

Determination of optimal longwall face methane monitoring locations

A.B. Cecala, J.A. Zimmer and E.D. Thimons

Abstract — *The US Bureau of Mines performed a study to determine optimal locations for longwall face methane monitoring equipment. Longwall face ignitions continue to be a concern to the US coal mining industry. Gains in ignition control technology have been somewhat negated by advances in longwall productivity. More reliable, heavy duty longwall face systems generate higher production rates and increase methane liberation rates. These rates will likely continue to rise as further coal production increases occur. Efforts will continue in the areas of methane drainage, methane containment and methane dilution. In addition, more effective face methane monitoring is needed. As technology continues toward automated longwall panels, the importance of monitoring for methane at the shearer becomes even more significant. Since the primary face ignition source is the shearer mining machine, the Bureau ran tests to determine the best location to take methane readings on the shearer. This information, in conjunction with data obtained from field studies, provides a knowledge base for selecting optimum face methane monitoring locations.*

Introduction

Face ignitions are a concern for many US longwall mines and will continue to be until better control technology can be developed or until reliable and accurate knowledge can be provided as to when an explosive concentration is present. Figure 1 shows the number of reported US underground longwall ignitions from 1980 to 1990. The number of longwall panels have remained relatively constant over this time period with 89 reported in 1980, compared to 96 in 1990.

In spite of technological improvements in mining over the past decade, no significant reduction in the number of longwall face ignitions has occurred. One factor contributing to this is that the US coal industry is mining gassier seams, causing methane liberation rates on the average to be higher (Trevits, 1991; Grau, 1987).

Another factor is the development and implementation of more reliable, heavy duty longwall face systems that are generating higher production rates and higher methane liberation rates. Additionally, the average panel width in 1991 was 217 m (714 ft), a 44% increase from 1980 when faces averaged a width of 151 m (495 ft) (Merritt, 1992). Increases in panel width also impact total face methane emissions.

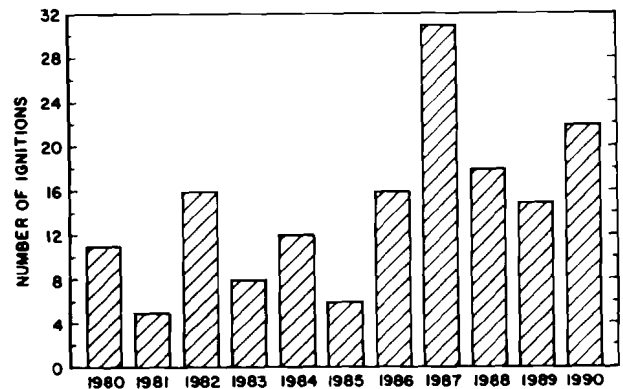


Fig. 1 — Frictional ignitions on longwalls from 1980–1990.

Substantial advances in control technology have been made in methane drainage, methane containment and methane dilution. In some mines, efforts to drain methane in advance of mining have proven effective, but geological conditions often preclude this approach (McCall, 1984; Ely, 1989). In other cases, ventilation air quantities of more than 47 m³/sec (100,000 cfm) and face velocities of more than 5 m/sec (1000 fpm) have been implemented on longwall panels.

Other operations have implemented anti-ignition spray systems that use water sprays behind each cutting bit to quench the hot streaks created from cutting noncoal materials (Courtney, 1990). Other control techniques, such as the modified shearer clearer system and ventilated drum, have been used to increase the amount of turbulence and ventilation around the cutting drums, thus reducing methane levels (Cecala, 1986; Divers, 1987).

The Bureau of Mines was involved in a coordinated effort with a western coal operation to reduce ignitions on its

A.B. Cecala, J.A. Zimmer and E.D. Thimons are mining engineer, physical science technician and supervisory physical scientist, respectively, with the US Bureau of Mines, Pittsburgh Research Center, Pittsburgh, PA. SME Preprint 93-14, SME Annual Meeting, Feb. 15-18, 1993, Reno, NV. Manuscript Feb. 22, 1993. Discussion of this peer-reviewed and approved paper is invited and must be submitted, in duplicate, prior to May 31, 1994.

longwall section through the implementation of several control technologies (Cecala, 1988). This effort consisted of:

- installing anti-ignition sprays on both cutting drums,
- reducing drum speeds from 33 to 22.5 rpm,
- using a modified shearer clearer system,
- increasing the face velocity by 15 m/min (50 fpm),
- decreasing cutting depth from 813 to 406 mm (32 to 16 in.) and
- slowing the tram speed during gate road cutouts.

This work was successful in reducing the number of ignitions from 16 to just two over a similar four-month period. The development and implementation of new engineering control techniques should continue to be pursued in an effort to reduce methane ignitions. However, until techniques are developed that are 100% effective, it is important to effectively monitor for methane.

Methane concentrations and response times are two factors to consider when deciding where methane monitoring equipment should be located on longwall faces. Methane sources need to be considered when evaluating these two factors. There are a number of sources of methane contamination:

- methane liberated by the shearer during mining,
- methane emission from face bleeding, roof and floor strata or other coal seams,
- methane already present in the ventilation airflow when entering the longwall panel and
- methane flowing into the face from the gob area.

It has been the Bureau's experience that in most mines the bulk of the methane on the face comes from the cutting of coal by the shearer.

In addition, the shearer is the primary ignition source on most longwall sections. The tailgate monitor may not effectively or rapidly warn of a potentially high concentration at the shearer. A study performed by the Bureau a few years ago examined methane patterns on various longwall faces (Cecala, 1985). Figure 2 shows the methane concentration recorded by a machine-mounted monitor during one particular tail-to-head pass. During the headgate cutout, methane concentrations approached 2.5% on the body of the machine. At no time during this particular pass did the tailgate walkway monitor record a concentration more than 1%. Additionally, the delay in response time of a tailgate monitor is a consideration. This longwall panel was 158 m (520 ft) wide with an average face air velocity of 4 m/sec (810 fpm). It would take about 39 seconds for the methane gas liberated during the headgate cutout to reach the tailgate walkway monitor. Such a lengthy response time would have minimal impact on reducing the possibility of a shearer generated ignition.

Full-scale longwall test procedures

Testing was performed at the full-scale longwall test gallery at the Bureau's Pittsburgh Research Center. A Joy 1 LS shearer mining machine was used for testing and was positioned near the center of a 1.8-m (6-ft) high face that was about 20 m (65 ft) long.* A wooden frame structure covered with plastic was fabricated to simulate the working face area. All testing was performed to simulate a tail-to-head cut sequence.

For this cut sequence, the headside drum was raised and cutting the top of the coal seam. The tailside drum was

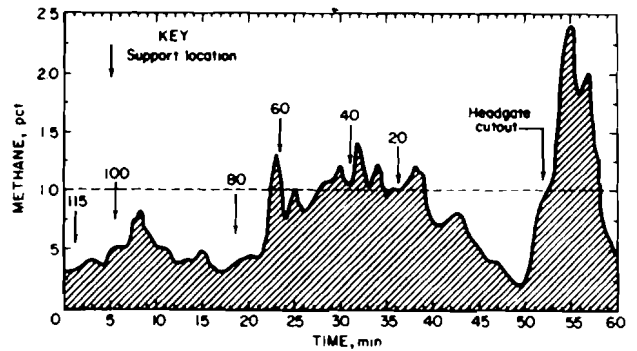


Fig. 2 — Methane levels on shearer during tail-to-head pass.

lowered and cutting the bottom as well as loading coal into the panline. For this laboratory testing, the shearer remained in a stationary location so that there was no actual mining of the seam.

Before each day of testing, all instruments were calibrated. This included a hydrocarbon analyzer and two continuous recording methane monitors. A fan was used to ventilate the test chamber. This fan provided an airflow along the face of about 6.6 m³/sec (14,000 cfm) at a velocity of roughly 1.3 m/sec (250 fpm). A continuous recording vane anemometer was located in the test chamber to assure that face velocities were consistent for all tests.

Figure 3 shows the layout of the test chamber. It indicates the dimensions of the chamber and locations of the vane anemometer and two continuous recording methane monitors. Figure 3 also indicates the 14 gas sampling locations on the shearer mining machine. Sample locations 1 through 10 were spaced on 0.6-m (2-ft) intervals. Two gas sampling locations, 11 and 12, not located on the shearer are also indicated.

For each test, after all instruments were on and stabilized, a continuous 7.5 L/min (0.26 cfm) volume of 93% methane in air gas mixture was released at 207 kPa (30 psi). This volume was regulated by a float controlled flowmeter connected in series with a digital mass flowmeter to assure a consistent and accurate release. This gas was simultaneously released at eight points in a simulated sump coal block to represent the release of methane underground as the headside drum cuts the coal.

Two test series were performed. Test series No. 1 determined the variation of gas levels along the face side of the shearer at sample locations 1 through 10 on top of the shearer body. In addition, these tests also determined the effects of turbulence caused by watersprays on the headside drum. Pencil point water sprays were used on the headside drum operating with the pick point flushing design. These sprays, operating at a pressure of 758 kPa (110 psi), delivered about 60 L/min (16 gpm) of water.

Test series No. 2 determined gas gradients over the shearer as well as how the gas cloud dispersed as it traveled downstream. Sample locations used for this test series were: 4, 4A, 6, 6A, 8, 8A, 10, 10A, 11 and 12. Sample locations, designated with an A, were located 760 mm (30 in.) further from the face than the other sample locations. Water sprays were always used during this second test series.

For all tests, the order of sampling the various locations was randomized using a computer generated sequence. An 8 L/min (0.28 cfm) air sample from each location was drawn through 8 m (26

* Reference to specific manufacturers is for information only and does not imply endorsement by the Bureau of Mines.

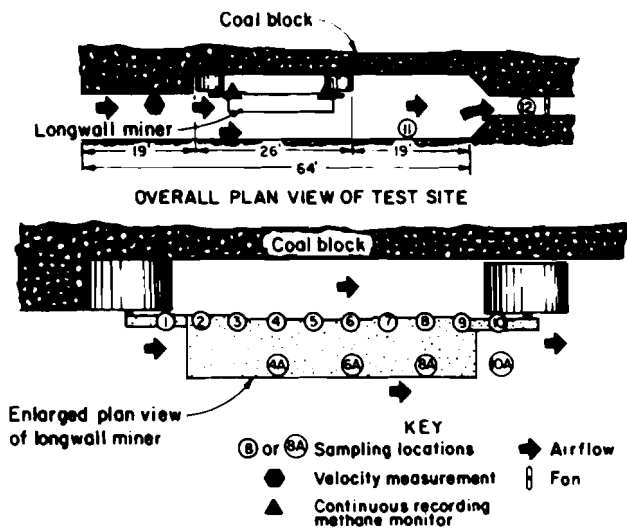


Fig. 3 — Laboratory test chamber.

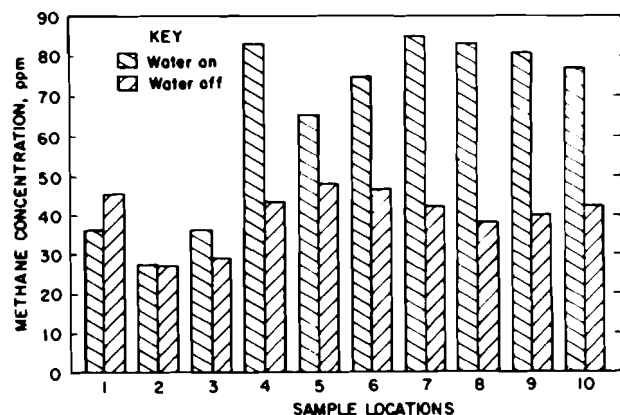


Fig. 4 — Methane levels at top face-side of machine with and without water sprays.

ft) of 9.5 mm (0.37 in.) semi-rigid tubing using four constant flow sampling pumps, (2 L/min or 0.07 cfm each). The same length of tubing was used from each sampling location to eliminate any tubing biases. There was a 1.9-second lag time for a sample to be drawn through this tubing. The sample traveled through a desiccant chamber to remove any moisture that would negatively bias the hydrocarbon analyzer. A portion of this sample was then drawn into a Meloy Laboratories HC500-2C Hydrocarbon Analyzer using 3-mm (0.12-in.) capillary tubing. Each location was monitored for a five-minute time period. After that, the gas was turned off and the test chamber was allowed to clear of gas for two minutes before the next sample location was monitored.

Gas concentrations determined by the hydrocarbon analyzer were simultaneously recorded to a strip chart and solid state data logger. The strip chart recorder allowed test personnel to visually determine that everything was working properly. Vane anemometer air velocity measurements were also recorded on this chart. After all locations were sampled, the data logger was transferred to a computer for data storage and analysis. For each test series, the sampling sequence was repeated in a randomized order seven times to provide for a statistically sound data base. After all test series were completed, the data was then analyzed using commercially available data manipulation and statistical software packages.

Laboratory results

Table 1 shows the results of both test series performed at the longwall test gallery. Each value is the average of seven different runs for each of the sampling locations.

There were several significant findings from these tests. The first test series showed that water sprays created a substantial amount of turbulence and yielded higher concentrations of methane at the gas sampling locations on the top face side of the shearer machine than when no sprays were used. Figure 4 shows the comparison of methane levels at the top face-side monitoring locations (1-10), with sprays both on and off. The turbulence created by the water sprays, which are typically used on the shearer, caused higher levels of methane at the body of the machine as the gas cloud was mixed

and was not allowed to remain against the face. With water sprays, sample location No. 4 was the first location where gas concentrations seemed to reach near peak levels on the top of the shearer body. This location was about 1.8 m (6 ft) downstream from the headside cowl. Methane levels along the top face side of the shearer seemed to remain relatively constant from this location (No. 4) to the end of the shearer body (No. 10).

In cases where there is a substantial build-up of coal along the face side of the shearer to the extent that a top face-side methane monitor sensor head could become buried in coal, another location would have to be considered for a shearer mounted monitor. Test series No. 2 (Table 1) evaluated alternative sensor locations on the machine that are less likely to be buried or damaged. These findings indicate that location No. 10A is probably the best alternative for a shearer mounted monitor. The No. 10A sample location was near the gob-side tail end of the shearer machine. The gas concentration at this location was about 50% of the concentration at sample location No. 4.

Also of interest were the gas concentrations at sample locations No. 11 and No. 12. Location No. 11 was located 2.7 m (9 ft) from the end of the tailside drum and 2.6 m (8.5 ft) from the coal face. This location simulates a methane monitor in the walkway of a longwall face just downwind of the shearer. Location No. 11 averaged 9 ppm during testing, which was 89% lower than at location No. 4.

Location No. 12 was about 7 m (23 ft) from the end of the tailside drum and in the 760 mm (30 in.) exhaust tubing. This gas

Table 1 — Results of laboratory testing

Location	Test No. 1, CH ₄ concentrations				Test No. 2, CH ₄ concentrations		
	Water on		Water off		Location	ppm	SD
	ppm	SD	ppm	SD			
1	36.5	11.3	45.5	14.2	4	77.7	31.4
2	27.5	9.3	27.1	8.2	4A	12.6	4.4
3	36.2	9.6	29.0	7.6	6	60.1	16.2
4	82.9	25.2	43.5	10.8	6A	22.3	8.1
5	65.3	17.4	48.2	9.3	8	72.8	9.8
6	74.8	19.0	46.5	13.1	8A	26.8	7.5
7	84.7	10.6	42.0	7.0	10	70.8	5.7
8	82.9	13.0	38.0	7.3	10A	40.7	3.7
9	80.6	11.7	40.0	6.3	11	8.7	1.5
10	76.7	7.6	42.0	5.1	12	33.8	9.4

concentration was about 43% of the concentration at location No. 4. This was somewhat representative of a tailgate monitor reading since the gas was well mixed with the ventilating air due to the turbulence at the exhaust tubing inlet.

Discussion

The shearer is the primary ignition source on a longwall section and any improved methane monitoring system for longwall sections should consider monitors being placed on the machine. This could have a measurable impact on reducing the number of shearer-generated methane ignitions and would supplement other longwall methane control techniques. In addition, if the trend continues toward increasing panel widths, the difference between methane levels and response times at the shearer and those at the tailgate walkway monitor could increase on many faces.

The optimum location for a single monitor on the shearer, as determined from the laboratory study, would be on the top face side of the shearer body, at least 1.8 m (6 ft) down from the headside cowl. This provided representative concentrations on the machine as well as fast response times. Testing indicated that there is not one specific point at which to locate a monitor, but that once methane levels reach near peak levels on the top face side of the machine, they remain relatively the same to the end of the machine. The only drawback with a location along the face side of the shearer is that it may be more prone to be damaged or covered with coal or rock.

The best second choice for a monitor would be at a location at the gob-side tail end of the machine, similar to location No. 10A from the laboratory study. This location has a number of advantages. It is less likely to be damaged or covered with product. It is less likely to be contaminated by water sprays. It is easier to calibrate. The recorded methane levels were about 40% to 50% lower at this location than those at the face side monitoring locations, but it still offers the advantage of a rapid response time relative to the tailgate monitor. With any type of contaminant release from a point or area, such as the cutting area of the shearer drum, a concentration gradient will occur as the contaminant moves downstream from the release area. This was seen in this laboratory study. Gas concentrations along the front sampling locations (4, 6, 8 and 10) of the machine were consistently higher than those at the corresponding back locations (4A, 6A, 8A and 10A), even though they were only 760 mm (30 in.) apart. Using a linear regression analysis on these sample rows indicated that at about 5 m (16 ft) down from the end of the shearer, the gas cloud would have been dispersed to a degree that similar gas concentrations would have been measured at both locations.

Response time of different monitor locations is also an important consideration. Assuming a face velocity of 2 m/sec (400 fpm), there would be a 1.8-second increase in the response time from location No. 4 to location No. 10. Considering all other aspects as equal, it would be advantageous to locate the monitor near location No. 4 to minimize response time. However, this variation in response time on the shearer is minor when compared to the time it takes for methane liberated during cutting by the shearer to reach a tailgate walkway monitor. On a 152-m (500-ft) panel, it would take about 75 seconds for the gas liberated by the shearer during cutting near the headgate to reach a tailgate walkway monitor if the face velocity was 2 m/sec (400 fpm). Because of this, the effectiveness of a tailgate monitor to detect substantial methane liberations by the shearer is significantly reduced.

The results of the laboratory study also indicate that walkway monitors, even at locations closer to the shearer, would have limited ability to predict shearer generated ignitions. The walkway monitor in these tests produced methane readings significantly lower than the methane readings recorded by the shearer mounted monitors. Methane monitors located in the walkway can supplement a tailgate monitor in detecting overall high methane levels, but appear to be inadequate at detecting shearer methane levels.

The effectiveness of an automated shearer methane monitoring system depends on the capability of the system to accurately and quickly detect methane concentrations at the machine. A system that is similar to those used on continuous miners should be considered.

Conclusions

The intent of this research was to find an optimum position for longwall face methane monitors. Although there has been a considerable amount of research aimed at reducing methane levels on longwall sections over the past decade, the number of ignitions each year still remains substantial. Since most longwall ignitions are caused by the shearer, it seems logical to attempt to avoid these ignitions by detecting when a potentially explosive concentration is present at the machine. In addition, as longwall automation continues, determining methane levels at the shearer will even be more significant because there will not be men at this location to take methane readings with a handheld spotter.

The following are the authors' findings based on the results of the laboratory testing. The first choice for a machine-mounted monitor would be on the top face side of the shearer from at least 1.8 m (6 ft) down from the headside cowl to the end of the machine.

At those operations where coal and/or rock accumulations on the front part of the machine are a problem, a monitor location near the gob side tail area should be considered. This monitor location is less likely to be damaged by coal or rock, or negatively effected by water sprays. Walkway monitors do not appear to be very beneficial in quickly responding to high gas levels at the shearer. A methane monitoring system on the shearer should be viewed as a safeguard when engineering controls fail to keep gas levels at safe concentrations. ♦

References

- Cecala, A.B. and Jankowski, R.A., 1986, "How to lower methane concentrations around longwall shearers," *Proceedings*, Longwall USA, pp. 357-362.
- Cecala, A.B., Bruno, A.D. and Watson, R.W., 1988, "Controlling longwall face ignitions — a case study," *Proceedings*, Longwall USA, pp. 118-126.
- Cecala, A.B., Jankowski, R.A. and Kissell, F.N., 1985, "Determining face methane liberation patterns during longwall mining," US Bureau of Mines IC 9052, 9 pp.
- Code of Federal Regulations, 1981, Chapter 1, Title 30, Part 75.313 on Methane Accumulation in Face Areas.
- Courtney, W.G., 1990, "Frictional ignition with coal mining bits," US Bureau of Mines IC 9251, 25 pp.
- Divers, E.F., Jankowski, R.A. and Kelly, J., 1987, "Ventilation drum controls longwall dust and methane," *Proceedings*, 3rd Mine Ventilation Symposium, SME, Inc., Littleton, CO, pp. 85-90.
- Ely, K.W. and Bethard, R.C., 1989, "Controlling underground coal mine methane safety hazards through vertical and horizontal degasification operations," *Proceedings*, 4th US Mine Ventilation Symposium, SME, Inc., Littleton, CO, pp. 500-506.
- Grau, R.H., 1987, "An overview of methane liberations from US coal mines in the last 15 years," *Proceedings*, 3rd Mine Ventilation Symposium, SME, Inc., Littleton, CO, pp. 251-255.
- McCall, F.E., et al., 1984, "Cross-measure borehole technology for gob gas control," *Mining Engineering*, Vol. 36, No. 12, pp. 1672-1676.
- Merritt, P.C. 1992, "Longwalls having their ups and downs," *Coal*, pp. 26-35.
- Trevits, M.A., Finfinger, G.L. and LaScola, J.C., 1991, "Evaluation of US coal mine emissions," *Proceedings*, 5th Mine Ventilation Symposium, SME, Inc., Littleton, CO, pp. 177-182.