CONTROL AND MONITORING OF GAS IN BLIND AUGER HEADINGS

Jon C. Volkwein
Pittsburgh Research Center, P.O. Box 18070, Pittsburgh, Pennsylvania

ABSTRACT

Advances in mining technology have enabled deeper seams of coal to be mined from the surface. Highwall mining is frequently used to mine areas at the perimeters of a surface mine when removal of the overburden becomes uneconomical or threatens environmentally sensitive surface features. At the same time, advances in materials and technology have enabled highwall mining of coal that create blind headings over 300 meters in length. Deeper surface mining and deeper highwall penetration depths have lead to more frequent encounters with methane gas. While this coal is remotely mined from the surface, underground ignitions of methane have propagated to the surface and injured miners.

Methods described in this paper show how this hazard can be correctly monitored and controlled for auger type highwall mining machines. Research indicates that small quantities of gas liberated during mining migrate to the face, creating higher gas concentrations than would otherwise be expected. Using the same principles that cause the gas to migrate to the face, researchers have shown that inert gas introduced at the collar of the hole can inert the entire hole, thus ensuring safe conditions for mining.

INTRODUCTION

The highwall coal mining method is used to recover coal reserves from a surface mine when removal of overburden with surface mining equipment becomes uneconomical. Auger and continuous miner head machines are the two major types of equipment used in U. S. highwall mining. The auger type machines use a horizontal auger to literally drill coal from under the highwall in a series of parallel holes. These augers vary in size from 50 cm to 2.3 m in diameter and penetrate up to 150 m under the highwall. Continuous miner type machines use a remote controlled continuous mining machine coupled with a continuous haulage system to penetrate to depths over 300 m.

Historically, coal mined from the surface is relatively shallow and over time the methane associated with the coal has dissipated through the surface. In most circumstances, little methane has been found associated with highwall mining. However, mining technology has enabled surface mining of deeper reserves of coal. Furthermore, environmental constraints have forced the highwall extraction method to be used to recover coal under wetlands, further increasing the chances of encountering methane. In fact, mine inspectors have been more frequently reporting the finding of small accumulations of methane near the entrance to auger holes.

In the early 1990's an increasing incidence of ignitions at highwall mining operations was reported. The source of these ignitions was reportedly methane gas, with some involvement of coal dust, that was presumed to have been ignited from picks striking rock. A number of injuries and one fatality from ignitions resulted in the Mine Safety and Health Administration (MSHA) requesting that the Bureau of Mines help develop solutions to the ignition problem. While the number of occurrences was relatively small, the accident rate for the small highwall industry was high and aggravated by the fact that no technology was available to either effectively evaluate the extent of the problem let alone to ensure safe highwall mining. While an inert method to prevent ignitions has been developed (Volkwein 1993) operators still have no sensors to assess gas conditions during mining. In fact, a recent ignition in January 1996 demonstrates a need for the development of a real time gas sensor for auger machines.

Approaches to prevent ignitions included ventilation, blast shields, and pumping inert gas to the face through the shaft. The ventilation of augers is unreliable because of the difficulty in establishing a leak free low pressure intake and return airpath to the face. If adequate ventilation can not be guaranteed and monitored, then partial ventilation may create an unsafe condition by combining air with a nonexplosive rich methane mixture to create an explosive mixture. Furthermore, ventilation may not prevent a dust explosion in such a mining configuration. Lack of access through the shafts of the augers further limits the ability to add water or air to cool bits to prevent an ignition source from developing. Blast shields are considered unacceptable since any unplanned explosion is potentially unsafe. The study of the highwall ignition problem has resulted in a better understanding of how methane accumulates in auger excavations and in the development of an effective method that uses inert gas to prevent ignitions.

MONITORING METHODS

Assessment of the auger excavation environment is a primary requirement to determine if in fact any methane gas hazard exists. The highwall mining method represents a unique niche between surface mining of coal in the open air and underground mining. With this method, coal cutting takes place underground, but mining is controlled from a surface location. There has been no U. S. legislation requiring that gas measurements be taken and only recently has there been an MSHA policy directive to monitor for methane at the collar of the excavation. The reason for this originates from an old belief that coal seams above drainage do not contain methane gas and therefore no assessment was required. However, the 1974 mining law recognized that some "above drainage" seams did contain methane and hence the law considered all underground coal to contain gas. (Code of Federal Regulations 1974) This law, plus the recent incidences of ignitions, has

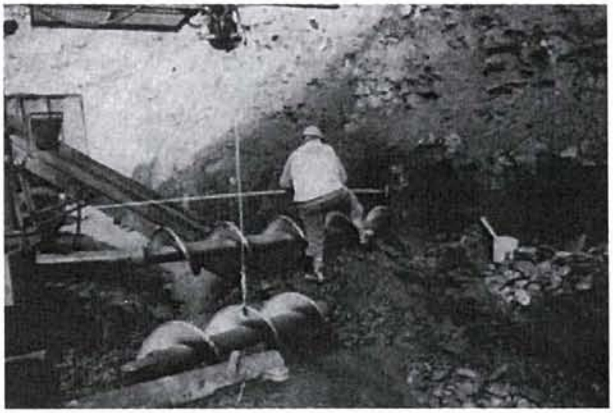

Figure 1. Current hand held and probe measurement of methane in auger mining.

prompted an increased need for more accurate gas assessments in highwall mining.

Current Monitoring Practice

Currently, methane in highwall mining is assessed using underground methods. These underground methods measure gas levels with machine mounted methane monitors, or hand held gas detectors. The machine mounted monitor can be used for the continuous miner type highwall machine, but cannot be easily adapted to an auger machine since the mechanism fills the entire excavation and would require multiple electrical connections whose safety protection would be difficult to maintain. Auger miners currently use only hand held devices to check for methane gas. Safety considerations prevent miners from entering an auger excavation to take gas readings and therefore, hand held readings can only be obtained at the collar of the hole or at best using a short probe to reach about 3 meters inby the collar as seen in figure 1.

Hand held methods give misleadingly low estimates of true face methane gas levels. Operators reported that little methane gas was observed at collar measurement locations when coal was being extracted, but when augers were being removed from the hole after mining, methane could be detected. During research on the use of inert gas for prevention of ignitions, methane gas levels were observed to increase with hole depth. Data trends in figure 2 indicates that during auger penetration, no gas would be detected at the collar of the hole (depth 0) and that small quantities could be observed after removal of the augers. Of more importance is the fact that higher methane levels deep in the hole

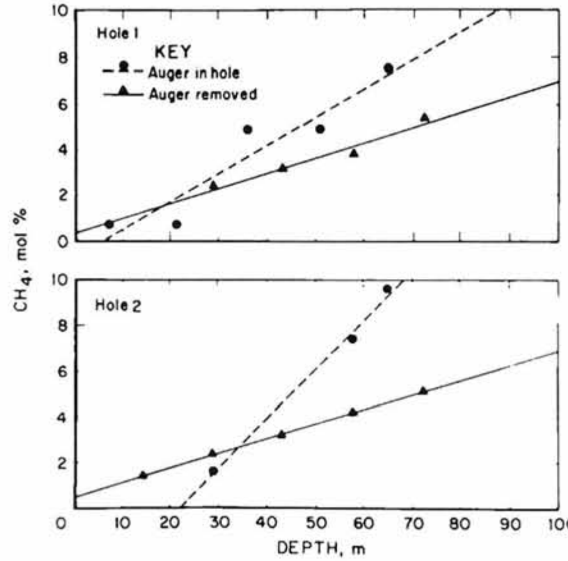

Figure 2. Profiles of in-hole methane content with augers in place and immediately after auger removal.

cannot be detected by collar measurements.

Gas Movement Inside Hole

Further study of the situation shows that gas must replace the volume of coal removed from the mining face. In most instances this replacement gas is air from the hole collar. However, small quantities of methane gas liberated inside the excavation will also replace the coal volume removed. In fact, small volumes of gas liberated within the hole will tend to follow and volumetrically increase near the cutter head. Figure 3 illustrates the principle that as coal is removed, methane gas liberated inside the hole more easily replaces the coal that has been removed than air from the outside of the hole. The net result being an accumulation of methane near the cutting head. This is counter intuitive to most ventilation engineers experience where methane levels continually dilute. This does not imply that methane self concentrates, but that it travels to the face replacing air as the diluent resulting in an increased methane percentage at the face. Data from Table 1, taken under inert gas conditions, show methane concentrations 40 m into the hole at a hole depth of 52 m were 5.66%. When the hole was completed at a depth of 110 m, gas concentrations at 40 m were 1.59%. The high concentration gas originally at 40 m was now detected closer to the cutting head. At a distance of 70 m, methane concentration was 9.55%. Conditions precluded measurements closer to the cutting head.

Table 1. Auger hole methane concentrations increase toward the face

Hole depth, m	Probe depth, m	Methane, vol%
52	40	5.66
110	30	1.59
110	61	7.38
110	70	9.55

This discovery of gas movement within the hole lead to the successful development of an inert gas technique to prevent ignitions on auger machines and will be discussed later. The motive

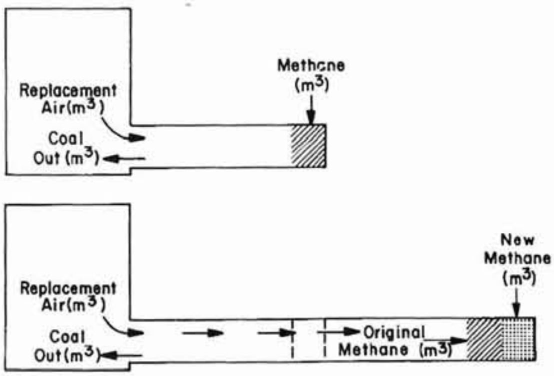

Figure 3. Principle of gas volume replacing the removed coal volume and the accumulation of methane within the hole.

force of gas movement in the hole comes from the removal of the coal from the face and the replacement of that coal volume with an equal volume of gas. Furthermore, in the absence of other ventilation forces, this replacement phenomena occurs in any dead heading, including the continuous miner highwall type systems.

Continuous Assessment of Gas Levels During Mining

Because collar measurements of methane levels are clearly inadequate, continuous measurement methods of in-hole gas levels are being developed. Research techniques used for in-hole measurements during the development of the inert gas system are not practical for everyday use or even for periodic MSHA inspections. We therefore investigated a method of using a permissible recording hand-held multi-gas monitoring instrument to record methane and oxygen levels during mining.(Volkwein 1994) Briefly, this monitor was inserted into the center of the auger and supported with an inflatable bladder. Air from the hole was pumped to the instrument, data recorded and then retrieved after the auger was removed from the hole. Details of this method are in the reference. Figure 4 shows the methane gas data for a gassy coal (using the inert gas system) and a "non-gassy" coal. Note that as hole depth increases, methane gas levels increase. Of particular interest is that the coal considered non-gassy did in fact contain small amounts of methane that did accumulate towards the face. The results of the study of recording data during mining convinced researchers that electronic instrumentation could survive the stress of being mounted to a rotating auger being used to cut coal. Furthermore, data gathered during the testing provide compelling evidence that gas levels in auger excavations should be continuously monitored.

Work in progress is focusing on the use of a wireless technique to transmit data from the head of the auger to the machine operator's station. In principle, perfection of this data transmission technique should be useful for transmitting various types of data from the interior of auger holes to the operator's location. The criteria for this system is that it be inexpensive, intrinsically safe, battery operated, and be able to transmit gas data. The machine operator's unit will then decode the signal and give a real time measurement of the methane, or oxygen concentration near the head of the mining machine.

IGNITION PREVENTION

Study of the dynamics of highwall mining lead to a successful

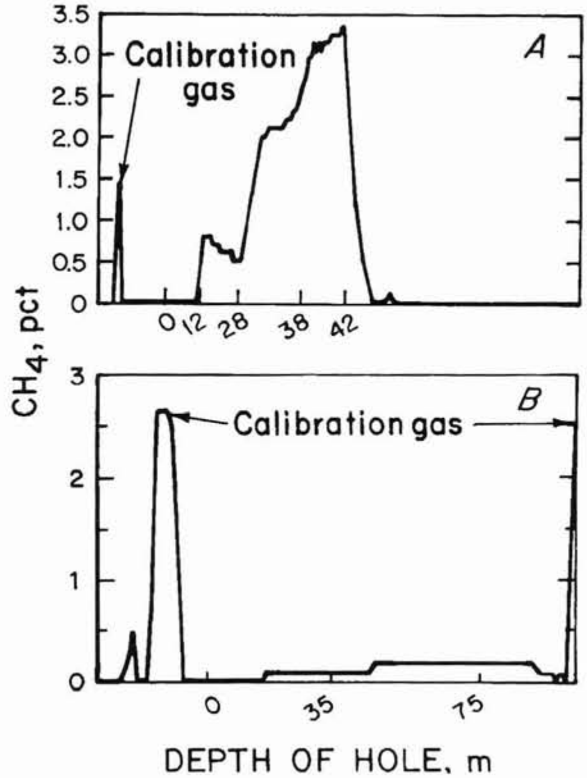

Figure 4. Continuous methane gas concentrations during mining of a gassy and non-gassy coal.

use of inert gas as a means of preventing highwall ignitions. The use of inert gas to prevent ignitions in coal mining had been considered in the past (Cyrus 1970; Poundstone 1975; Castanoli 1954) but never implemented due to, among other reasons, the inability of placing gas at the face of the cutting machine. Previous ideas on using inert gas to prevent ignitions on a coal mining face all relied on utilization of a second conduit through which inert gas could be delivered to the face. This could not be easily accomplished with auger type machines since the auger fills the entire cross sectional area of the hole. Delivering the gas through the center of the auger steel would require major modification to each auger section and development of a method to get the gas into the interior of the auger. Better knowledge of gas movement within the auger hole lead to the current technique of filling the collar of the auger hole with inert gas and allowing the displacement of the coal to provide the motive force for transporting inert gas to the cutting head.

This method, shown in figure 5, prevents ignitions of both methane and dust by reducing oxygen levels below explosive limits. This is done by replacing oxygen with an inert gas consisting primarily of nitrogen and carbon dioxide. Inert gas may be obtained from several sources on highwalls, but the simplest approach is to generate the gas on-site using combustion processes to burn oxygen from the air. For the initial testing a combination of gasoline and diesel combustion engine exhaust gases were used to achieve enough gas to replace the coal volume and contain less than 12% oxygen by volume. Alternatively others have used furnace type technologies to produce the correct inert gas quantity and quality.

Briefly, the system as tested consisted of combining exhaust

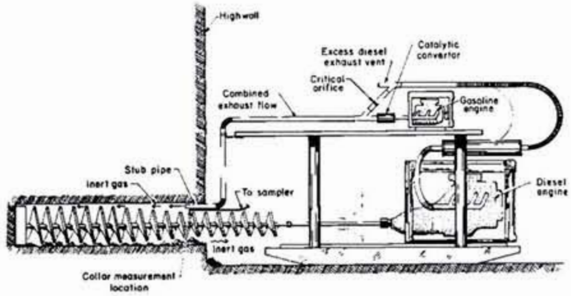

Figure 5. An inert gas system for an auger mining machine.

gases from a gasoline engine and the machines diesel engine in equal volumes and ducting these gases to the collar of the auger hole. Delivery of the inert gas into the hole and up to the cutting head involved the use of a pipe at the top of the auger hole to jet the gas toward the interior of the hole. This effectively creates a plug of inert gas at the collar that is in excess of the volume of coal that is removed such that as gas is needed to replace the coal, only inert gas is drawn into the hole. Details may be found in the first reference.

Results in figure 6 showed that for all samples taken during mining of gassy coal, all conditions remained nonexplosive. In fact during testing, methane concentrations of 9% were encountered but oxygen levels were below 10% leaving the mixture nonexplosive. Approximately 1 million tons of gassy coal have been safely mined in the U. S. to date using this system.

CONCLUSION

The increased incidence of ignitions in highwall mining has resulted in study and better understanding of gas flows in unventilated blind auger holes. These findings have resulted in research methods to take measurements during mining and in the preliminary development of real time means to assess gas levels during mining for machine operators. In the mean time, the knowledge of gas movement in the hole has resulted in a simple but effective inert gas system to protect workers during mining of gassy coal.

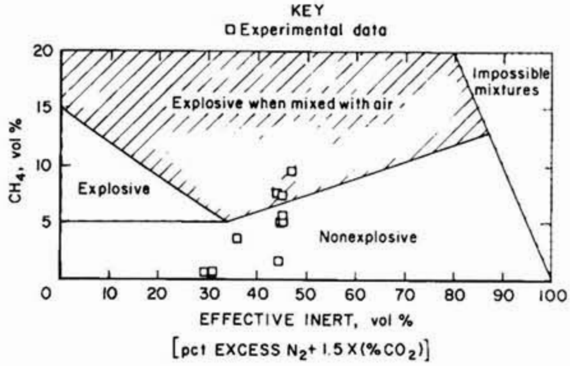

Figure 6. Explosibility diagram with observed in hole gas data using inert gas system.

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