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A Method To Measure Gas Levels During Auger Mining of Coal

By Jon C. Volkwein and Alexander D. Prokop

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

With Factors for Conversion to U.S. Customary Units

Abbreviation	Unit of measure	To convert—	Multiply by—
cm	centimeter	inches	0.39
m	meter	feet	3.28
ppm	part per million		
pct	percent		

A METHOD TO MEASURE GAS LEVELS DURING AUGER MINING OF COAL

By Jon C. Volkwein[1] and Alexander D. Prokop[2]

ABSTRACT

The U.S. Bureau of Mines has developed a method to measure methane and other gases during the auger mining of coal. An intrinsically safe commercial gas detector with a built-in data logger was mounted in the center of the hollow conveying auger. A sampling head through the wall of the auger conducted a gas sample to the detector. Results showed that gas levels can be monitored on a continuous basis during the auger mining of coal and the data retrieved upon completion of the hole.

[1]Physical scientist.
[2]Mechanical engineering technician.
Pittsburgh Research Center, U.S. Bureau of Mines, Pittsburgh, PA.

INTRODUCTION

Auger mining recovers near-surface coal reserves by horizontally drilling coal from a surface mine after the overburden-to-coal ratio of surface mining becomes uneconomical. Improvements in the low-cost auger mining method have led to larger diameter cutting heads, deeper penetrations, and corresponding increases in power. At the same time, surface mining technologies have permitted the mining of deeper coal reserves. Consequently, this results in auger mining of deeper coal deposits.

Historically, few ignitions of methane gas or dust have been reported involving auger-type highwall mining machines. However, in the last several years there have been about a dozen reported ignitions involving highwall mining machines. Reasons for the increase in the number of ignitions are not known, but may be related to the improved mining technologies that permit recovery of deeper reserves.

Current methods used to detect methane gas hazards involve testing for methane at the collar of the hole during mining. These tests are conducted using a handheld or probe-extension methanometer. On a hole depth of 30 to 150 m, this measurement location has little relationship to the concentration of methane near the cutting head, the most likely source of a frictional ignition. Another, somewhat better indication of a gas hazard is to monitor for gas at the hole collar during removal of the cutting head. This method does not provide an accurate assessment of gas conditions during mining, but if methane is detected, it indicates that greater quantities of methane were most likely present during mining.

Because of their proximity to the surface, most highwall mines are regarded by their operators as above the water table, and hence nongassy. It is difficult, however, to classify a coal seam as gassy or nongassy because of the high variability of individual conditions. Underground mine operators attempted to make this distinction but abandoned the concept in the 1973 Health and Safety Act in favor of a policy declaring all underground coal mines as gassy.

As part of the mission of the U.S. Bureau of Mines (USBM) to promote mining safety, a new USBM system is currently being used to prevent ignitions on auger-type highwall mining machines. This system uses inert gas to reduce the amount of oxygen available for creating an explosive mixture.[3] While this technology has been successful, it relies on the measurement of oxygen concentrations and volumes outside of the hole to predict the oxygen levels at the cutting head of the machine. Determining in-hole concentrations requires complex and expensive equipment to insert a sample tube into the hole and retrieve gas samples. While this can be done for research purposes, machine operators and Mine Safety and Health Administration (MSHA) inspectors require simpler techniques to ensure that nonexplosive gas mixtures are being maintained during mining.

This paper details a USBM developed method to measure methane and oxygen levels near the cutting head of auger highwall machines during mining. The data are collected during mining, recorded, and retrieved at the conclusion of the hole. While this method does not warn an operator of imminent danger, it does provide an accurate assessment of gas conditions during mining.

METHODS

THEORETICAL CONSIDERATIONS

In designing a method to monitor in-hole gas concentrations, some understanding of gas movement in the hole is required. Unlike underground mining, the auger mining system fills the entire cross-sectional area of the hole being mined. This prevents the establishment of two separate streams of air to dilute and carry away gases liberated or produced during mining. However, as coal is removed by the auger, the volume that the coal occupied must be replaced by an equivalent volume of gas. This gas (air) normally comes from the collar of the hole and moves to the cutting head. However, methane liberated during mining can also replace the cut coal. Since the methane is liberated at the cutting face, it stays at the face, replaces the cut coal volume, and follows the cutting head into the hole. There is turbulent mixing of the liberated gas and air as the auger turns.

Freshly cut coal, when exposed to air, undergoes a partial oxidation process that produces carbon monoxide and carbon dioxide gases, and consumes small quantities of oxygen. This mixture also follows the cutting head into the hole and results in increasing carbon monoxide levels and decreasing oxygen levels.

Monitoring methane using catalytic-type sensors in low oxygen environments can lead to inaccurate readings. These detectors require oxygen to burn the gas and heat the catalytic surface. This temperature increase changes the electrical resistance of a wire and is proportional to the methane concentration.[4] Since two parts of oxygen are required to oxidize one part of methane, the catalytic

[3]Volkwein, J. C., and J. P. Ulery. A Method To Eliminate Explosion Hazards in Auger Highwall Mining. USBM RI 9462, 1993, 14 pp.

[4]Chilton, J. E., and T. Kubala. True Flammable Gas Detecting System. USBM IC 9163, 1987, 11 pp.

sensor is generally accurate up to a maximum level of 10 pct methane. It follows then that in a 10-pct oxygen environment, the catalytic sensor should be accurate to a 5-pct methane level. Above this methane concentration, sensor response will underestimate the true concentration.

INSTALLATION OF HARDWARE

As in underground methane monitoring, the methane sensor cannot be placed on the machine cutting head. In practice, the underground location is approximately 2 to 3 m from the face on the boom of the cutting head. For similar practical reasons the sensor for highwall machines is on the second auger section. In the case of the smaller machines, the second auger is 3 to 4 m from the face. On larger machines this distance is about 7 m.

Auger sections used to convey coal away from the face are built from sections of pipe to which the auger scroll is welded. The ends of the pipe are fitted with male and female square-lug-type connectors. The female lug end is hollow to the interior of the pipe. The inside of this pipe provides a good location for mounting the gas monitoring instrumentation for a number of reasons: (1) the pipe interior is at the center of the axis of rotation, which minimizes mechanical shock; (2) this area is readily accessible through the female lug fitting; and (3) the area is very well protected from coal or rock damage.

To mount the instrument inside the auger, an inflatable bladder is used to surround the instrument. Two types of bladders used have included inflatable medical splints for the smaller augers and garden-tractor inner tubes for the larger augers. Small pieces of foam packing material and cloth provide additional protection. Figure 1 shows a schematic of the system.

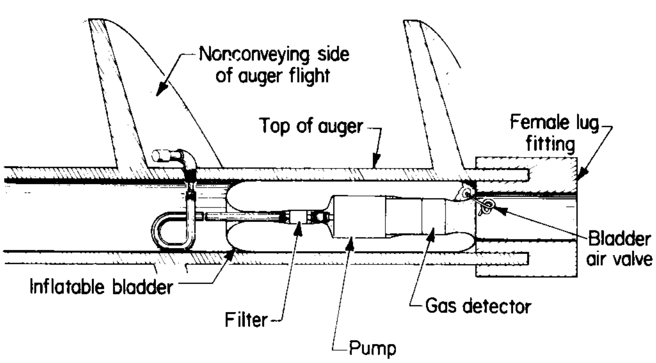
The gas detection instrument chosen for this application was the multigas TMX410 from Industrial Scientific[5] with the industrial-hygiene data logging function. The methane-detector portion of the instrument was catalytic, and therefore results with high methane or low oxygen may be inaccurate. For practical purposes, however, explosive or adequate inert gas concentrations will be evident from the continuous data log. In addition, the optional pump was also used to pull the gas sample to the detector from outside of the auger pipe. This intrinsically safe instrument package is less than 10 cm^2 and has an overall length of about 30 cm. These dimensions allow for the insertion of the instrument into the smallest augers in general use.

To conduct the gas atmosphere to the instrument, a sampling inlet (figure 2) must be installed on the outside of the auger. This inlet must be located to provide good protection and good exposure to the hole atmosphere. Augers convey coal on one side of the flighting so the other side provides a somewhat protected location. The inlet should be located on the same side of the auger as the lift eyelet. This ensures that when auger sections are added or removed from the string, the inlet stops on the top of the auger, out of the coal. The inlet itself has been built from 1/2-in black iron pipe.[6] During the course of this study we have broken two of these structures and recommend that more malleable steel, stronger steel (schedule 80 fittings), or other reinforcement be used. To protect the pump and gas detector from dust, the inlet pipe included a course, copper-wire prefilter and a fritted metal gasoline-line-type filter.

[5]Reference to specific manufactures is for information only and does not imply endorsement by the U.S. Bureau of Mines.

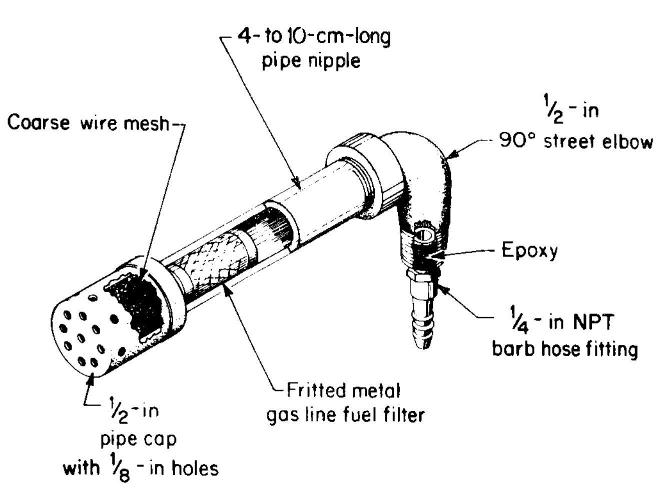
[6]Measurements in inches are actual hardware sizes.

Figure 1



Placement of instrument inside auger.

Figure 2



Gas inlet detail, measurements in inches are actual hardware sizes (NPT is National pipe thread).

FIELD-TESTING PROTOCOL

The following procedure is used to install the monitoring system. A nominal 1/2-in-pipe thread hole is drilled and tapped into the auger adjacent to the nonconveying side of the auger flighting and within about 0.7 m from the female end of the auger that follows the cutting head. Approximately 1 m of 0.5-cm-thick plastic tubing is connected to the barb fitting and threaded into the auger section. The inlet fittings are then assembled. The TMX410 and pump are turned on, wrapped in a cloth, connected to the plastic tube, placed in the inflatable splint, and carefully inserted into the auger. The splint is then inflated in place. Calibration gas is applied to the inlet of the system prior to mining to ensure that the system is functioning properly at the start.

Mining proceeds normally with depth of hole recorded along with the time of the observation. These data can then be used to judge the approximate depth at which a gas reading was recorded.

At the conclusion of mining, calibration gas may again be applied to ensure proper operation of the system at the conclusion of the hole. The installation procedure is reversed and the hole sealed with a pipe plug.

Data are then downloaded from the TMX410 with manufacturer-provided software to computer disk. These data may also be displayed at this time to determine gas levels.

RESULTS AND DISCUSSION

METHANE DETECTION

Using this technique, 11 auger holes have been sampled at 4 mines in 4 coal seams. Data from eight holes were successfully collected. Data from the other three holes were lost during debugging of the hardware installation procedures. One of these mines was experimenting with the installation of an inert gas system to prevent explosions.

Similar patterns emerged for all seams sampled. These patterns showed that gases liberated or generated in the hole followed the cutting head into the hole, and that inert gas placed at the collar of the hole followed the cutting head into the hole.

Figure 3 for example, drawn from data from a northern West Virginia mine in the Pittsburgh Seam, demonstrates that small concentrations of methane, less than 0.2 pct, can be detected in the hole when no concentrations are found around the collar. Even with this small quantity of gas, the accumulation of methane with increasing hole depth is evident from these data. Total depth of the hole was 79 m.

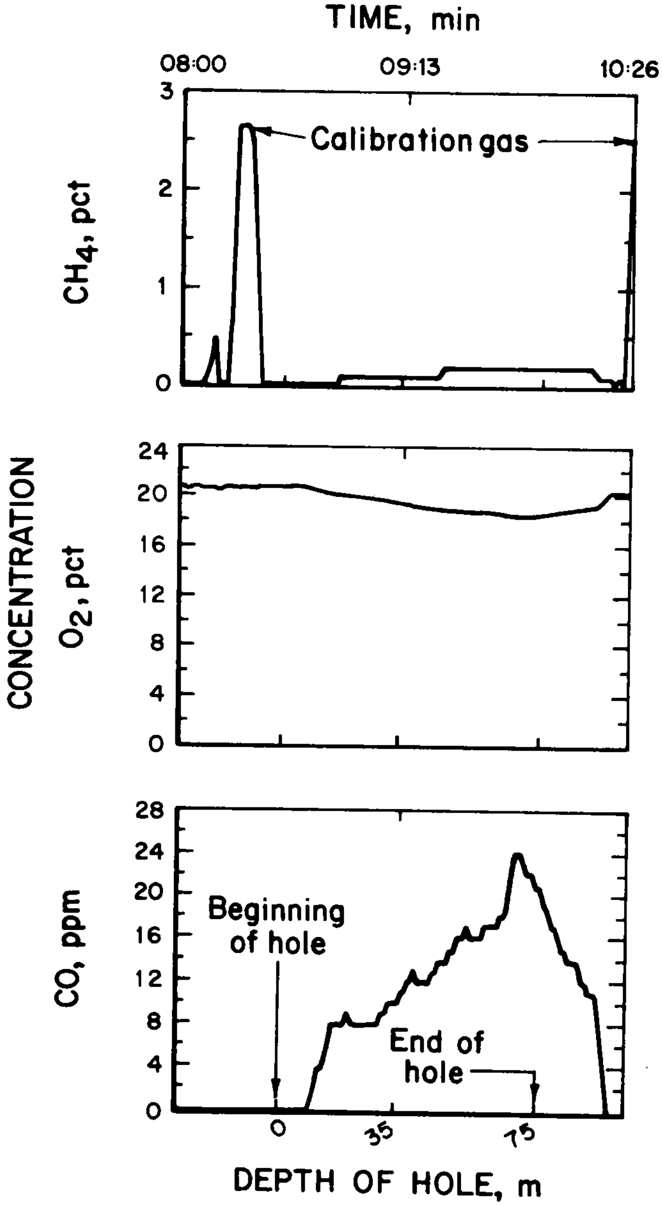
Also seen in figure 3 is the steadily increasing level of carbon monoxide. Carbon monoxide is an intermediate reaction product generated in the hole as the freshly cut coal surfaces oxidize to principally carbon dioxide. The instrumentation used in this study did not monitor for carbon dioxide, and therefore, the intermediate carbon monoxide serves as a nonquantitative measure of coal oxidation. This oxidation process reduces the oxygen content in the hole, in this case to 18.6 pct. Different coals have different reactivities to this oxidation process. Figure 4 shows the results from a mine cutting the Lower Block Seam in Indiana, which was penetrated to a depth of 91 m. Oxygen levels dropped to 15.1 pct. Carbon monoxide was not measured in this mine because of a sensor malfunction. Note that this hole also started to accumulate small quantities of methane near the end of the hole.

MEASUREMENT OF INERT GAS EFFECTIVENESS

Maintaining low oxygen levels at the auger cutting head is an excellent method of preventing both methane gas and coal dust explosions. To date no simple methods exist to monitor oxygen levels near the cutting head. The method described in this paper provides the necessary data. Figure 5 shows the results of one such test where the operator was testing a new inert gas generator. Several observations are in order:

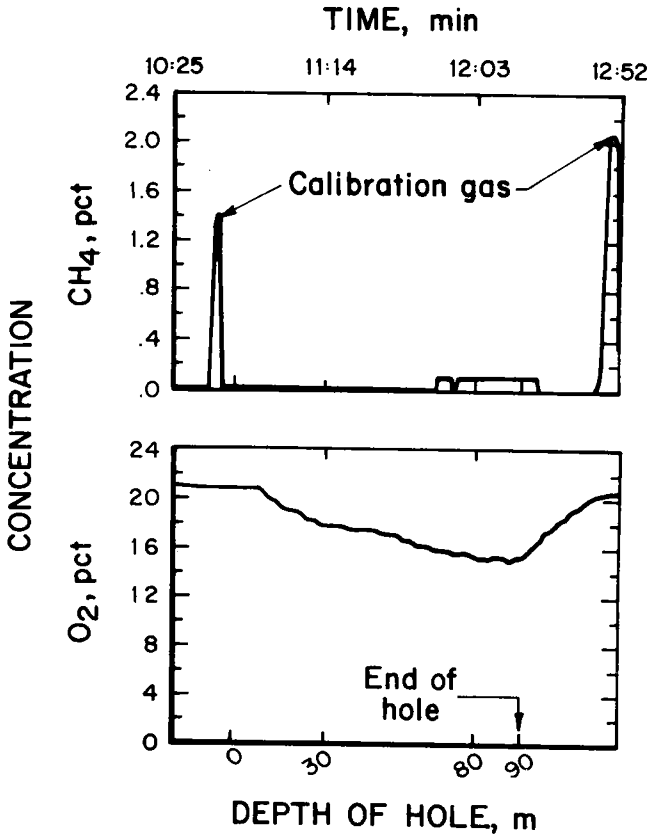
- First, and most importantly, the operator believed that testing was being conducted in a nongassy portion of the coal seam. The data were a surprise when nearly 1-pct methane was detected less than 12 m into the hole. Measurements by MSHA, the operator, and the USBM with handheld methane detectors at the collar never detected any methane. The methane data further show a stop in mining at 12 m for inert gas generator changes, and again at 38 m while waiting for a truck. Otherwise, and as predicted, gases liberated in the hole continued to accumulate

Figure 3



In-hole gas concentrations from Pittsburgh Coal Seam in northern West Virginia.

Figure 4



In-hole gas concentrations from Lower Block Coal Seam in Indiana.

as they follow the cutting head into the hole reaching a peak level of 3.3 pct methane.

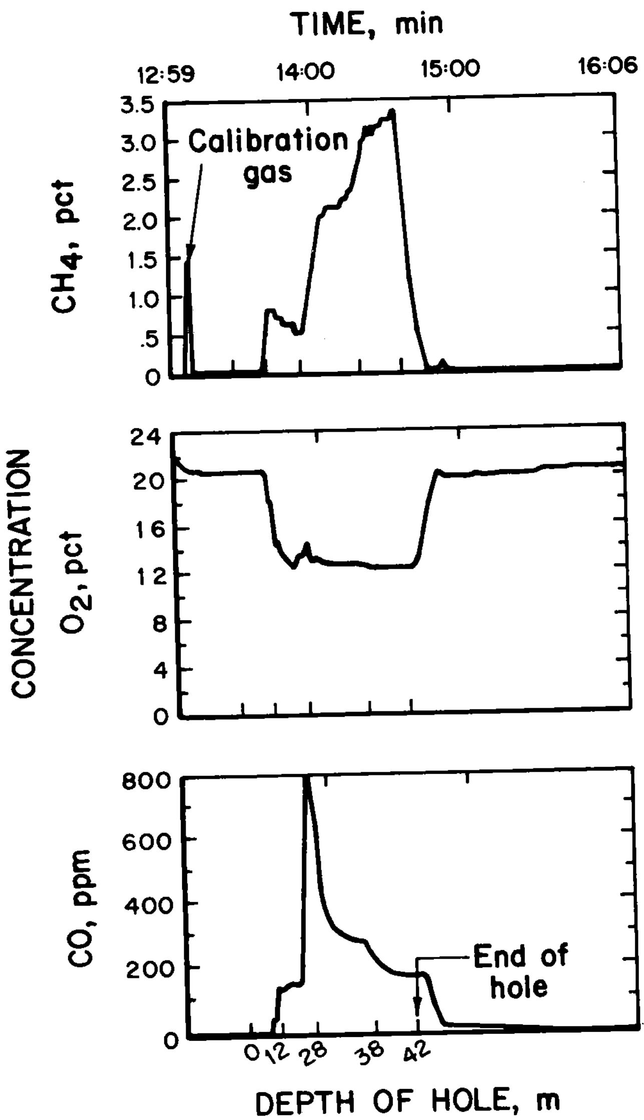
- Second, oxygen levels did not decrease below the recommended 12-pct value for effective ignition suppression. Note the change in all gas data at 27 m. This was a result of adjustments made to the inert gas generator to produce lower oxygen levels. There was a slight decrease in oxygen levels.
- Third, at the same time, a significant elevation of carbon monoxide was produced by the inert gas generator. This overwhelmed the gas sensor; therefore, data after the peak carbon monoxide level in figure 5 are unreliable. High carbon monoxide levels from combustion-type inert gas generators would tend to obscure carbon monoxide produced from coal oxidation.

Based on these observations, it can be concluded that use of this in-hole multigas monitoring method provides a simple method of monitoring the effectiveness of the inert gas engineering control system. However, this method is not intended to replace the real-time monitoring of the oxygen levels placed at the hole collar.

LIMITATIONS

This first effort to measure gas concentrations near the cutting head of auger-type machines has some limitations. First, the method does not address the real-time needs of operators who inadvertently encounter high methane levels. The method is limited to providing a historic record of the hole gas concentrations available as soon as the instrument is retrieved. Second, the method is a research tool at this point, and some additional engineering effort to secure the instrument in the auger is required to make the method mine worthy. To make the method more mine worthy, consideration must be made for mining in heavy water conditions. A durable substitute is needed to replace the vinyl inflatable bladders, which would not be expected to last through extended use. While the TMX410 is a rugged and mine-worthy instrument for handheld use and survived all of these tests, the life of the instrumentation under continuous mine use is unknown.

Figure 5



In-hole gas concentrations from Indiana No. 6 Seam, Indiana, using inert gas explosion prevention system.

CONCLUSIONS

Consistent with good safety practices, monitoring should never replace properly designed engineering controls. The method herein described can provide data to determine the need for such controls, or can serve as a tool to measure the compliance or effectiveness of an inert gas system used as an engineering control. This improved monitoring method may enable better decisions on the formulation of safe mining practices for highwall mining systems.

Future direction of this work will include testing a telemetry system to send the gas concentration data in real time to the machine operator. Real-time monitoring of gas conditions combined with appropriate engineering controls offer improved safety to the auger highwall mining system.

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