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RECENT DEVELOPMENTS OF UNDERGROUND MONITORING EQUIPMENT IN UK COLLIERIES

İNGİLİZ KÖMÜR MADENLERİNDE YERALTI GÖZLEM SİSTEMLERİNDEKİ SON GELİŞMELER

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ABSTRACT: The coal mining industry in the United Kingdom has long recognized the importance of monitoring underground environmental parameters. These mainly include, methane, carbon dioxide, carbon monoxide, hydrogen sulphide, temperature, humidity and air velocity. To comply with legislation underground environmental monitoring in UK Collieries was initially developed by British Coal in the late 1960's. Regulations in the UK are amongst the strictest in the world and this has led to the development of sophisticated monitoring equipment. Environmental monitoring is now a routine for all mines and is carried out not only to satisfy legal requirements but to increase the safety of the mine in general.

ÖZET: İngiltere'de kömür madenciliği yeraltı ocak havası parametrelerinin gözlenmesinin önemini uzun süredir bilmektdir. Bu gözlemler başlıca; metan, karbondioksit, karbonmonoksit, kükürtlü hidrojen, sıcaklık, nem ve hava hızını içermektedir. Yönetmelik gereği, 19601ı yılların sonlarına doğru İngiliz işletmeleri tarafından, kömür madenlerinde yeraltı hava gözlem sistemleri geliştirilmeye başlanmıştır. İngiliz yönetmelikleri dünyadaki en katı olanlardandır, bu ise gelişmiş gözlem ekipmanlarının yapilmasina imkan saglamistir. Yeraltı havasının gözlenmesi bugün bütün ocaklarda uygulanmakta olup, bu yanızca yasal bir zorunluluğun yerine getirilmesi için değil, ayni zamanda madenin genel anlamda emniyetinin artırmak için yapılmaktadır.

1. INTRODUCTION

On a purely safety basis it makes sense to use an underground monitoring system. In the past miners relied on the flame safety lamp to detect the presence of dangerous gases and as technology developed portable instruments became available. As time wore on portable instruments became more sophisticated and perhaps more importantly were supported by the use of fixed instruments that were capable of continuos monitoring. Fixed sensors were introduced into British Coal Mines in the late 1960's and within a decade there were approximately 8500 hand held methane detectors and some 300 fixed methane detectors in use (Morris & Gray, 1977). It quickly became evident that the development of fixed sensors was the key to a mine wide environmental monitoring system. They alleviated the difficulties associated with the use of hand held instruments such as, high cost of labour, the limited value of spot readings and the frequency of the observations.

Over the years fixed sensors became more numerous and are now in common use in every large coal mine. This paper presents a description of some of the state of the art monitoring equipment that is currently available within the UK.

2. UNDERGROUND ENVIRONMENTAL MONITORING

Coal mining in the UK has undergone a radical change and all of the former British Coal mines are now in the private sector. British Coal initiated a comprehensive environmental monitoring system that was installed in the- 1970's recognizing the need to monitor underground environmental parameters for safety and production requirements. The quality and state of the underground air must be tested for contaminants according to mining legislation which states that the quantities of noxious, asphyxiant or inflammable gases must be less than a specified level. Environmental monitoring is now a routine for all mines and is carried out not only to satisfy the legal requirement but to increase the safety of the mine in general.

There are now two main forms of environmental monitoring in use and these are fixed and portable systems.

3. FDŒD SYSTEMS

An older form of environmental monitoring is that provided by the tube-bundle system. In this system

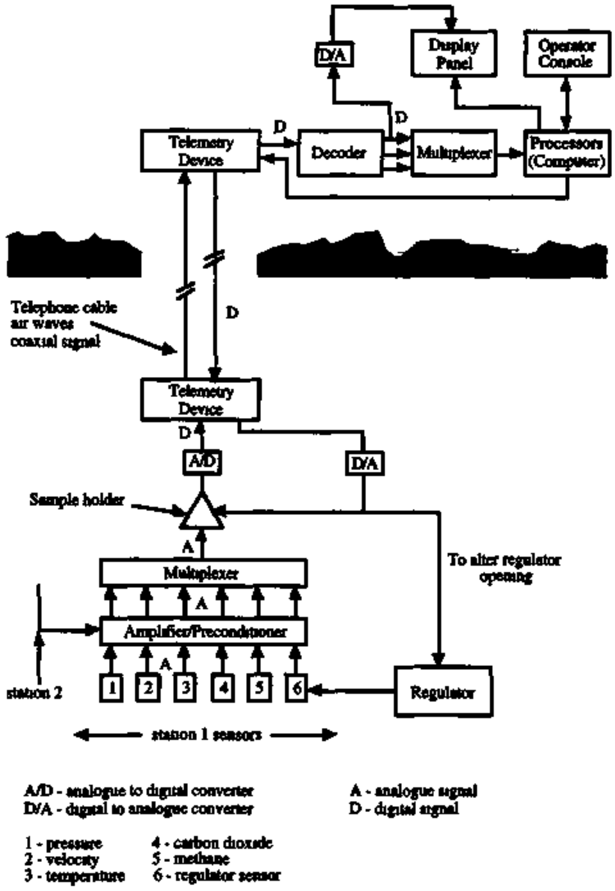


Figure 1 Diagram of a Real-Time Automated Monitoring and Control System (after Hormozdi, 1979).

mine air is drawn through small diameter plastic tubes and analysed at the surface. A tube is taken to a particular sampling point and although each sample stays discrete a number of tubes are clustered as a bundle for easier sample transportation. The major drawback of this system is the delay associated with the travelling and sampling time of the gas. This can be up to 2 hours long and so the system cannot be regarded as providing real-time knowledge of the mine atmosphere.

The most important environmental information is that provided by a real-time system. These rely on the use of electronic instruments that provide information covering the whole spectrum of gasedus pollutants (Hormozdi, 1979). By using transducers and electronic signal transmission the colliery control room knows instantly the condition of the mine atmosphere and there can be no doubt that such systems are invaluable to the safe and productive operation of any mine (Figure 1).

3.1 Requirements and Components of a Real-Time Monitoring System

Some essential requirements of a real-time environmental monitoring system are,

1. reliable electronic transducers,
2. fast response time to changing environmental parameters,
3. instantaneous data transmission.

This list is not exhaustive and the final system should do all that is necessary to achieve information that is a true reflection of the underground conditions at an instant in time.

The basic components of a real-time environmental monitoring system are,

1. a detector or sensing head,

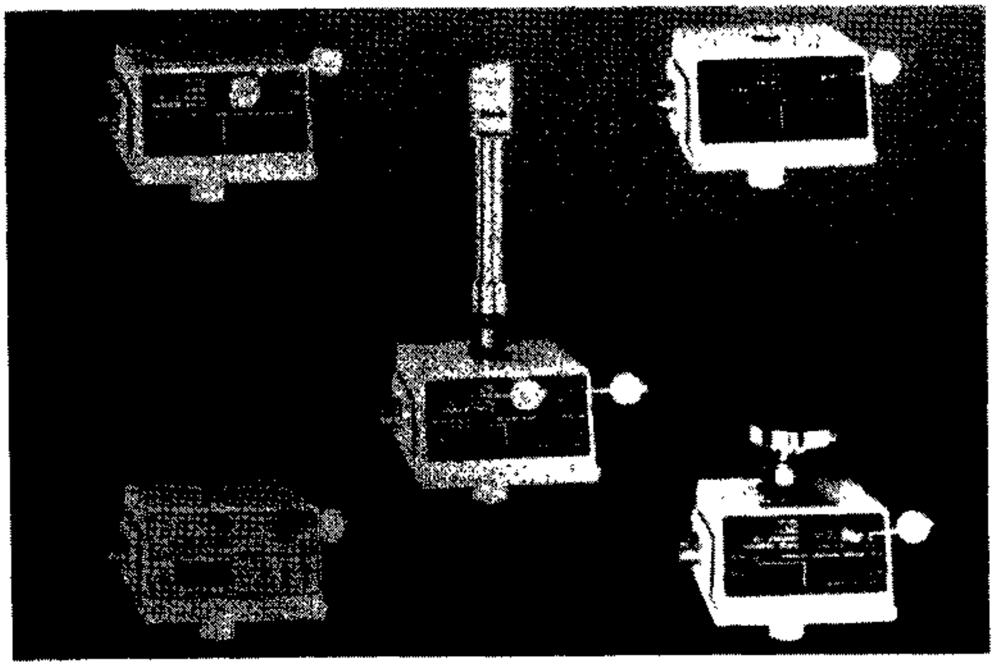


Figure 2 **Typical Status** Scientific **Environmental** Monitors.

Top left - methane Top right - carbon monoxide
Middle - air velocity
Bottom left-oxygen Bottom right - POC's

2. **a data** transmission system,
3. a computer system for data display, analyses, recording and storage.

Detector heads are used to test for a particular parameter e.g. methane concentration and provide an electrical output that is in a known proportion to the quantity of contaminant in the sample. This signal is then sent by a data transmission system to the surface where it is received by a computer and stored for further use.

3.2 Data Transmission System

The signal or voltage produced by an environmental monitor as a response to the presence of a contaminant is transmitted to the surface by a medium known as multiplexing. Multiplexing is a method whereby a number of signals are combined and transmitted together along a single line. The analogue voltage from the monitor is converted into a digital signal. Two forms of multiplexing can be used and these are,

1. time division multiplexing (TDM),
2. frequency division multiplexing (FDM).

In time division multiplexing the signal from each monitor is transmitted digitally as a series of pulses along with an identity pulse. The number of signals that can be transmitted depends on the frequency of the pulses. Only information from one transducer is transmitted at any one time. Frequency division multiplexing is similar but varies the frequency of the transmitted signal. Each transducer signal has its own encoder with an associated frequency. Many signals can be transmitted at the same time in FDM. The FDM system is more expensive than TDM but is less susceptible to electrical interference.

4. INSTRUMENT CALIBRATION

It is imperative that a comprehensive calibration policy is in effect otherwise substantial benefit from the sensors will be lost. There are a number of factors that can affect the calibration of an instrument In the case of a methane detector its use in a high methane environment can cause poisoning of the sensor and the presence of other hydrocarbons can cause the sensor to indicate a false reading of methane. A vane-type anemometer may Jose its calibration due to dust on the vanes or have Suffered some mechanical damage. Whatever the possible cause of an instrument losing its calibration the only solution is to regularly check it. This generally involves removing the instrument and sending it for calibration testing to either the manufacturer of a suitable technical service centre. This can be expensive and necessitates a store of replacement instruments. Ideally, a portable calibration system would be favourable since it would reduce the need to remove instruments that may be in calibration for checking. With the inevitable strive for cost cutting such a facility would be invaluable.

5. TYPICAL ENVIRONMENTAL SENSORS

A number of instruments are now available to monitor a large range of gases and it is intended to concentrate on a detailed description of two very common types of sensor, the methane sensor and the air velocity sensor. Figure 2 shows a number of different instruments that form the Status Scientific Control instrument family.

5.1 Methane Concentration

For the purpose of this paper information on instruments were supplied from Status Scientific Controls Ltd. This company designs and manufactures a full range of modern, fixed and portable gas detection, equipment, air velocity equipment, power and battery units and outstations.

A typical general air body methane concentration detector is the Status type CH4/Ö3 methane system, illustrated by Figure 3. The CH4/03 system is comprised of a regulator/display unit and a methane sensor head which can be placed up to 3 m distant from the regulator/display section. The regulator/display unit contains the circuitry to perform power supply regulation, and transmit its signal to an outstation. The CH4/03 monitors continuously and a relay circuit within it has the ability to shut-down electrical power in a district when methane levels reach a pre-set alarm point. The instrument range is 0 to 3% methane at an accuracy of ±0.1% methane by volume, or ±8% of the true value, whichever is the larger. The CH4/03 monitor utilizes the standard British Coal 0.4 - 2 V analogue output (to BS5754) for data transmission purposes. It also features an LCD display which can indicate the methane concentration, 'power', 'fault' and 'over-range' conditions. The CH4/03 can be powered by a number of external power sources.

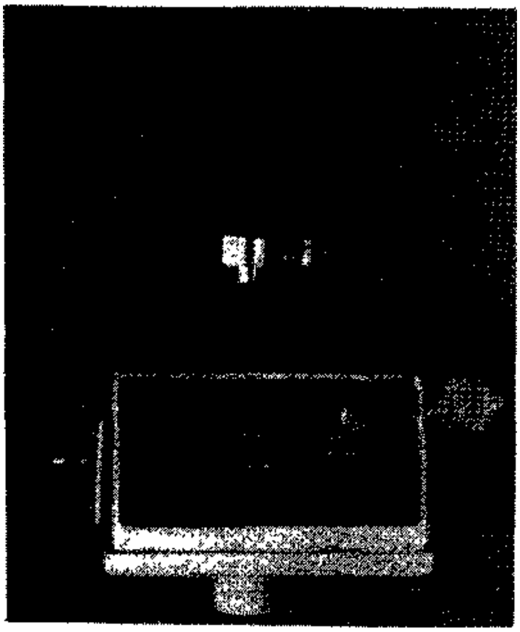


Figure 3. A Status Methane Unit and Sensor.

The sensing head of the CH4/03 contains a pair of pellistors housed behind a pair of sintered metal filters between which is sandwiched an active carbon cloth filter. A filter is used as protection against substances which may poison the pellistors. Gas is allowed to reach the pellistor by natural diffusion. Electrical current flows through the catalytic elements (pellistors) which are arranged into a Wheatstone bridge. The methane present in the sensing chamber is oxidised and the heat from this reaction increases the temperature of the catalytic elements resulting in a change of their electrical resistance. One of the pellistors is an active catalytic detector whilst the other is non-active and provides temperature compensationr The methane concentration is **proportional to the change** in resistance and in the case of the CH4/03 is linear over the 0 - 3% measurement range. This type of sensing head is only suitable for methane concentrations of less than 5% in air although heads to measure concentrations from 0 - 100% are available. At concentrations in excess of 5% methane, oxygen content can be decreased which may result in an incorrect reading. If the oxygen content is below 12%, perhaps due to very high levels of methane or another gas such as carbon dioxide, a false low reading will be obtained. Response time of the sensor head is approximately 10 seconds to reach 90% of a final reading. A dummy head is available to check the regulator unit output voltages, the calibrated offset zero and a zero to greater than full-range variable signal-voltage.

In circumstances where the methane concentration is likely to exceed 5% sensors employ a method based on the principle of thermal conductivity. Two thermal conductivity sensors are incorporated into the sensing head and arranged as a Wheatstone bridge. One is kept as a reference and is sealed in air while the other, the active sensor, is exposed to the air/methane mixture. Current is passed through both sensors and if methane is present the active sensor cools down. The cooling-effect depends on the concentration of methane and causes the current flowing through the active sensor to drop resulting in an imbalance in the bridge from which the methane concentration can be determined.

Problems were experienced with early versions of methane sensing heads in the late 1960's and early 1970's when it was found that sensor reliability deteriorated if they were subjected to methane concentrations >0.8% and high relative humidities for long periods of time (National Coal Board, 1983). This situation was resolved by the introduction of more robust pellistors. Methane concentration values are very often characterized by rapid fluctuations in level. This can be a problem due to the inertia of the sensing head which can have a profound effect on the accuracy of readings if the time interval between observations is small and the methane level is fluctuating rapidly. Research work (Krzystolik & Swiergrt, 198S) has identified factors that influence a sensing heads response time. These can be classified as external influences such as the ventilation ram effect whereby the response time is reduced due to ventilation pressure and correct siting of the sensing head, and internal influences such as the construction of the sensing head.

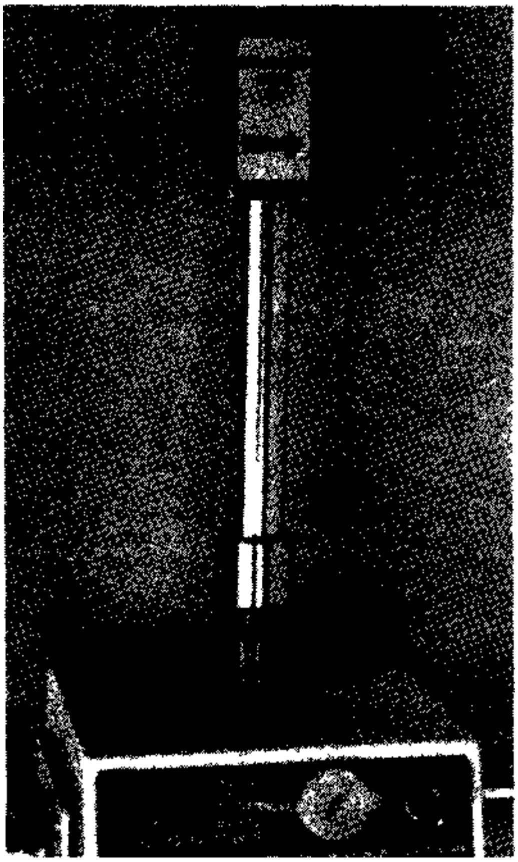


Figure 4. A Status Air Velocity Instrument.

5.2 Air Velocity

A typical air velocity sensor is the Status type AV/02/030 velocity monitor, shown in Figure 4. Similar to the CH4/03 it is comprised of a regulator/display unit and a detatchable sensing head. The monitor can measure velocity in a number of ranges from 0.5 to 30 m/s at an accuracy of ±10%. The sensing head operates on the vortex shedding principle and requires no moving parts. The vortex shedding principle is where air flowing past an obstruction results in the creation of vortices in a region downstream of the obstruction. The vortex frequency is proportional to air speed and by measuring this frequency it is possible to produce an electrical output signal that is proportional to air velocity. It is advantageous to use this type of sensing head rather than an anemometer type sensing head where damage to the vanes by dust or tampering can alter the velocity value. The sensor has been specially designed to cope with out of alignment variations and yaw angles of up to ±15° from normal do not adversely affect the velocity measurement. The control unit has a switched powered output tor an externally intrinsically safe flameproof relay so that power can be cut-off if the measured air velocity falls below a pre-set level.

6. PORTABLE INSTRUMENTS

The simplest and that which gives only a limited indication of environmental conditions is the use of portable detection instruments. These' range from the flame safety lamp which can be used to provide an indication of the presence of methane or lack of oxygen to portable hand held detectors for a range of gases. The latest electronic instruments feature integrated capabilities that replace the flame safety lamp, spot-reading methanometers, aspirated chemical tubes, portable oxygen meters and the canary (for carbon monoxide testing) by a single unit.

6.1 The SSC Portable Gas Detector

The Status Scientific Controls portable gas detector (Figure 5), known as the Mentor, is a state of the art instrument offering a host of features. It is a small compact unit that has been specially designed for underground use and is certified for all UK mining applications.

The unit can be fitted with up to 3 sensors in any combination of toxic, oxygen and flammable. It can be calibrated on site using a dedicated automatic calibration unit that also gives a information relating to the performance of the sensors and whether they need' replacing. Automatic calibration can be performed in 8 minutes and so each instrument can be kept in top condition. A further feature is the units data logging capability. Depending on the frequency of each logged reading the unit can store up to 16 hours worth of data from 3 sensors. This data can be downloaded to a PC (Figure 6). This facility has been used by the authors to monitor methane emission patterns along long wall coal faces and is mus a valuable research aid.

These instruments are now gaining popularity in the telecommunications industry, sewer maintenance and petro-chemical industries.

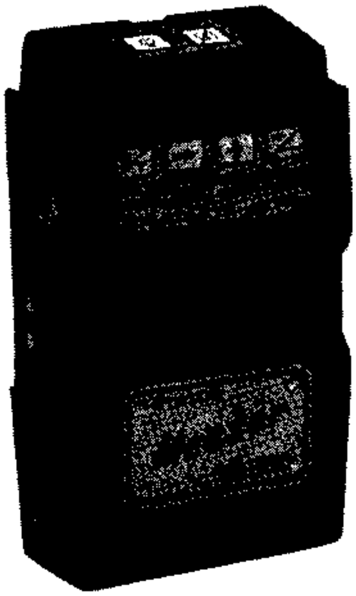


Figure 5. The Status Portable Gas Detect«-.

7. FACTORS INFLUENCING THE SITING OF MONITORS

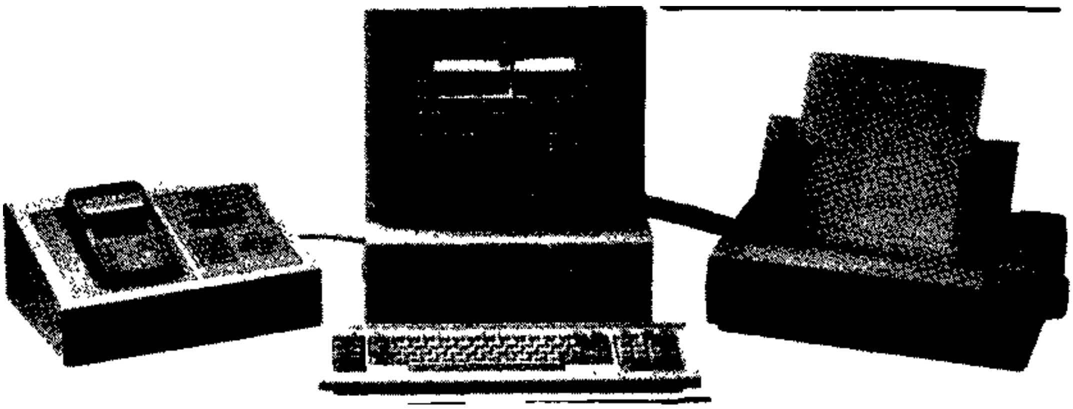
It is to be expected that the positioning of the sensing heads of monitors is an important criteria in achieving representative data.

Recommendations by the US Bureau of Mines advise that the methane sensing head be placed at least 30cm from the roof and well away from the ribside (Welsh et al, 1987). This is because methane is lighter than air and the highest concentrations are likely to be found near the roof. When measuring air velocity the best place is the geometric centre of the airway cross-section. The sensing head should also be placed in an area free of obstructions both upstream and downstream.

For example, consider the placing of an air velocity sensor in the middle to top right-hand corner of a roadway. The value of velocity measured in this part of the roadway is only a point value and would not be the truest possible. In fact the sensor is in the worst position for accurate measurement of velocity. In the area close to the rib or roof large changes in the true airflow may not be apparent in the values measured by the sensing head placed in a low-flow boundary layer. Ideally it should be placed close to the middle of the roadway but usually this is not possible. A method to overcome this difficulty is to assume that a constant relationship exists between the velocity measured by fixed sensing head and the average velocity at that airway cross-section (Fisher & Cohen, 198S). If this is assumed then the velocity measured by the sensing head can be related to the true average velocity at the specific cross-section by a constant. This constant changes with velocity level. Periodically the vortex-shedding head of the air velocity monitor was cleaned with a small brush to remove dust and dirt.

8. ERRORS DUE TO DATA TRANSMISSION

Once the instruments have sent their signal to an outstation this then sends the data to the surface. Errors in data transmission can be caused by interference from electromagnetic noise. This can be



Fifui»6. Downloading Data from the Portable Gas Detector to the PC and Printer.

a problem in mining but can be minimized by careful cable shielding and the use of a system whereby once the colliery control computer receives a signal it asks the transmitting device to verify the signal. Most colliery data transmission systems subject incoming signals to a number of tests to decide whether it is valid data. However, it was found that most errors were caused not by the data transmission system but by the colliery information system computer. It may have been that actual values for a monitored parameter were erroneous, i.e. if methane concentration of 1.01% was observed but the control computer reported it as 1.11% and this sort of error cannot be detected without signal verification. This type of error occurs because the data contains transmission noise that can be miss-read as a different value on de-multiplexing. Tests carried out by MRDE at Bedlay Colliery to investigate data inaccuracies of the mines environmental management system identified two main sources of error (National Coal Board, 1983). The first was due to the fluctuating behaviour of some monitored parameters such as methane concentration and air velocity where additional signal noise could be enough to produce erroneous values. The second was caused by electrical noise and this was identified as the most significant problem. This problem was resolved by better earthing and cable shielding. Ultimately, for the purpose of data analysis, errors associated with data security during transmission are ignored unless it is obvious that a reading is vastly different to its preceding and succeeding values.

In most mines, the monitors send their information or signal to an outstation which waits for instructions from the control room computer to send data. The actual data transmission is usually by time division multiplexing. The outstation receives a signal from a monitor continuously but does not send a mean value, for the time interval that has passed since the last transmission. This means that the transmitted data are actually spot values. This is no real problem so long as the level of the monitored parameter has been fairly constant over the time interval between the data transmission. If a parameter is known to be fluctuating then it would be better to use instruments that transmitted a mean value to smooth the fluctuations. For example (Dixon, 1992), methane concentration and air velocity often show marked fluctuations in value and there was no way of knowing how much variation in value occurred during the monitoring time interval. This is not ideal and unfortunately is a difficult problem to resolve.

9. CONCLUSION

This paper has briefly reviewed some typical equipment for use in underground environmental monitoring systems. A mine is dependent on its ability to monitor the underground environment and without the use of modern equipment safety cannot be guaranteed and lives are put at risk. There is a large range of both fixed and portable equipment available for what is a relatively small cost when compared to the overall budget of a mine. This is a low price to pay for safety and knowledge of the state of the underground environment.

10. ACKNOWLEDGEMENTS

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