Minetech, Volume 24, No. 6, P 1-13 Nov.-Dec. 2003

TRAPPED MINERS DETECTION, LOCATION AND COMMUNICATION SYSTEM

Arvind Kumar*, S.K. Chaulya#, S. Kumar# and L. K. Bandyopadhyay#

ऐसी खनन दुर्घटनाओं में जिनमें श्रमिक भूमि के नीचे खान में फंसे हों, त्वरित एवं पर्याप्त बचाव प्रयास आवश्यक होता है। त्वरित एवं पर्याप्त प्रयास न केवल बचाव कार्य की सफलता बल्कि बचाव कर्मियों की सुरक्षा भी सुनिश्चित करता है। अधिकांश भारतीय खानें संकट-सूचना सिस्टम से युक्त हैं यथा दुर्गन्ध गैस, श्रव्य अथवा दृश्य अलार्म, दूरभाष एवं संदेश वाहक जो अग्नि अथवा अन्य खतरों से श्रमिकों को आगाह करते हैं। ये साधन सामान्यत: धीमी गति से काम करते हैं और पूरी खदान के लिए अपर्याप्त होते हैं। विभिन्न देशों में भिन्न-भिन्न द्रुत गति वाले संचार सिस्टम का प्रयोग किया जा रहा है ताकि दुर्घटना होने पर बचाव दल और फंसे श्रमिकों के मध्य शीघ्रता से सम्पर्क किया जा सके और खान में उनकी सही स्थिति का पता लगाया जा सके। इस आलेख में द्रुत पड़ताल एवं संचार के दो प्रमुख सिस्टम प्रथम भूकम्पीय और दूसरा विद्युत-चुम्बकीय का विस्तृत अध्ययन किया गया है।

INTRODUCTION

Survival for an underground miner during disaster, fire or other emergency can be measured in terms of minutes. An emergency warning that arrives late can result in tragedy. Existing warning system for underground mines, such as horn, siren, stench gases through the ventilation system, or messengers (other miners), can be slow and ineffective. This prompted the development of wireless, ultra low frequency electromagnetic signalling technology for warning and paging systems for the mining industry (Allen and Linefield, 1973; Zamel, 1990; Kumar et al., 2002).

Different types of systems are commonly used in combination for communication purpose in underground mines. Types of communication systems include fixed wire telephone, leaky feeder and optical fiber based systems. These existing technologies can not meet all emergent communication requirements for a mine especially in the event of mine disaster such as, explosion, roof fall and water inundation when miners may be trapped in underground. It becomes difficult to locate the trapped miners as well as establish contact with them, thereby affecting the rescue operation of the men trapped in mine disasters. The rescue personnel and the miners trapped in an underground mine working exchange the signal directly through the strata for communication between them. Experience in post disaster rescue work has indicated that there is a need for reliable means of quickly locating trapped miners. The ultimate objective of the rescue operation is to reach trapped miners in a timely manner before they succumb to the effect of injury and exposure to toxic atmospheres. The key to early successful rescue lies in the rapid location of the trapped miners and establishment of communication between the rescue personnel and trapped miners.

As early as 1899, Nicola Tesla, France suggested the use of extremely low frequency communication system using an earth medium (Wheeler, 1961). Pioneering research was conducted by the former U.S. Bureau of mines (USBM) on the propagation of radio waves through the earth and detection of trapped miners (Westinghouse Georesearch Laboratory, 1973; Powell, 1976; Shope et al., 1980; Dobroski and Stolarczyk, 1982; Lagace et al., 1980 & 1982). Subsequent USBM research (Hjelmstad and Pomroy, 1991) showed that ultra-low-frequency electromagnetic signals from 630 Hz to 2 KHz could be transmitted through mine rock for distance as great as 1,645 m to an intrinsically safe receiver. The prototype wireless system of the previous research used off-the-shelf components and state-of-the-art technology to ensure high reliability and low cost. The technology enabled simultaneous and instantaneous warning of all personnel, regardless of their underground location or work activities, by flashing their cap lamp (Wadley, 1949).

The communication systems capable of detecting and locating trapped miners are principally of two types, namely, (i) seismic and (ii) electromagnetic. The seismic techniques have been developed to sense the vibration caused by a miner trapped in the part of a mine and the electromagnetic

* Junior Scientific Assistant; '#' Scientists, Central Mining Research Institute, Dhanbad – 826 001

technique includes narrowband signaling, where a periodic pulse is transmitted. Both the techniques are described below.

SEISMIC METHOD

In the seismic system, in case of disaster, the trapped miners strike a part of the mine with any heavy object they could find nearby. The resulting vibrations would then be detected on the surface by the use of seismic transducers (seismometer) which will be referred to as geophones. The geophones convert seismic signals to voltages that are then amplified, filtered and recorded in a seismic van placed on the surface **(Fig. 1)**. The location of a trapped miner at the underground can be found by the signals obtained from various geophone arrays through suitable processing scheme (Ruths, 1977).

Fig. 1: Seismic system for locating trapped miners (Shope et al., 1982)

Principal

The seismic rescue system uses an array composed of several sub-arrays rather than the same number of individual geophones to receive seismic signals; the reason is that a sub-array will give a better SNR (signal-to-noise ratio) than a single geophone. The miner is instructed to do the following in the event he is trapped underground:

(i) When all possible escape is cut off, the miner is to erect barricade for protection from possible toxic gases and waits for a signal from the surface before beginning to signal the seismic system.

(ii) As soon as the system is in a state of readiness, the surface crew detonates three explosive charges that can be easily heard by the trapped miner.

(iii) After hearing these three shots, the miner is to pound 10 times on any hard part of the mine, preferably the roof or a roof bolt, with any heavy object that can be found nearby; a heavy timber is best.

(iv) Following this, the miner is to rest for 15 minute and then repeat the pounding. While resting, if the miner hears five shots from the surface he knows the signaling has been detected and help is on the way.

(v) If the miner hears no shots, he repeats signalling after every 15 minute.

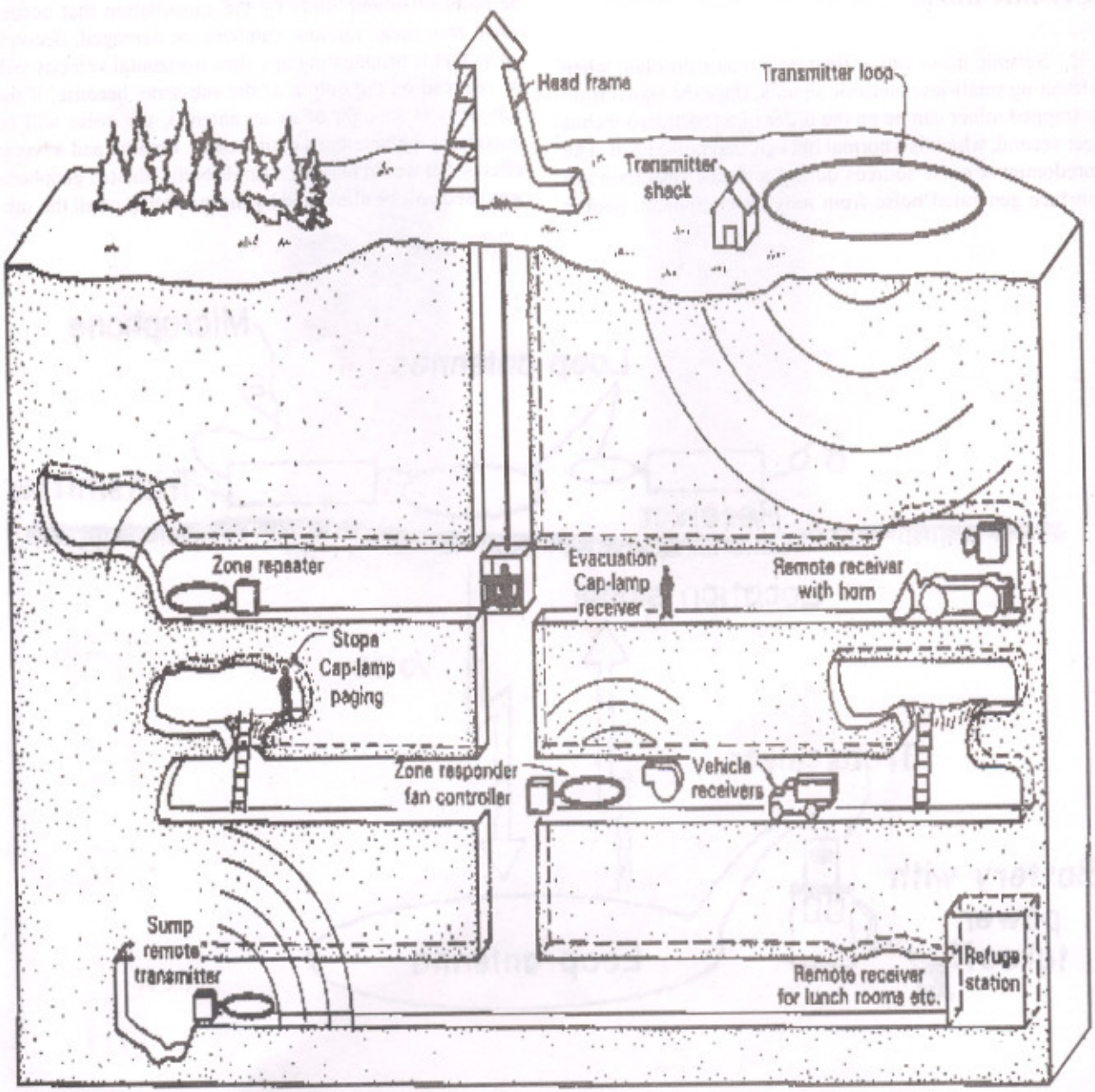

Fig. 2: Conceptual representation of a mine depicting capabilities of the communication and signaling system (Conti and Yewen, 1997)

Probability of detection

It is desirable to determine the probability that a surface array will detect an underground source. The configuration normally used, seven sub-arrays are placed on the surface to monitor a portion of the subsurface. A method has been developed to calculate the probability that m sub-arrays or more, with $1<=m<=7$, will detect a miner's signal. The detection of a signal by one sub-array may be sufficient to identify the signal as coming from an underground miner. However, identification can be more certain if several sub-arrays can detect the signal. To locate, at least three sub-array detections are required, and five or more are desirable for better accuracy (Ruths, 1997).

Seismic noise

Seismic noise can at time be a major problem when detecting small-level seismic signals, since the signal from a trapped miner can be on the order of a few micro inches per second, which is a normal background noise level. The predominant noise sources during a rescue operation are surface generated noise from moving equipment, people walking and power lines. Thus, information is needed on the types of noise sources, the expected amplitude ranges, and the amplitude variation with frequency and time. There are various signal noise processing techniques available to enhance the signal to noise ratio.

Three common noise sources are typically encountered in the field: (i) natural seismic background noise, (ii) man made seismic noise and (iii) man made electromagnetic interference coupled into the field equipment. For the noise reduction, the seismic rescue system uses an array, composed of sub-arrays rather than seven individual geophones to receive seismic signals. The reason is that a sub-array will give a better SNR than a single geophone. This improvement is achieved principally in three ways. First, noise that is uncorrelated between the geophones will be reduced in amplitude by the cancellation that occurs when zero mean random numbers are averaged. Second, noise that is propagating at a slow horizontal velocity will be reduced on the output of the sub-array because, if the sub-array is thought of as an antenna, the noise will be outside of the antenna's main beam. Finally, and adverse effects that would result if a single badly planted geophone was used will be alleviated by the averaging of all the sub-

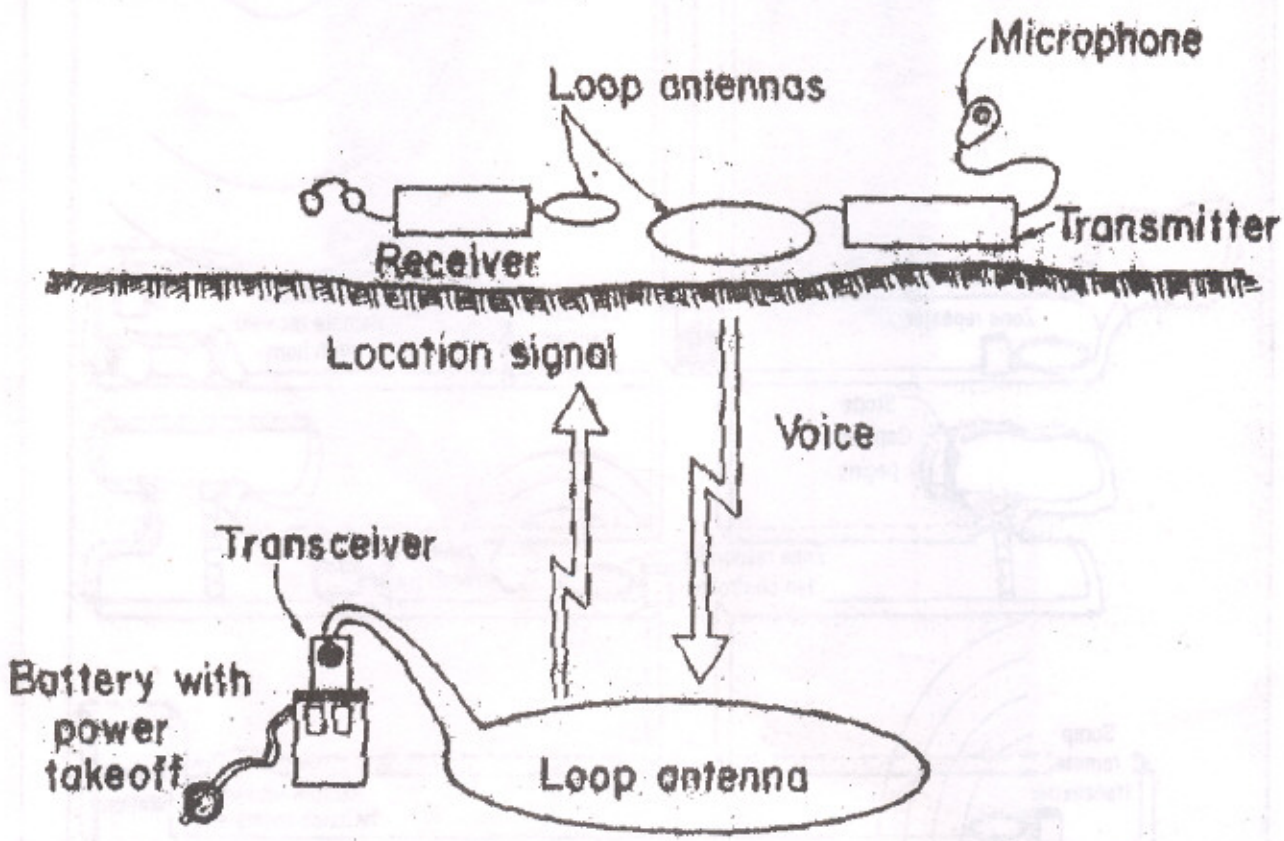

Fig. 3: Block diagram of electromagnetic system for location and communication with trapped miner (Dobroski and Stolarczyk, 1982)

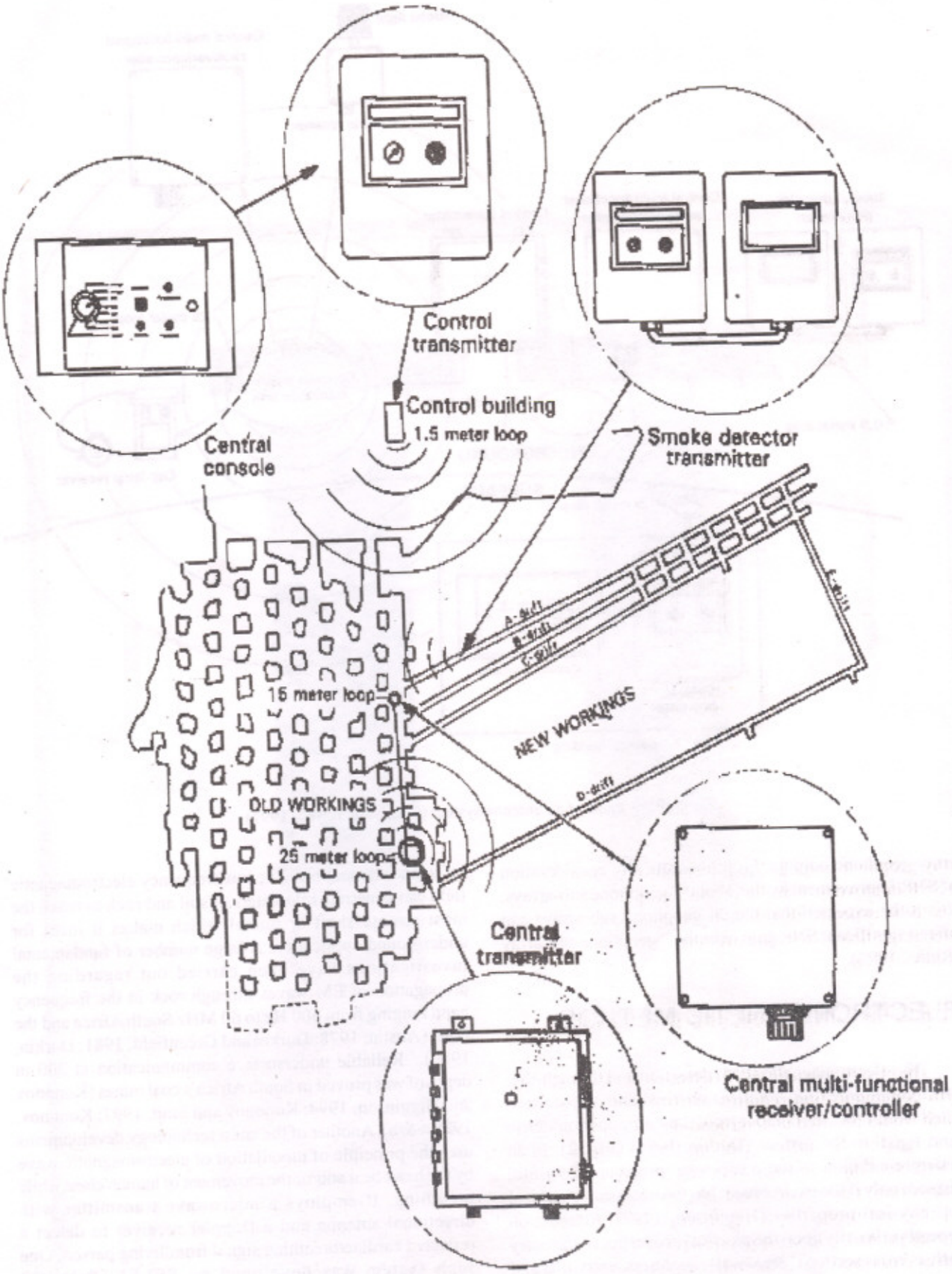

Fig. 4: Block diagram of an electromagnetic signaling system (Conti and Yewen, 1997)

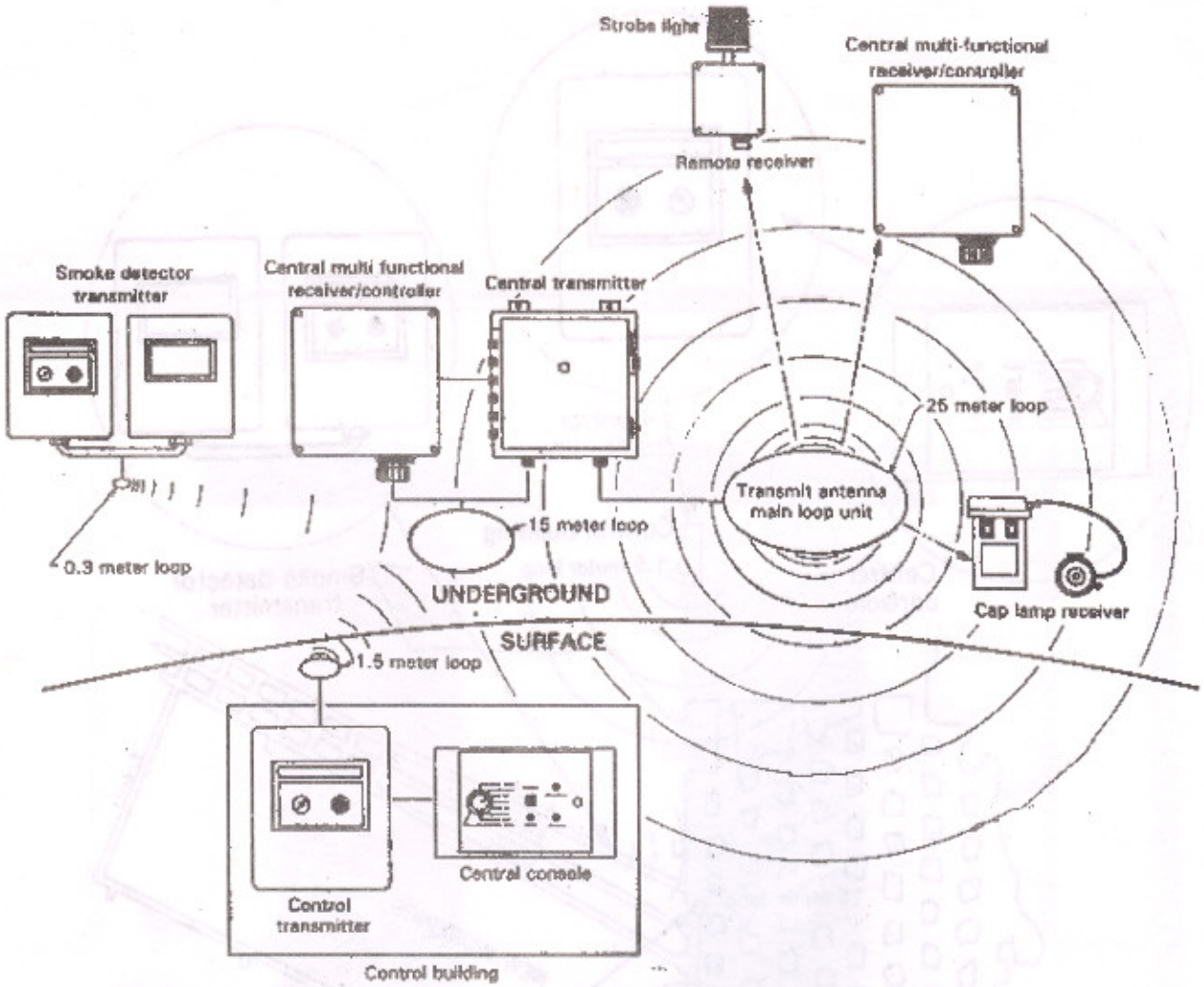

Fig. 5: Flow chart of an antenna system (Conti and Yewen, 1997)

array geophone outputs. From theoretically consideration of SNR improvement by the 24 and 7 geophone sub-arrays, it is to be expected that the 24 geophone sub-arrays can offer a significant SNR gain over the 7 geophone sub-array (Ruths, 1997).

ELECTROMAGNETIC METHOD

The electromagnetic (EM) detection and through-the-earth communication requires narrowband transmitter, which would be, used underground by a trapped miner to send signal to the surface (Durkin, 1984) (**Fig. 2**). In an underground mine, a radio wave can propagate an useful distance only if the environment has the necessary electrical and physical properties (Higginson, 1992). Attenuation depends primarily upon the physical properties of the entry such as cross sectional area, wall roughness, entry tilts and obstacles in the propagation path. Secondary effects such as the dielectric constants and the earth conductivity also influence attenuation. The low frequency electromagnetic field can penetrate kilometers of soil and rock to reach the most remote shaft or tunnel which makes it ideal for underground application. A large number of fundamental investigations have been carried out regarding the propagation of EM waves through rock in the frequency band ranging from 600 Hz to 60 MHz South Africa and the USA (Austin, 1978; Durkin and Greenfield, 1981; Durkin, 1982). Reliable undersurface communication at 200 m depth of was proved in South Africa's coal mines (Kononov and Higginson, 1994; Kononov and Smit, 1997; Kononov, 1998 a & b). Another of the latest technology developments uses the principle of modulation of electromagnetic wave by the heart beat and/or the movement of human chest while breathing. It employs a microwave transmitter with directional antenna and a Doppler receiver to detect a reflected cardiac/breathing signal from living person. One such system was developed by SELECTRONICS (Germany) in 1995 and manufactured under the name SIRUS. The system is capable of identification a living

person at distance of 90 m in the air and about 20 m through walls and debris.

Principal

This type of system consists of a low frequency transmitter that can be strategically placed at selected location to create an electromagnetic signal, which can completely envelop most mines without the use of repeater system. The system consists of two parts, a transmitter, and a surface system for detection and communications (**Fig. 3**). The transmitter can be carried on miner's belt and is powered by a cap lamp battery. The transmitter serves as a radio beacon to help rescue personnel and locate trapped miner under or behind roof falls or barricades, or in other inaccessible places. A compact loop antenna which can either be carried by the miner or strategically located in the mine is used to generate electro-magnetic field that is sensed by a mobile receiver on the surface. On the surface, sensitive receivers detect the signal and locate the source. Once detection and location are made, a large surface transmitter is deployed above the trapped miner (**Fig. 4**). The transmitter is powerful enough to send voice message by radio, directly down through the earth (Conti and Yewen, 1997).

In an emergency, the miner would connect his tone transmitter to the deployed loop antenna. The transmitter supplies a current to the antenna with low frequency range. The known interval of the intermittent signal allows the receiver on the surface to distinguish between the signal and the electromagnetic noise or interference.

Antenna: Practically all of the available systems in the international market or prototypes just developed and tested are basically different types of loop antennas (**Fig. 5**). These antennas vary from a single turn loop formed by 27 m wire which may be deployed by a trapped miner to a short ferrite antenna. Regardless to transmitting power or

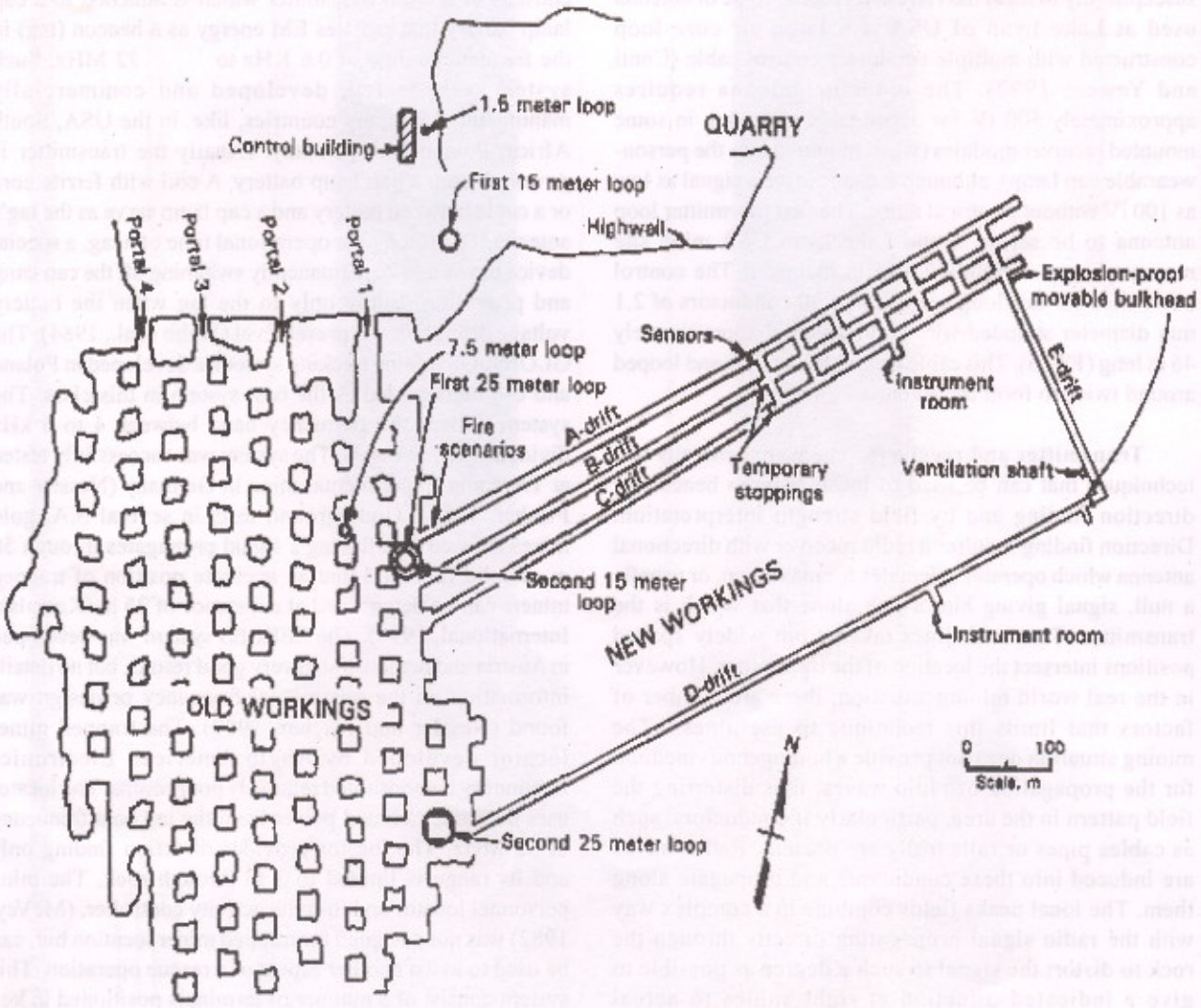

Fig. 6: A typical plan view of an electromagnetic system with locations of loop antenna (Conti and Yewen, 1997)

receiving sensitivity all these antennas have different efficiency. An antenna's radiation resistance and, therefore its efficiency could be increased by increasing the operational frequency. In practical it is desirable that no special efforts are required from the trapped miner to be detected, therefore, the tag and its antenna must be the integral part of the miner's body, being compact and robust, and do not interfere with normal operations, as well as being constantly in a stand by mode. Ferrite antenna could comply with all these requirements, but in many cases are not able to provide the required operational distance under reasonable size and weight. Even if required sensitivity could be obtained with ferrite antenna, but transmission performance is poor due to high loss in a coil and ferrite itself. From the first development in 1986, another negative aspect of using ferrite antenna in a tag is the possible "null' orientation of the receiving/ transmission lobs in the two axises of rotation or levels of freedom, which can make it more difficult to detect a trapped miner. The most important features of the loop antennas are directivity and reduced susceptibility to local interference. Another type of antenna used at Lake Lynn of USA is a large air core loop constructed with multiple conductor control cable (Conti and Yewen, 1997). The inductor antenna requires approximately 500 iV for dependable operation in some mounted receiver modules (when mounted into the person-wearable cap lamp), although it can receive a signal as low as 100 iV without electrical noise. The first transmitter loop antenna to be set up at the Lake Lynn USA mine site measured approximately 7.5 m in diameter. The control cable used for this loop consisted of 30 conductors of 2.1 mm diameter stranded wire and measured approximately 46 m long (**Fig. 6**). This cable was laid in a circle and looped around twice to form the antenna.

Transmitter and receivers: There are generally two techniques that can be used to locate a radio beacon by direction finding and by field strength interpretation. Direction finding requires a radio receiver with directional antenna which operator orientates for maximum, or usually a null, signal giving him a line alone that which is the transmitter. Two such lines taken from widely spaced positions intersect the location of the transmitter. However in the real world mining situation, there are number of factors that limits this technique to usefulness. The mining situation does not provide a homogenous medium for the propagation of radio waves, thus distorting the field pattern in the area, particularly if conductors, such as cables pipes or rails trolly are present. Radio waves are induced into these conductors and propagate along them. The local peaks fields combine in a complex way with the radio signal propagating directly through the rock to distort the signal to such a degree as possible to give a indicated direction at right angles to actual transmitter location. Field strength techniques depend on the fact that the signal strength falls off at the square of the distance in the field and at the cube of the distance for the prime component when in the near field. Thus, while using low frequencies it has to be ensured that the rescue operation is in the near field zone, small changes in the position of a receiver, equipped with a signal strength meter, can be used to accurate determination of the miner's location.

Trapped miner detection and location: In case of disaster when miners are trapped in underground, the proper information on the area where it happened and how many miners are affected must be properly assessed. It should be understood that the detection of the any trapped miners presence in a vicinity, and location of each of them, are two different processes which require different time period, as well as effort to implement. In order to detect a miner in the searching vicinity, the miner has to carry some kind of transponder or a tag. Tags are basically two types as discussed below and these can also be used in combination.

Active tagging: This type of tag is commonly used for locating trapped miners. An active radio tag normally consists of a radio transmitter which is attached to a cap lamp battery that radiates EM energy as a beacon (tag) in the frequency range of 0.6 KHz to 32 MHz. Such system were tested, developed and commercially manufactured in many countries, like, in the USA, South Africa, Poland and Germany. Usually the transmitter is powered from a cap lamp battery. A coil with ferrite core or a cable between battery and a cap lamp serve as the tag's antenna. To prolong the operational time of a tag, a special device blows a fuse, permanently switching off the cap lamp and providing supply only to the tag when the battery voltage drops below a preset level (Webb et al., 1984). The GLON-LOP mining tracking system is developed in Poland and can be regarded as the best system in this class. The system utilizes the frequency band between 4 to 6 kHz divided into 8 channels. The system was successfully tested at Tremonia Experimental mine in Germany (Nessler and Fischer, 1989). Underground tests in several S.A. gold mines showed that the tag's signal propagates through 50 m of solid rock and that an accurate position of trapped miners can be determined at a distance of 25 m (Kowalski International, 1994). The SERLES system was developed in Austria and demonstrated very good results, but no details information on the operational frequency or design was found (Nessler and Fischer, 1989). The trapped miner locator developed by Anglo American Electronics Laboratory demonstrated relatively poor results. The locator uses the same radiated power from the tag on a frequency of 32 MHz. The locator provides direction finding only and its range is limited to 3 m through rock. The mine personnel locator and in-mine activity controller, (McVey, 1982) was not designed for trapped miner location but, can be used to assist another aspect of a rescue operation. This system consist of a number of terminals positioned in key underground areas and is connected to a host computer and miner's personal transponder, which are mounted in the cap-lamp battery's cover. The transponder is an active receiver and transmitter that radiate identification code.

Every few seconds all the terminals transmit a short interrogation signal at 49.6 MHz which can be received by any transponder within a line of sight range of about 60 m.

Passive tagging: A passive receiver accumulates energy received from a search transmitter over time and uses this energy to re-transmit a location signal (Yewen, 1987). The passive tag has an indefinite operational life, but its location distance is limited by the power and duration of the transmission cycle of the searching transmitter. SIEMENS introduced a REDAR which include a passive transponder connected to the belt to protect miners from entering dangerous areas. Its operational distance however was less than 1 m in debris. REDAR refers to its RFID system as the ASDIC (Area Surveillance Device with Identification Capability) system. Its product line includes readers, antennas, tags, radio frequency (RF) units and hand-held units. The ASDIC system employs two frequencies, 434 MHz (915 MHz in the United States) for transmission and 455 kHz for reception. Two different antennas are employed. Each reader station can handle up to four antennas, which can be separated by up to 2 m. Transmitted power is normally below 5 mW. The tracking system MIRIS uses a personnel transponder in the form of a bracelet. The system can handle up to 15000 people and the detection range is up to 5 m through air from the interrogators. Davis Derby (UK) modified Texas Instruments Radio frequency Identification System (TRIS) to comply with intrinsic safety and flame proofing standards and commercially manufactures this system for British Coal (Hind, 1995). Similarly the TROVAN passive transponder ID system is manufactured by AEG (Germany) which also provides up to 1.5-1.8 m in air operational distance at best. In 1994 CSIR, Australia developed a passive tag under the name Super Tag, which could be used in mining conditions.

Combined method: This method combines a passive or active receiver with an active transmitter that leads to an increase in detection distance. The combination of the active receiver and active transmitter is able to provide the best operational distance (McVey, 1982). In 1986, SELECTRONIC (Germany) also developed a combined identification and trapped miners location system, which uses an active receiver and active transmitter. The improved system, which came on market on 1984, provided an accurate location of trapped miners up to 14 m in respect of position, distance and direction. A modified version of the system under the name PIM201b was tested in South Africa in 1997 at Elandsrand Gold Mine on 75 levels. The demonstration proved that it is possible to locate and rescue trapped mineworker through at least 20 m of solid rock as well as heavy rock fall in the underground working of the mine (Marx, 1997). The latest Selectron-Safe PIM-200 provides an operational distance 25 m (Hochhold, 1998). Following are the four methods to increase communication or detection distance:

i. Proper selection of operational frequency, which provides the lowest channel (through rock) attenuation,

ii. Increase radiated power on a tag's side,

iii. Increase a searching receiver sensitivity, and

iv. Increase antenna's frequency

The total cost of the miner's tag and a battery life time are the main factors which limit tag performance such as radiated power and sensitivity and, therefore, operational distance. In case of searching equipment, radiated power is limited by the capacity of a mobile power supply (battery), its size and weight, as well as by intrinsic safety (IS) requirements for coal mines. Sensitivity is limited only by underground background noise, which is relatively low and in total is able to compensate for drawbacks in the tag's performance. Radiated power of 5-20 W and a sensitivity of 0.1 V should be the set limits. It is a fact that till now, the available system, which provides for trapped miner detection and location through 30 m of solid or fragmented rock.

Field strength: The two most important factors that indicate how well a signal will propagate through the earth are the overburden bulk conductivity and the mine depth. Unfortunately, the geological structure of the overburden above coal mines differs from mine to mine, which causes the electrical conductivity to vary also. Therefore, for a given mine depth, one would expect the signal transmission characteristics to vary from one mine to the next. In order to predict the signal strength at any mine, one must rely on a statistical assessment of the data to determine signal strengths at a mine based on depth alone.

CONCLUDING REMARKS

Seismic and electromagnetic techniques are the most widely used methods for detection, locating and establishing communications with trapped miners in underground mines. The system based on seismic technique is an effective means for detecting and locating miners trapped in underground following a mine disaster. Expected signals from miners pounding on the roof of a mine are of sufficient strength to enable detection over a large area of a mine. Estimations of the location of the trapped miner can be made with sufficient accuracy to aid the rescue team. The attractiveness of this technique is that it does not require active devices to be carried by underground miner. The components necessary for utilizing this method are readily available in any mine. A limitation of the seismic location system is that it provides no communication capability.

The electromagnetic system makes use of a belt-worn-radio-type transmitter or loop antenna that the miner activate when trapped. The signals from the transmitter are sent to the surface where surface personnel can detect them and locate the miner's position. Once location is determined, surface personnel can transmit voice signals to the miner

to establish communication. Various studies are continuing for designing of loop antenna and transmitter to make the electromagnetic system more efficient.

ACKNOWLEDGEMENT

Authors are thankful to Director, Central Mining Research Institute, Dhanbad for giving permission to publish this paper.

References

Allen, J.W. and Linefield, R.F. "Trapped miners location and communication system". Development Program, Westinghouse Electric Corporation, May 1973, Vol. 1-4.

Austin, B.A. "Underground radio communication techniques and system in South African mines". Proceedings of the Workshop on Electromagnetic Guided Waves in Mine Environment, Boulder Co, Institute for Telecommunication Science, 28-30 March 1978, pp. 87-102.

Bandyopadhyay, L.K., Chaulya, S.K. and Kumar, S. "A proposed wireless communication system for underground mines". Proceedings of the International Conference on Mineral Industry, Issues on Economics, Environment and Technology. Mining, Geological and Metallurgical Institute of India, Kolkata, India, 2002, pp. 317-324.

Conti, R.S. and Yewen, R.G. "Evaluation of a signaling and warning system for underground mines". Report of Investigations 9641, US Department of Health and Human Services, National Institute of Occupational Safety and Health, Pittsburgh, May 1997, 17 p.

Dobroski, H. Jr. and Stolarczyk, L.G. "Medium frequency radio communication system for mine rescue". Proceedings of Post Disaster Survival and Rescue Research, Bureau of Mines Technology Transfer Seminar, Pittsburgh, PA, US Department of the Interior, Bureau of Mines, IC 8907, 16 November 1982, pp. 39-48.

Durkin, J. "Electromagnetic detection of trapped miners". IEEE Communication Magazine, Vol. 22, No. 2, February 1984.

Durkin, J. "Performance evaluation of electromagnetic techniques for location of trapped miners". Report of Investigations 8711, US Bureau of Mines, 1982.

Durkin, J. and Greenfield, R.J. "Evaluation of the seismic for locating trapped miners". Report Investigations 8567, US Bureau of Mines, 1981, 55 p.

Higginson, M. "Radio propagation experiments Durban deep gold mine". Draft report on investigation, COMRO, September 1992, 4 p.

Hind, D.J. "Application of radio frequency identification system in the mining industry". Mining System, July 1995, pp. 219-225.

Hjelmstad, K.E. and Pomroy, W.H. "Ultra low frequency electromagnetic fire alarm system for underground mines." Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, RI 9377, 1991.

Hochhold, K. "Personal communication on SELECRONIC system evaluation". Meeting at CSIR Miningtek, Johannesburg, 21 October 1998.

Kononov, V.A. "Investigation into and report on early warning and communication systems for irrespirable atmospheres in underground operations". SIMRAC Final Project Report GEN413, Pretoria: Department of Minerals and Energy, 1988b, 60 p.

Kononov, V.A. "Presentation of GEN502 project to SIMRAC". Chamber of Mines, 4 February 1988a.

Kononov, V.A. and Higginson, M.R. "Trapped miner locator (marketing feasibility)". CSIR Miningtek, Final report Y5162, Johannesburg, 1994, 10 p.

Kononov, V.A. and Smit, J.J. "Global mining warning and monitoring system". Proceedings of the 27th International Conference of Safety in Mines Research Institute. New Delhi, India, 20-22 February 1997, pp. 947-953.

Kowalski International. "Miner tracing system successfully tested on South African gold mines". Mining Mirror, January 1984, 78 p.

Kumar, S., Bandyopadhyay, L. K., Kumar, A. and Narayan, A. "Improvised wireless communication system for underground coal mines utilizing active antenna" Minetech, Vol. 24, No.1, Jan-Feb 2003, pp. 38-41.

Lagace, R.L., Dobbie, J.M., Doerfler, T.E., Hawes, W.S. and Spencer, R.H. "Detection of trapped miner electromagnetic signals above coal mines". Cambridge, MA: Arthur D. Little, Inc. U.S. Bureau of Mines contract No. J0188037, 1980.

Lagace, R.L., Dobbie, J.M., Raisbeck, G., Spencer, R.H., Degatano, M.A., Lambiase, F.J. and Moussa, N.A. "System study of mine rescue through electromagnetic means". Cambridge, MA: Arthur D. Little, Inc. US Bureau of Mines, Contract No. J0113043, 1982.

Marx, C. "Support for mining safety and equipment selectron-safe". DME letter PW11/11-28W, 23 May 1997.

McVey, J.R. "Mine personnel locator and in-mine activity controller". Information Circular 8907, Proceedings Post Disaster Survival and Rescue Research, Bureau of Mines Technology Transfer Seminar, Pittsburgh, November 16, 1982.

Nessler, N.H. and Fischer, D. "Location of buried miners-new systems". Proceedings of the 23rd International Conference of Safety in Mines Research Institute. Washingtun, DC, 11-15 September 1989, pp. 451-461.

Powell, J.A. "An electromagnetic system for detecting and locating trapped miners". Report of Investigations 8159, US Bureau of Mines, 1976.

Ruths, M.A. "The reference correction method for improving accuracy in the seismic location of trapped coal miners". M.S Thesis, Pennsylvania State University, College of Earth and Mineral Sciences, University park, PA, November 1977, 141 p.

Shope, S., Durkin, J. and Greenfield, R. "Finding and communication with trapped miners". Information Circular 8907, Proceedings of Post Disaster Survival and Rescue Research, Bureau of Mines Technology Transfer Seminar, Pittsburg, 16 November 1982, pp. 49-78.

Wadley, T.L. "Radio communication through rock on the Witwatersrand mines". CSIR report CTR-4, August 1949.

Webb, W.E., Church, R.H., Pittman, W.E. and Boyle, J.R. "A short-range locator system for detecting trapped miners, Report of Investigations 8844, US Bureau of Mines, 1984.

Westinghouse Georesearch Laboratory. "EM location system prototype and communication station modification". Boulder Co., U.S. Bureau of Mines Contract No. H0232049, 1973.

Wheeler, H.A. "Radio-wave propagation in the earth's crust". Journal of Research of the National Bureau of Standards 65D (2), 1961, pp. 189-191.

Yewen, R.G. "Passive tag identification system and method". US Patent No. 4,663,625, 1987.

Zamel, G. "A break through in underground communication for enhanced safety and productivity". Proceedings of Mine safe International, An International Conference on Occupational Health and Safety in the Mineral Industry, Chamber of Mines and Energy of Western Australia, Inc., Perth, Australia, 1990, pp. 763-766.

माइनटेक कैसे प्राप्त करें?

कृपया 400/- का बैंक ड्राफ्ट सी.एम.पी.डी.आई., राँची के पक्ष में भेजकर माइनटेक का वार्षिक ग्राहक बनें। ड्राफ्ट - जो भारतीय स्टेट बैंक, सी.एम.पी.डी.आई. शाखा (राँची) में देय हो, को संपादक, माइनटेक, सी.एम.पी.डी.आई., गोंदवाना प्लेस, राँची - 834 008 के पते से भेजें।

सभी ग्राहकों को अगले वर्ष के लिए अपनी ग्राहकता का नवीनीकरण दिसम्बर माह में करा लेना चाहिए। पता में परिवर्तन होने पर शीघ्र सूचित करें।

प्रामाणिक पुस्तक विक्रेता अपना नाम संपादक, माइनटेक के पास पंजीकृत करा लें और वार्षिक ग्राहक बनावें जिसके लिए 25% कमीशन देने का प्रावधान है।

How to get Minetech?

Please enroll yourself as annual subscriber to Minetech by sending a Bank Draft of Rs. 400/- in favour of CMPDI, Ranchi. The Draft payable at SBI, CMPDI Branch, Ranchi may be sent to Editor, Central Mine Planning & Design Institute Ltd., Gondwana Place, Kanke Road, Ranchi - 834 008.

All subscribers are required to renew their subscriptions for next year in the month of December.

Bonafide book sellers are requested to register their names with the Editor, Minetech for enrolling the annual subscribers of Minetech for which they will be entitled to 25% commission