supply a direct link from within a mine to the surface, should this become necessary.

The antenna becomes a major consideration when designing an lf system. A good low-frequency antenna is both large and heavy. In addition, the generation of sufficient power may result in a transmitter/antenna system which is not intrinsically safe. Two types of base antennas have been considered. The first consists of a single-turn loop of wire wrapped around a coal pillar, the second is a length of wire connected between two or more roof bolts. The single-turn loop may be attached to J-hooks and thereby kept out of the way by running it alongside other wiring in the mine. In most cases each loop will be a different length and will have varying amounts of other metal and wiring coupled to it. These factors affect the input impedance of such a loop, resulting in a need to individually match each antenna to its transmitter. In the absence of individual matching, optimum radiation of the base station power can not occur.

The roof bolt antenna may be installed in a manner similar to that used with a loop, by attaching the wire to J-hooks. Overburden characteristics and the length of the roof bolts in use cause the input impedance of this type of antenna to vary even more than that of a loop. As a result, to obtain maximum radiated power, it becomes even more important to have a good adjustable matching system built into the base station. The matching system must be easily adjusted for best operation by untrained personnel.

Only one form of antenna appears to be practical for use at the personal portable end of an lf system. This is the loop, wound to form a vertical magnetic dipole. There are two possible locations for such a loop. One of approximately 8-inch diameter may be wound around and molded into the protective cap. To maintain intrinsic safety, it might be necessary that at least the power amplifier or the antenna matching network also be part of the cap. A second possible loop configuration could be built into a new form of the belt used to carry the lamp battery, self-rescuer, etc. This would be a more complex assembly, with its need for a connection and the requirement that the length be adjustable, but the larger diameter is a more efficient radiator. There is a similar antenna presently in use in South African mines. This loop is formed into a bandolier. The loop is of a reasonable size but is an unwieldy item that interferes with movement on a section.

The antenna used on a vehicle is under far fewer restrictions than that carried by a man. Either a monopole or a fairly large loop may be installed without difficulty. As always at low frequencies, antenna tuning for maximum power transfer is very important.

The major difficulties in the lf region involve propagation characteristics and bandwidth. Signal attenuation versus distance is very high, and rises with increasing frequency. Some electromagnetic interference (EMI) is present, generated by machinery within the mine. Some tests have been made indicating that a way may exist to get around at least part of this drawback. By using the high lf band, or perhaps by going into the low mf (300- to 3000-kHz) region, the trolley, track, etc, conductors within the mine may be made to serve as a virtually continuous antenna. Since such conductors are located at or near nearly all points of activity they may serve to provide a wired/wireless system. The testing that has been done has not indicated the reception distance that may be expected as the receiver is moved into adjacent entries. Neither has there been any work done to optimize the power transfer into the intramine conductors, or to determine the reverse characteristics in which the portable station transmits and signals are picked up off the mine wiring.

The Q of both the fixed and portable loop antennas is very high. As a result, the transmit matching networks may be expected to handle only one, or at the most two, operating channels. At the lower frequencies even the bandwidth of a single voice channel is difficult to attain. This difficulty is not normally present when using roof bolt antennas, as their resistive component is relatively high.

3.3 WIRED SYSTEMS

A wired communication system can be simpler than any other type. It can also be easier for the user to operate properly. The simplest wired system is enough like the public telephone system that minimal training in its use is required. Finally, a single-channel wired system, operating with baseband audio, forms the least expensive system that can be installed.

One problem with the single-channel system using baseband audio is that it does not meet the needs of any mine that has been studied. In every case either supplementary systems have been installed or mine personnel "make do" with the equipment installed, rarely realizing the adjustments made to cope with an inadequate system.

A number of methods of adding channels are available. One involves multiple independent systems. Each system includes its own wiring, power, functions, and station locations. Users of one system cannot talk to users of another. As a result, either each group of users is isolated or one or more persons must act as an information transfer point, repeating messages which must be "interconnected" between systems. In many mines a switchboard operator interconnects systems as needed. To obtain any form of privacy, separate private-line circuits must be installed, and the privacy only exists between the points where the private-line terminals are located. With more than two stations connected to a given circuit, the attendant loss of privacy is partially compensated by the conference capability gained.

A complete private branch exchange (PBX), either manually or automatically operated, may be installed as another way to increase channel capacity within the mine. This provides voice privacy, as every circuit is independent; however, a separate pair of wires must be installed between the control switching point and each station. General paging becomes much more difficult, although the ringer on the phone serves to alert those in the vicinity of a terminal when it is being called and individual phones may be designed to page instead of ringing. To page a person whose location is unknown, a completely separate additional system must be installed, and to direct vehicles yet another system is required (assuming the vehicles are trolley powered). If the vehicles are self-powered they remain out of communication at all times.

Yet another form of wired system provides multichannel capability with minimal wiring by multiplexing signals on a single pair of wires. Such a system requires minimal intramine wiring, can provide any number of required channels (all of which are private) yet can also give an "all call" paging signal throughout the mine when an individual's location is unknown. It shares a disadvantage of any wired system in that the called party must be near enough to a system terminal to hear or see a "ringing" indication or to hear a page. As with any of the wired systems, signals may be coupled to a separate trolley phone system so vehicle occupants may call or be called. Again, as with any wired system, self-powered vehicles are out of communication except as they happen to pass a terminal.

3.4 MIXED SYSTEMS

A mixed system, containing both wired and wireless elements, solves most of the problems of either type alone. The wired portion of the system provides the multichannel capability needed. All channels may be either private or conferenced, as determined by the switching center. Assuming a multiplexing type system, this capability requires only minimal intra-mine wiring. The wireless portion of the system may then be configured to provide one or more channels of party-line communications, for use when personnel are away from fixed terminals. One of the wireless channels can serve purely as a calling channel, directing that the person called go to the nearest terminal. By eliminating the need for transmission by the portable unit problems of transmitted power, antenna configuration, and intrinsic safety of the unit are eliminated or drastically reduced. Vehicles may still interface with the system via a trolley wire or wireless transmitter-receivers on a common channel. The use of a party line channel for vehicular traffic is highly desirable to keep all vehicle operators informed concerning the location of others, thereby reducing the possibility of accidents.

4.1 OPERATIONAL REQUIREMENTS

The primary operational requirement may be stated as: An individual must be able to initiate and receive communications as necessary regardless of his location within the mine. In practice, this basic requirement will normally be modified. The size and age of a mine and the operating conditions will affect the degree to which a system installation is fully integrated to provide maximal communications capability. Economic considerations as assessed by the mine management may result in the selection of a system providing anything from minimal capability upward to full communications integration.

The operation of a system should be as familiar as possible to the user. As a goal, this operation should match that of the public telephone system. A handset should be used except under special circumstances and there should be no push-to-talk switch on this handset. Calls should be initiated by means of a pushbutton dial. The less special training required, the more likely the user is to react properly under stress.

A fully integrated ommunications system should provide interconnection capability so that selected phones can place and receive calls on the public system. Each station should be individually addressable without regard to the total number of available communication channels. This separation of addresses or phone numbers from channels or circuits permits 10 to 14 private line phones to be installed for each available channel with little chance of a user finding all channels busy. A central switching system ensures that any given phone is connected to the next available channel. The capability increases in importance as system size increases.

In addition to the normal private line operation with each phone addressable, there should be a reversion mode for abnormal conditions in which all stations operate on a common party line channel until the system can be restored to normal. The party line channel would also be used whenever an originating party chose to dial an "all call" address rather than an individual address.

As features are deleted, the phone system requires more and more of the user, until only the essential capabilities are left. In this minimal system very few operating channels are available. One channel is a party line "all call" or paging channel on which initial contact is made. The parties involved then manually select a nonbusy working channel to conduct their business. All channels are party line. The ability to select private line operation on a channel is the first feature that should be added in increasing system capabilities.

Vehicles operating on rails within a mine should have a communications unit mounted in every powered vehicle (required in some states). This installation is desirable for various reasons. Among them: operational safety is increased when there is an intervehicular communication system. Operators can report to each other or to a central dispatcher, thereby reducing the chances of a collision. Carried to the ultimate, the central dispatcher can control the movement of all vehicles at all times. Additionally, with communications in every vehicle an individual may be contacted any time he is needed as he moves about in the mines. If a given vehicle is needed at a specific location, its operator can be notified. Essentially the same reasons exist for placing communication gear on rubber-tired vehicles as exist for those operating on a system of tracks, the exception lying in a lessened need for vehicular position control.

The vehicular system should selectively interconnect with, and use one or more channels of, the main communications system. The interconnection should not require the use of a dispatcher for patching or relaying, but should be included in the design of a fully integrated system. One channel must be common, monitored by all vehicle operators at all times. There should be selective access to this channel by any phone in the system. If additional operating channels in the vehicles are desired, they can be used either for initiation or reception of calls. The continuous monitoring of the common channel is required during operation on any additional channels. The system may have direct addressing of each individual vehicle, or the common channel may be used as a calling channel, followed by a call-back or the selection of a mutually agreed-upon channel. In a minimal system only the single common channel needs to be implemented. Access between the vehicular equipment and the balance of the mine phones is then controlled by the dispatcher or by a separate paging control on the vehicular phones. In the latter, less desirable case the units in the vehicles would then hear all paging calls on the main phone system.

Ofttimes there is a need to call a man who is away from his own phone and cannot tell that he is being called. In many cases he is not near any phone. As a minimum, some form of one-way paging capability should be included in the overall mine phone system. The paging receiver light and/or tone can be used to tell a called party to go to the nearest phone and return the call.

An intermediate grade of paging system will both page and deliver a voice message to a selected individual. When implemented, one-way page must be used only for paging purposes and not be used to deliver one-way messages or instructions. The advantage of voice paging lies in the ability to direct call-back to a specific number rather than to a party line channel. Until this call-back is received, there is no assurance the page has been received. To assume otherwise is unsafe. Since proper usage of one-way voice paging cannot be enforced, its use has been forbidden in many parts of Europe.

A highly desirable wireless paging system includes full two-way communication. This grade of equipment should include selective calling of the portable unit and should permit the portable to access the balance of the system and selectively address any other station.

4.2 TECHNICAL SPECIFICATION

4.2.1 Environmental

No complete study has been made to identify the environmental limits experienced in coal mines.

Equipment is mounted on top and throughout the mines.

Mining is done at various depths and mines are located in areas with widely differing climates.

An overall study should be performed so a complete and definitive environmental specification can be written.

In the absence of data from such a study, the following recommendations are made. They are the result of observations, on-site interviews, and engineering estimates.

4.2.1.1 Temperature

4.2.1.1.1 Operating

Inside buildings: 0 °C (+32 °F) to 50 °C (+122 °F)
Ambient air at top or near air entries: -30 °C (-22 °F) to +40 °C (+104 °F)
Location unrestricted: -30 °C (-22 °F) to +55 °C (+131 °F)

4.2.1.1.2 Nonoperating and Storage

Any location: -40 °C (-40 °F) to +85 °C (+185 °F)

4.2.1.2 Humidity and Moisture

Top-mounted: To 95 percent relative humidity
In-mine: To 100 percent relative humidity with condensation
Additional requirement: In-mine equipment to be dripproof and splashproof

4.2.1.3 Shock

Measurements have not been made to determine the precise shock environment to be expected on vehicles and machines.

Accelerometers and recorders should be fitted to a number of vehicles in each of a number of mines.

Analysis of the data obtained will determine the actual operating environment seen by equipment mounted to or carried in the various vehicle types.

The effects of differing track conditions within the mines will also be seen.

Lacking precise data, an estimate must be made. Collins maintains an extensive environmental facility that has been in operation for over 25 years. Over this period tests have been performed and data gathered on a wide variety of equipment, this equipment designed to be used under virtually all possible operating conditions. Personnel experienced in the shock and vibration areas within the environmental facility were consulted for their recommendations before selecting the following requirements.

4.2.1.3.1 Operating

Fixed equipment: Unlikely to receive shocks while in operation.
Mobile mounted:
Vehicles on rails: 600 g with 2 ms duration at 1-second intervals
Rubber-tired vehicles: 20 g with 25 ms duration.

4.2.1.3.2 Nonoperating and Transit

Transit and handling shock is best simulated by drops of up to 36 inches onto a hardwood surface.

4.2.1.4 Vibration

4.2.1.4.1 Operating

Fixed equipment: Not significant
Mobile Mounted:
Vehicles on rails: 0.010 inch double amplitude, 5 to 100 Hz
Rubber-tired vehicles: 0.020 inch double amplitude, 5 to 70 Hz.

4.2.1.4.2 Nonoperating and Transit

Smooth vibration: 0.030 inch double amplitude, 10 to 55 Hz.

4.2.1.5 Dust

Equipment shall remain operational under highly dusty conditions.

A rock or coal dust buildup shall not damage or degrade performance of cases, handsets, loudspeakers, controls, or connectors.

The abrasive effects of the dust must be considered in all designs.

4.2.1.6 Corrosive Materials

All equipment shall be designed to withstand the effects of the corrosive materials encountered in a mine.

Mine acids, chiefly sulfuric, may be expected to drip or condense on any surface.

Components exposed to these acids must be protected.

4.2.1.7 Abuse

All equipment shall be designed to withstand abusive treatment while continuing to operate normally.

Particular attention must be paid to any cords and attachments as to abrasion resistance and pull strength.

Microphone/handset cases shall be impact resistant.

Equipment cases shall be as nearly unbreakable as possible.

Projections and controls shall be protected against being struck or abused in any conceivable way.

4.2.2 Reliability and Repairability (Usability)

4.2.2.1 Reliability

The minimum acceptable mean-time-between-failure (MTBF) shall not be less than six months.

Routine service shall not be required at less than 6-month intervals with a 1-year interval as a goal.

Greater MTBF is desirable, but not at the expense of repairability.

4.2.2.2 Repairability

The mean-time-to-repair (MTTR) shall not exceed 30 minutes.

A shorter MTTR is desirable, with a goal of 10 minutes.

Equipment shall require minimal test equipment for troubleshooting and repair.

The preferred repairability technique involves the following:

a. Ready equipment access
b. Modular construction
c. Self-test or minimal test
d. Small, lightweight spares arranged for ready transport

Repairable modules should be returned to a central facility, not field repaired.

4.2.3 Minimal Fixed-Mount Intramine Communications

4.2.3.1 System Performance

A minimal system provides for the basic communication requirements within a mine.

The system is basically a party line but should provide a limited private line capability.

It supplies minimum required intramine communications only, providing no added interoffice or public phone connections required by the mine office complex.

The objective is to keep system hardware as simple as possible, so operator skills must make up for any lack of equipment sophistication.

4.2.3.1.1 Channel Capacity

The base equipment shall have a 6-channel capability.

The equipment shall be capable of expansion to accommodate additional channels.

Expansion to 12 channels shall be provided, with expansion to 20 channels desirable.

All channels shall be usable either as voice or data paths.

4.2.3.1.2 Calling Channel

One of the operating channels shall be at baseband.

This channel is to be used as a calling and emergency channel.

The use of baseband permits single-channel party line operation in the event of failure of channel selection capability.

4.2.3.1.3 System Operation

Initial contact should be made on the calling channel.

This channel shall function as a paging channel to contact the desired party.

After contact is made, it is the operators' responsibility to select a nonbusy working channel to conduct their business.

At the termination of a contact it is desirable that the phones automatically revert to the calling channel.

4.2.3.1.4 Paging

A page call shall be heard at all phones.

Phones in an "on hook" condition shall broadcast the page over a loudspeaker.

At phones which are "off hook" the page shall be heard in the earpiece, added in to any call in progress.

4.2.3.1.5 Page Control

A pushbutton or momentary switch shall be used to place the system in a page mode.

This control shall be placed on the body of the phone and shall be recessed or otherwise protected to prevent damage or inadvertent operation.

4.2.3.1.6 Private Line Communications

At least two of the working channels should be equipped to provide private line operation.

When this is implemented only the parties involved in the contact shall be able to hear one another.

4.2.3.1.7 Channel Busy

It is desirable that a means of indicating busy channels be provided.

The indicator will prevent disturbance of contacts in progress while searching for an available working channel.

4.2.3.1.8 Data Communications

Data exchanges shall be possible over any channels not required for voice communications.

These channels shall accommodate any combination of voice-bandwidth control and monitoring devices. Data channels shall be dedicated to data exchanges, inaccessible from standard phones.

4.2.3.2 Multichannel Implementation

Single sideband suppressed carrier signaling is recommended when multiplexing channels on a single cable.

Use of single sideband, along with a hybrid balancing network, permits full duplex operation within a single frequency segment.

Suppressed carrier transmission extends battery life since less power is consumed than is required for full carrier operation.

4.2.3.3 Equipment Power

Equipment shall operate from self-contained power.

The preferred technique involves a rechargeable power pack maintained by the phone interconnecting cable.

A nonrechargeable power pack is acceptable if attention is required at six-month or greater intervals.

When a rechargeable power pack is used, a nickel-cadmium battery is nonpreferred because of its apparent loss of capacity when kept fully charged.

4.2.3.4 Interconnecting Cable

All units shall connect with a single cable, run as necessary throughout the mine.

The cable should be rugged, insulated, and inexpensive such as nonmetallic sheathed cable (type NM) as defined in the National Electrical Code.

An acceptable cable is a shielded line such as coaxial cable or shielded pair, however shielded line systems require careful design and installation to avoid noise pickup via ground currents.

Parallel-wire cable should be twisted when installed to reduce noise pickup.

Cable hangers must release during a roof fall so they do not cause cable breakage.

4.2.3.5 Cable Connections

Units should connect to the cable via bridging taps, so that attachment or removal of a given instrument leaves the line undisturbed.

Series connection in which the cable loops through each phone is undesirable but acceptable if failure of any one phone does not degrade the performance of the remainder of the system.

4.2.3.6 Redundant Communication Paths

Fixed systems should be designed so the interconnecting cable can be connected back on itself, providing an alternate path to maintain communications in case of damage.

Neither a broken nor a shorted cable should affect operation of a redundant system.

4.2.4 Fully Integrated Fixed-Mount Intramine Communications

4.2.4.1 System Performance

This grade of system provides for all communication needs within a mine.

All connections are private line, but more than two parties may be involved.

Full integration permits expansion to interconnect the entire mine, as well as any office complexes associated with the mine, into a single functional system.

Operator skills need be little higher than those required to operate a dial telephone.

4.2.4.1.1 Channel Capacity

A fully integrated installation shall have at least a 10-channel capacity.

It shall be expandable to at least 40 channels, with a minimum capability of 100 channels desirable.

Any usable channel shall be capable of serving as either a voice or data link.

4.2.4.1.2 Station Capacity

The system shall accommodate a minimum of 100 stations.

It shall be expandable to at least 400 stations, with expansion to 1,000 desirable.

4.2.4.1.3 Interconnectability

It shall be possible for any given station to call any other given station directly.

The system shall be designed so interconnection may be forbidden between selected stations or groups.

4.2.4.1.4 Emergency Communication

Under emergency conditions all stations should revert to a common channel.

The common channel should be at baseband; however, the use of a common system channel is acceptable.

4.2.4.1.5 System Operation

The system should function as nearly like a public telephone system as possible.

Selection of a called party should be by means of a pushbutton dial or suitable alternate, sealed against dust damage.

Standard "dial," "ringing," and "busy" tones should be used to appraise the operator of the status of a call.

It should be possible not only to select any other fixed station, but to call mobile stations such as those on vehicles or carried on one's person.

4.2.4.1.6 Ringing

The called station should provide both an audible and visible indication that it is being called.

Either type of indicator shall be as attention-getting as possible.

4.2.4.1.7 Channel Assignments

Channel assignment for a given connection shall be made automatically by the equipment.

This method permits the greatest number of stations to operate in a given size system without interference.

4.2.4.1.8 Communication Security

It shall not be possible for parties other than those involved in a given connection to monitor that connection.

4.2.4.1.9 Conference Calls

It shall be possible to set up multiparty connections.

It should be possible for any party to set up multiparty operation without central operator or dispatcher assistance.

4.2.4.1.10 Public Phone Interface

It shall be possible to place or receive calls on the public telephone system at any station without central operator assistance.

There should be a provision to selectively delete either or both of these capabilities at any given station.

4.2.4.1.11 Wireless Paging

Direct paging to transportable devices should be possible either as a standard or an expansion feature.

Such page may operate in either of two ways:

a. One-way page only. To call a given pager a number is dialed. The pager responds with an audible and/or visible signal. Answer back is via the nearest phone instrument.

b. Page with answer-back. Following a page as in a, above, the recipient is able to hold a two-way conversation with the calling party. A single remote channel must be provided for this feature, operated in a party line manner. To eliminate eavesdropping, the page receivers should not be able to access the channel until a paging signal is decoded.

4.2.4.1.12 Antinoise Provisions

Either standard or optionally the underground phones shall provide for effective communication in a high-noise environment.

Microphone elements with a noise-canceling feature should be available.

High level earpieces should be available, preferably with a user-accessible level adjustment.

4.2.4.1.13 Data Communication

Data exchanges shall be possible over any system communications channel.

These channels shall accommodate any combination of voice-bandwidth control and monitoring devices.

It should be possible to dedicate specific channels to data exchange, rendering them inaccessible to phone instruments.

4.2.4.2 Multichannel Implementation

Single-sideband suppressed carrier signaling is recommended when multiplexing channels on a single cable.

Use of single sideband, along with a hybrid balancing network, permits full duplex operation within a single frequency segment.

Suppressed carrier transmission extends battery life since less power is consumed than is required for full carrier operation.

4.2.4.3 Equipment Power

Equipment shall operate from self-contained power.

The preferred technique involves a rechargeable power pack maintained by the phone interconnecting cable.

A nonrechargeable power pack is acceptable if attention is required at six-month or greater intervals.

When a rechargeable power pack is used, a nickel-cadmium battery is nonpreferred because of its apparent loss of capacity when kept fully charged.

4.2.4.4 Interconnecting Cable

All units shall connect with a single cable, run as necessary throughout the mine.

The cable should be rugged, insulated and inexpensive such as nonmetallic sheathed cable (type NM) as defined in the National Electrical Code.

An acceptable cable is a shielded line such as coaxial cable or shielded pair, however shielded line systems require careful design and installation to avoid noise pickup via ground currents.

Parallel-wire cable should be twisted when installed to reduce noise pickup.

Cable hangers must release during a roof fall so they do not cause cable breakage.

4.2.4.5 Cable Connections

Units should connect to the cable via bridging taps, such that attachment or removal of a given instrument leaves the line undisturbed.

Series connection in which the cable loops through each phone is undesirable but acceptable if failure of any one phone does not degrade the performance of the remainder of the system.

4.2.4.6 Redundant Communication Paths

Fixed systems should be designed so the interconnecting cable can be connected back on itself, providing an alternate path to maintain communications in case of damage.

Neither a broken nor a shorted cable should affect operation of a redundant system.

4.2.5 Supplementary Communications

Each supplementary communication installation shall be an independent communication system capable of interconnection with the fixed-mount system.

4.2.5.1 Longwall Sections

All members of a longwall crew must be in continual party line communication with one another.

4.2.5.1.1 Wired Systems

The system shall consist of a base and a series of satellite stations.

The base unit should be mounted at the control position for the headpiece.

4.2.5.1.1.1 System Power

The system shall be powered from the base station.

Prime power shall be supplied by the longwall system power line.

Backup battery power should be provided to permit at least 6-hour operation in the event of prime power loss.

4.2.5.1.1.2 Wiring

Interstation wiring should utilize armored, jacketed cable.

Cable mounting should be resiliant so rock falls will not cause cable breakage.

4.2.5.1.1.3 Equipment Description

All switching capability shall be located in the base station.

Expansion capability shall include provision for interconnection with the primary intramine communication system.

Satellite stations should consist of a microphone and a loudspeaker.

Handsets should not be used.

Loudspeaker levels shall be such that one or more stations can be monitored from all working positions at all times.

Microphones shall be of the noise canceling type.

Particular attention shall be paid to audio intelligibility to combat the high noise levels on the longwall.

4.2.5.1.1.4 Intramine System to Longwall System Interface

4.2.5.1.1.4.1 Minimal System Interface

There shall be a dedicated channel assigned to each longwall section.

The entire longwall system shall monitor the dedicated channel, while the base station additionally monitors the paging channel.

The intramine system may be designed to permit either of two forms of access to the dedicated longwall channel. Either method maintains private line operation between the longwall party line and the balance of the mine.

a. All phones have access, but can only call; bidirectional communication is enabled at the base station.

b. Access is always bidirectional, but only selected phones (such as dispatcher, maintenance, mine foreman) can select the channel.

It shall be possible to switch the entire longwall system to full interconnection with the paging channel.

Either wired or wireless interconnection between the systems may be implemented.

4.2.5.1.1.4.2 Fully Integrated System Interface

Wireless interconnection with the intramine system is preferred, but a wired connection may be used.

The base unit of the longwall system shall serve as an extension of the intramine system.

It shall be possible to interconnect the audio of the two systems.

When interconnected, it shall be possible to answer an incoming call from the intramine system at any longwall system satellite position.

The satellites need not be capable of initiating calls.

4.2.5.1.2 Wireless Systems

Wireless longwall systems are preferred over wired systems for the safety value of section worker access regardless of position around the section.

A wireless system has no interconnecting cable subject to breakage.

4.2.5.1.2.1 System Configuration

There shall be a base unit mounted on the head piece.

A portable unit shall be carried by every workman on the section.

The system shall operate in a "party line" mode at all times.

The base station should serve as a repeater with the portable units operating full duplex, however, half duplex or simplex is acceptable.

4.2.5.1.2.2 System Power

The base station shall be powered by the longwall system prime power line.

Portable units should be powered off cap lamp or self-contained batteries.

If the base station operates in a repeater mode it should have battery backup to provide at least six hours of operation in the event of prime power loss.

4.2.5.1.2.3 Portable Unit Objectives

All or part of the unit should attach to or be molded into the miners cap.

The balance of the unit should mount to the equipment belt.

Any interconnecting cable should be molded with or clipped to the cap lamp cable.

There should be no manually activated transmit control; however, if a manual control is required, it should be attached to the equipment belt, attachable on either side.

An omnidirectional, nonpolarized antenna should be used.

Items mounted to the miner's cap should be as light as possible.

4.2.5.1.2.4 Intramine System to Longwall System Interface

4.2.5.1.2.4.1 Minimal System Interface

There shall be a dedicated channel assigned to each longwall section.

The entire longwall system shall monitor the dedicated channel while the base station additionally monitors the paging channel.

The intramine system may be designed to permit either of two forms of access to the dedicated longwall channel. Either method maintains private line operation between the longwall party line and the balance of the mine.

a. All phones have access, but can only call; bidirectional communication is enabled at the base station.

b. Access is always bidirectional, but only selected phones (such as dispatcher, maintenance, mine foreman) can select the channel.

It shall be possible to switch the entire longwall system to full interconnection with the paging channel.

4.2.5.1.2.4.2 Fully Integrated System Interface

The base unit of the longwall system shall serve as an extension of the intramine system.

It shall be possible to interconnect the audio of the two systems.

When interconnected, any incoming call shall be automatically answered by the longwall system so workers anywhere on the longwall may speak.

Disconnect of the call shall be controlled by the calling party.

The portable units need not be capable of initiating calls.

4.2.5.2 Trolley Phones

4.2.5.2.1 Power Sources

Trolley phones shall be powered from the vehicle power system.

Backup battery power shall be provided and should permit at least 6 hours of operation in the event of trolley power loss.

4.2.5.2.2 System Design

A trolley system must be designed to eliminate the standing waves which can result in signal dropouts.

Traps must be used to isolate power feed points.

Lumped impedances must be available to alter effective line lengths, eliminating resonant sections.

The trolley system should be designed around a modulation method in which limiters are used in the receiver for the best performance in the presence of the extreme noise levels on the trolley wires.

4.2.5.2.3 System Configuration

There shall be a station mounted on each piece of powered equipment.

For safety purposes there should be a dispatcher at a fixed location monitoring all communication on the trolley system and keeping track of the location of each vehicle.

4.2.5.2.4 System Operation

There shall be at least one simplex (one-way transmission) channel in each station.

There should be an expansion capability to at least two channels.

Regardless of the total number of channels implemented, the base channel shall be monitored at all times for safety purposes.

Full duplex (simultaneous transmission and reception) operation is desirable.

Operation shall be via microphone and loudspeaker.

Handsets should not be used.

Noise canceling microphones should be used on the vehicles.

Because of the high noise levels involved, particular attention should be paid to audio intelligibility.

Loudspeakers should be adjustable so they may be positioned for best operator intelligibility.

4.2.5.2.5 Intramine System to Trolley System Interface

In simplest form interface may be through the dispatcher.

The dispatcher shall have the capability of patching the trolley and intramine systems together.

4.2.5.2.5.1 Minimal System Interface

There should be a dedicated channel assigned to the trolley system.

4.2.5.2.5.1.1 Single Trolley Channel

The entire trolley system should monitor the dedicated channel, while the dispatcher additionally monitors the paging channel.

Privacy is maintained by allowing the dedicated channel of the fixed system to monitor only transmissions during which a special control has been operated.

The dispatcher shall have the capability of shifting the monitor connection to the paging channel of the fixed system.

4.2.5.2.5.1.2 Multiple Trolley Channels

The primary trolley channel should monitor the fixed system paging channel in the absence of a dispatcher.

Transmission from the trolley system to the fixed system should only occur when a separate control is operated.

The fixed system dedicated channel should be connected to a secondary trolley channel.

The dispatcher should monitor both the paging and working channels at all times.

4.2.5.2.5.2 Fully Integrated System Interface

Incoming calls shall ring at the dispatch point and on the secondary trolley channel unless patched into the primary channel.

Signaling shall be provided so trolley phones shall have full access to the fixed system.

If more than two trolley channels are implemented, each shall have its own phone number.

4.2.5.3 Nontrolley Vehicles

Nontrack, nontrolley vehicles do not require a party line channel to maintain traffic safety as do track vehicles, since one vehicle can move aside for another. Independent motion does not eliminate the need for this channel to provide communication at blind corners and similar situations.

4.2.5.3.1 Power Source

Phones shall be powered from the vehicle power system.

4.2.5.3.2 System Configuration

There shall be a station mounted on each piece of powered equipment.

For safety purposes there should be a dispatcher at a fixed location monitoring all communication on the vehicular system and keeping track of the location of each vehicle.

4.2.5.3.3 System Implementation

Fixed repeaters shall be located throughout the mine so vehicles are not out of communication while traveling normal paths. These repeaters may be independent or may be included as stations in the fixed intramine system.

4.2.5.3.4 System Operation

Each vehicular station shall provide at least one simplex channel.

There should be an expansion capability to at least two channels.

Regardless of the number of channels implemented, the base channel shall be monitored at all times for safety purposes.

Operation shall be via microphone and loudspeaker.

Noise cancelling microphones shall be available as an option.

4.2.5.3.5 Intramine System to Trolley System Interface

There shall be a dedicated channel assigned to the vehicular system.

This dedicated channel shall be used to interconnect the repeaters used to control the vehicles.

4.2.5.3.5.1 Minimal System Interface

Only selected phones (such as dispatcher, maintenance, mine foreman) shall be able to select the vehicular channel.

The dispatcher shall be able to patch other channels to the vehicular channel.

Interface in a multichannel system shall be by means of additional dedicated channels identical to the base channel.

4.2.5.3.5.2 Fully Integrated System Interface

Whenever the vehicular channel is dialed, a "ring" signal shall sound in all vehicles.

The calling party shall hear no transmission on the vehicular system unless a separate control is actuated by the answering vehicle.

All vehicles will monitor the call and any may join the call by actuating the control.

By actuating the control any vehicle shall be able to initiate calls on the intramine system.

Additional channels shall operate in the same manner as the base channel.

4.2.5.4 Hoist Communications

Hoist communication installations may be implemented as either a wired or a wireless system.

The wireless system is preferred as it is immune to interruptions resulting from cable damage.

Frequency diversity is not needed on wireless systems.

4.2.5.4.1 Minimal Systems

A fully independent single-channel system shall be operated between the shaft top, bottom, and the interior of the cage.

Operation shall be via a microphone and loudspeaker.

Handsets should not be used in the cage.

It shall be possible for the hoist operator to patch this system into the intramine communication system or;

As an alternate to hoist operator patch capability, a station on the intramine system may be installed in the cage.

4.2.5.4.2 Fully Integrated Systems

The cage shall contain an extension of the main intramine communications system.

Handsets should not be used in the cage.

All transmissions from this extension shall be monitored at the top and bottom, whether or not a number has been dialed.

A loudspeaker shall monitor transmissions from the hoist operator if no call is in progress.

Transmissions from the hoist operator shall be able to override any call in progress.

4.2.5.4.3 Portable Communications

A portable system shall be available so anyone performing inspection or maintenance within the hoist shaft will be in constant communication with the hoist operator.

A hand-held radio transceiver is suitable for this function.

Channels over and above those required to conduct the telephone business within the mine may be used to provide a number of nonvoice capabilities. There is a constant need to monitor conditions throughout the mine. Monitors may check items such as air flow, carbon monoxide, oxygen, and methane. Items monitored may be on either a proportional or a go/no-go basis.

Each channel diverted to monitor service can handle a number of items gathered throughout the mine on a time-shared, sampling basis. As an example, status of fans, pumps, and circuit breakers may be read remotely and their operation controlled in many cases. Data that must be monitored continuously can still be multiplexed on one channel as long as a 2400 bit-per-second data rate is not exceeded.

If a large amount of information must be transmitted, a dedicated channel is required. An example is provided in slow-scan closed circuit TV. A complete picture can be transmitted every eight seconds using 128-line resolution, or one frame per minute with conventional 525-line resolution.

If low-speed data is being sent, the encoding devices may be scattered throughout the mine. So long as each encoder operates on its own frequency, all may share a single data channel.

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15. Supplementary Notes

16. Abstracts

This report contains a recommended specification for an integrated coal mine communication system. The communications requirements within coal mines were determined following a series of mine visits during which existing communications were evaluated. Theoretical and experimental programs were performed to determine the relative rf propagation characteristics of LF and UHF emissions within mines. Details of all programs supporting the specification are included as part of the report.

17. Key Words and Document Analysis. 17a. Descriptors

Telecommunication
Telephone Systems
Radio Communication
Earth Current Communication
Intercom Systems
Multichannel Telephone Systems
Electromagnetic Wave Transmission
Electromagnetic Radiation
Coal Mines
Mine Haulage
Underground Mining

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group 0903

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