MICROSEISMIC MONITORING FOR GAS OUTBURSTS AT LEICHHARDT COLLIERY

By

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ABSTRACT

A program of microseismic noise monitoring for gas outbursts, in conjunction with other mining engineering measurements and observations, is being undertaken at Leichhardt colliery in Queensland. Headings are developed at present by shotfiring.

The equipment being used in this study includes piezoelectric accelerometer assemblies to detect microseismic noise which is then transmitted to a surface base station by cable. Data are recorded on an analogue magnetic tape recorder and are also analysed on-line using a commercially-available acoustic emission pulse analyser. It is proposed to re-interpret recorded data using various modes of analysis and to interface a desktop computer to the existing system to permit continuous monitoring on the mine site.

No outbursts have been recorded or analysed and only a limited number of development shots, and the resultant microseismic activity, have been recorded to date.

INTRODUCTION

Fracturing phenomena in coal and rock strata associated with stress re-distribution during underground coal mining generate acoustic emissions or microseisms (Blake et al.1974). These acoustic emissions comprise compressional and shear-type wave components and these waves may be detected by embedding suitable sensors within the coal seam (Blake et al. 1974). Analysis of microseismic data thereby facilitates real-time monitoring of this stress re-distribution and hopefully can be used to forewarn of stress concentrations leading to unexpected and violent releases of energy or 'bursts'.

Acoustic emission (AE) techniques have been used to evaluate the stability of underground mining operations and to predict the occurrence of violent underground disturbances such as rock and coal bursts for many decades (Hardy, 1975; Howarth, 1977). Several accounts of AE techniques applied to microseismic monitoring of underground coal mines for roof fall and gas outburst prevention may be found in recent publications (Hardy and Leighton, 1977, 1980). The United States Bureau of Mines (USBM) and Pennsylvania State University were principally responsible for much of the development work in these areas in recent years (Blake et al., 1974; Hardy, 1975).

In Australia microseismic monitoring studies in coal mines have been carried out since 1977 by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Division of Applied Geomechanics (McKavannagh et al., 1978; McKavannagh and Enever, 1980). CSIRO efforts have concentrated on West Cliff colliery in New South Wales (NSW) (McKavannagh et al., 1978; McKavannagh and Enever, 1980), with some additional work having been done in Collinsville in Queensland (McKavannagh, personal communication).

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The Broken Hill Proprietary Co. Ltd. (BHP) owns many underground coal mines, of which two, Metropolitan colliery in NSW and Leichhardt colliery in Queensland, have had a continuing history of gas outbursting problems. In 1979, a three year programme was initiated to establish immediate warning systems for gas outbursts at both Metropolitan and Leichhardt collieries. This programme is being principally funded by an Australian government National Energy Research, Development and Demonstration Council (NERDDC) grant and is being executed by BHP's Central Research Laboratories (CRL) and Rock Mechanics and Strata Control Laboratories (RMSC).

MICROSEISMIC MONITORING SYSTEM

SYSTEM DESCRIPTION

The microseismic monitoring system used in this study is shown schematically in fig. 1.

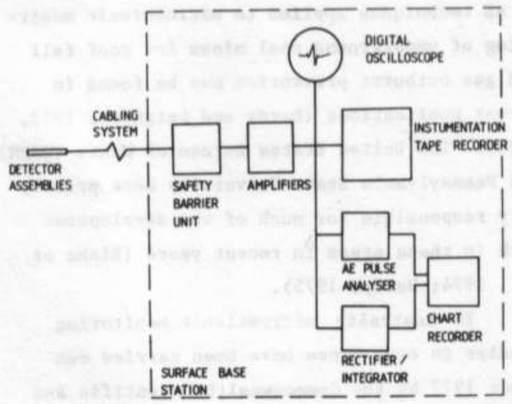

Fig. 1 - Microseismic monitoring system used at Leichhardt colliery.

The detector assemblies comprised two-metre PVC tubes of 42 and 75 mm external diameter with machined perspex ends. The smaller diameter tubes housed a single uniaxial accelerometer, stud-mounted to one of the perspex ends. A 40 dB fixed gain preamplifier was housed in the opposite end of the tubes. The larger diameter tubes contained a screw-mounted triaxial accelerometer at one end with three 40 dB fixed gain preamplifiers in the opposite end. The bandwidths of the accelerometers are specified as 0.2 Hz - 10.6 kHz and 1 Hz - 12 kHz (+ 10% limits) for the uniaxial and triaxial accelerometers respectively.

The detector tubes were grouted into 1.9 m diamond-finished horizontal holes of 43 and 76 mm diameter located normal to the rib in the mid-rib position. 'Plastibond', a two part polyester resin filler was used as the grouting medium. The minimum distance between working face and detector used to date has been five metres, with a maximum distance of 35 m. Both accelerometers and preamplifiers are recoverable.

Microseismic signals were transmitted to the surface base station through a six pair screened cable. A safety barrier interface unit, to isolate voltage and current surges from the hazardous area underground, was located in the base station. Adjustable gain amplifiers followed the safety barrier interface unit and allowed control of the signal level prior to recording on the instrumentation tape recorder. A recording speed of 38 cm/s was used and bandwidth limitations on the tape recorder at this speed are specified as DC - 5 kHz (±1 dB) in the frequency modulation (FM) mode and 500 Hz - 64 kHz (±3 dB) in the direct recording (DR) mode.

Signals were viewed on a digital oscilloscope.

Analysis of the microseismic signals was performed with a Bruel and Kjaer type 4429 AE pulse analyser. Only one channel could be analysed at a time in this manner using either of the two analysis modes available. Following the acquisition of a desktop computer which can be interfaced to the analyser, it will be possible to simultaneously monitor up to four channels.

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The analyser provides for three modes of analysis for AE signals - 'weight' mode, '4-channel' mode and 'locate' mode. The latter mode enables the source of AE activity to be determined using several (up to 4) detectors. The 'weight' and '4-channel' modes are used to analyse AE signals from individual detectors. Only one detector may be analysed using the 'weight' mode, whilst the '4-channel' mode allows for the simultaneous analysis of up to 4 detector inputs.

In the 'weight' mode of analysis, the AE signal from a single detector is analysed using all four channels of the analyser. The time during which the signal level exceeds four preset trigger levels having an amplitude relationship 1, 2, 4 and 8 is measured and, in effect, multiplied (weighted) by the amplitude difference between these levels. This results in a measured value which bears close proportionality to the area under the level versus time curve of the AE signal, as shown in fig. 2.

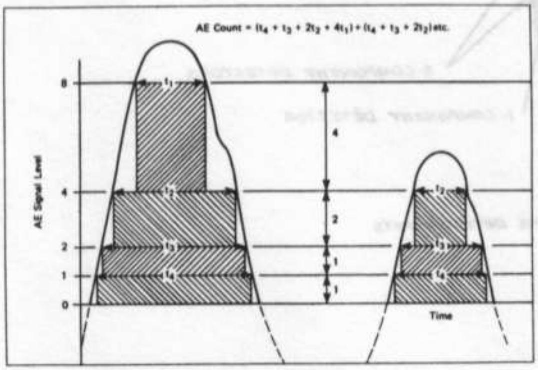

Fig. 2 - Measurement of the approximate area under the AE curve.

The '4-channel' mode of analysis, on the other hand, makes an approximate AE count which is similar to the traditional "ring-down count" method.

Whereas the "ring-down count" method registers a count of 1 each time a preset threshold level is exceeded, the '4-channel' mode registers the time (in μs) during which the AE signal level exceeds a common trigger level in each channel. With reference to fig. 2, the AE count obtained from the '4-channel' mode would be t_4. Clearly, the '4-channel' mode of analysis cannot closely approximate the area under the AE level versus time curve and therefore is not an energy-dependent measure of AE activity.

The output of the analyser was displayed as a DC voltage proportional to count rate on a chart recorder. An analysis interval of one second was used.

Also included in the system was a CRL-designed rectifier/integrator unit which could be adjusted to respond with a single sharp pulse for each microseismic event. The output of the rectifier/integrator unit was fed into the second channel of the chart recorder, thereby providing a visual cross-check of the level of microseismic activity. Some manual estimates of event rate were made from high-speed chart recordings. It is intended to re-process all recorded data using automated event counting.

SYSTEM PERFORMANCE

The main cable was installed in the downcast shaft at Leichhardt colliery and led inbye as shown in fig. 3. Uniaxial and triaxial detector assemblies were installed in the southern development headings as indicated. The midrib position in this area of the mine corresponded to approximately 25% of the seam height (six metre seam thickness). The depth of rib spall in the detector locations was estimated to be less than one metre.

Heading development at Leichhardt colliery was by shotfiring. Recordings were made up to 25 minutes following each full-face shotfiring. Only five shots and the following microseismic activity have so far been recorded. No outbursts or roof falls were observed during these recordings.

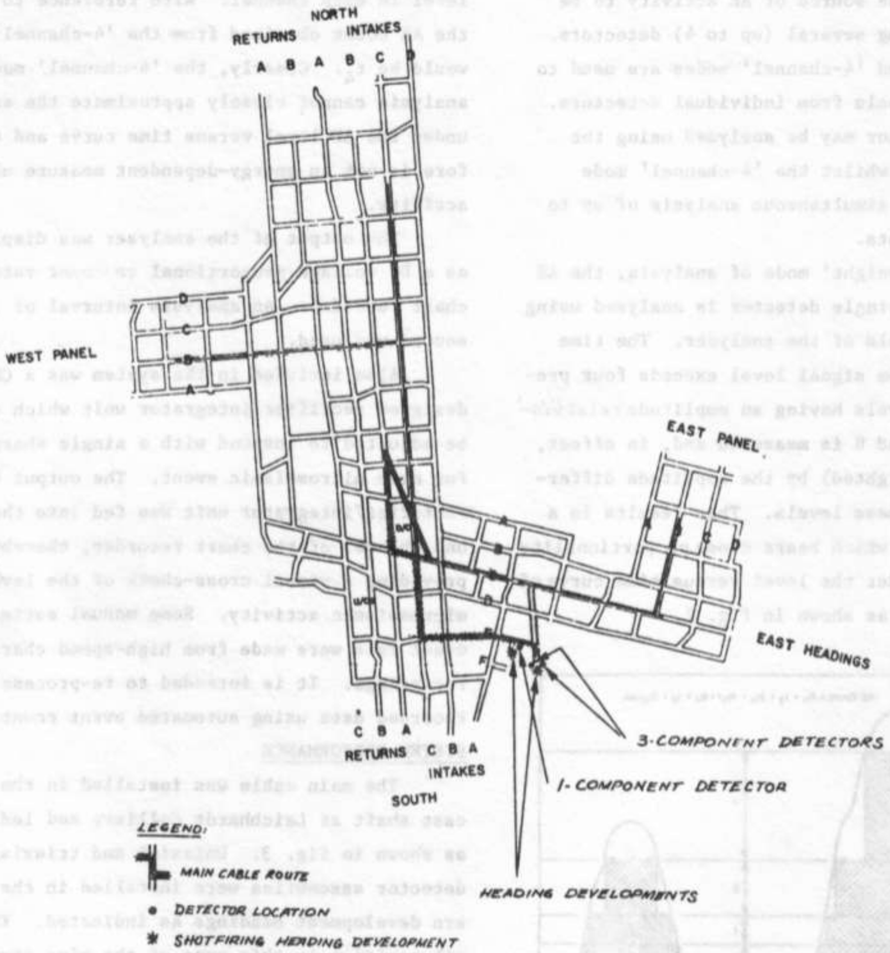

Fig. 3 - Microseismic monitoring test sites at Leichhardt colliery - January/April 1980.

An exhaustive analysis of these and other supporting data has not yet been performed.

However, fig. 4 shows typical examples of the type of analyses performed on these data.

In the example shown, sustained microseismic activity was observed for more than 20 minutes following shotfiring. Microseismic event rates were estimated to drop from 16 to 4 events per second during the first four minutes following shotfiring. An increase in event rate to 10 events per second was then observed, followed by a reduction in event rate to approximately one event per second. Ten minutes after shotfiring, a further increase in event rate to approximately four per second was observed. This was again followed after approximately one and a half minutes by a reduction in event rate to less than one per second. The significance of these observations cannot be determined.

It is, however, useful to note that, although the rectifier/integrator transcription of fig. 4 appears to indicate significant microseismic activity for considerable periods following the blast, the output of the AE pulse analyser indicates otherwise. Most of the sustained microseismic activity in this example was confined to the periods 0 - 5 minutes and 10 - 12 minutes after shotfiring. The other large number of apparent microseismic events were either insufficiently energetic or too infrequent to generate significant count rate results during the intervening periods. This may be attributable to small, highly localized events.

The ability to "resolve detail" in microseismic events may be improved by using the "weight" mode rather than the "4-channel" mode of analysis available on the AE pulse analyser. As previously discussed, the "weight" mode of analysis is more affected by AE pulse energy content than the "4-channel" mode and therefore may prove useful in identifying the nature and origin of microseismic events.

IMPLICATIONS

Any AE analysis system employed for microseismic monitoring for gas outbursts has as its most important requirement the ability to indicate an "alarm" condition as quickly and reliably as possible, irrespective of the nature of the AE analyses performed. The mechanisms of gas outbursts in underground coal mines have not yet been satisfactorily explained, but recent work by Brady (1977) suggests that these phenomena may be highly dynamic and be associated with short precursor times. If this proves to be the case, it would be clearly desirable to have an AE analysis system which operated on as short an analysis interval as practicable. Indeed, the converse would be undesirable for two reasons. Firstly, a long delay would result before an alarm condition could be indicated. Secondly, the nature of the phenomena which gave rise to the alarm condition may not be discernible from the results of the AE analysis. For example, cultural noises, such as continuous mining, roof bolting and drilling will interfere with AE analyses of microseismic data. The conventional approach to microseismic monitoring has been to filter out these cultural noises prior to performing AE analyses (Blake et al., 1974; McKavannagh et al., 1978). With the long (five minute) analysis intervals employed by McKavannagh et al., (1978), this has been unavoidable. This approach, however, can result in the loss of useful data and may be avoidable if short analysis intervals can be realized.

With the microseismic monitoring system described in this work, it is possible to indicate an alarm condition (corresponding to an AE count rate in excess of any arbitrary threshhold) within one second. Further, it is possible to continue AE analysis of microseismic data on a one second analysis interval, thereby refreshing the alarm condition if warranted. The choice of alarm threshhold would naturally have to be made after a period of continued and extensive microseismic monitoring, preferably including periods of outbursting, roof falls or other instability.

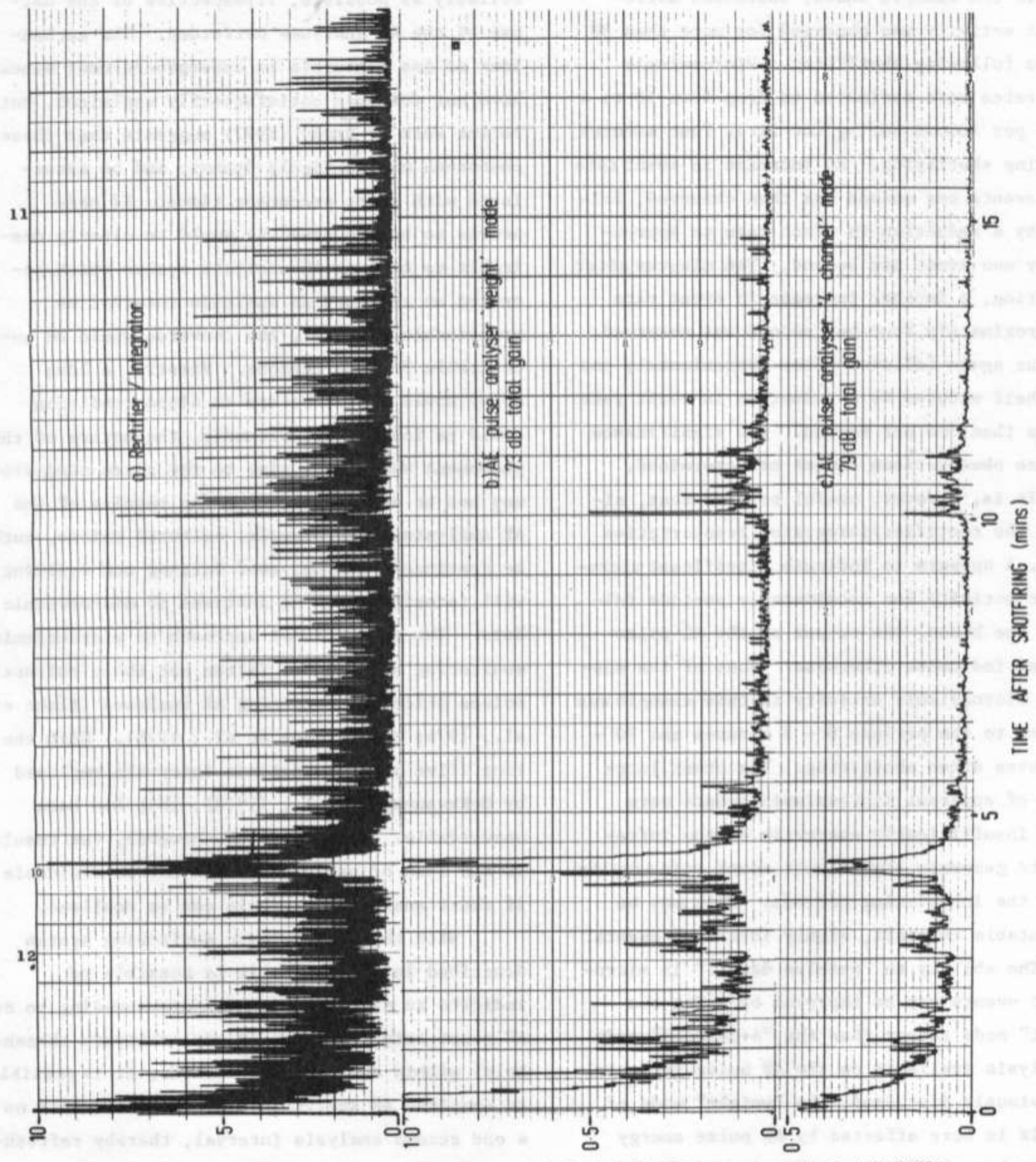

Fig. 4 - Typical results. Uniaxial detector 5m from face. Shot fired 15.2.80. Direct recording.

The practical implications of a one second analysis interval are considerable. The proof of the worth of such a system can, however, only come after rigorous and extensive evaluation under operating conditions. These operating conditions should embrace heading development in virgin areas, rather than possibly destressed longstanding pillars (as used to date in this work), the use of continuous mining units (rather than shotfiring development) and the operation of other forms of mining machinery (borers, shuttle cars etc). It is envisaged that, during the currency of this study, all of the above operating parameters will be considered.

CONCLUSIONS

A microseismic monitoring system comprising proprietary electronic components has been assembled, approved and is undergoing field trials at Leichhardt colliery. It is intended to duplicate this system to carry out similar work at Metropolitan colliery in NSW.

No recordings of mining in virgin areas, or of outbursts or roof-falls, or of continuous mining operations have yet been taken. All recorded data obtained to date relate to shotfiring heading development in or adjacent to longstanding (and therefore possibly destressed) pillars. An exhaustive analysis of these data and other supporting data has not yet been performed .

The features of the system include:

1. recoverable detector assemblies.
2. a one second analysis interval (other analysis intervals may be selected).
3. two selectable AE analysis modes.
4. the possibility of providing improved discrimination of microseismic events through the use of an energy-dependent mode of analysis.
5. relative ease of installation, testing and operation. With a brief period of familiarization, it should be possible to train mine personnel in the effective manual operation of the system as required. Operation of the full system would include the periodic movement of detectors to keep pace with the progress of mining.
6. the possibility of interfacing the analysis unit to a small computer to permit continuous surveillance and report preparation. This avenue will be explored during the currency of the present NERDDC grant application.

The preamplifiers and accelerometers are recoverable, although, due to their high cost, considerable efforts should be made to manufacture cheaper detector assemblies embodying adequate bandwidth and other specifications. Such ongoing development work is planned to be part of the present NERDDC-supported study.

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