From: Karl Zipf <rkarlzipfjr@gmail.com>
Sent: Tuesday, April 21, 2015 6:11 PM
To: zzMSHA-Standards - Comments to Fed Reg Group
Subject: RIN 1219-AB85
Attachments: MSHA RIN 1219-AB85_fromRKZipf.docx

Dear sir,

Please find attached a Word document with my responses to your request for information RIN 1219-AB85 (MSHA Docket Number 2014-0029).

If the attachment is not in a format suitable to you, please contact me.

Thank you for your consideration.

Respectfully submitted,

2015 APR 22 A 9:11

R. Karl Zipf, Jr., Ph.D., P.E.
Research Professor
Department of Mining Engineering
Colorado School of Mines

rkarlzipfjr@gmail.com
412-992-6085

AB85- Comm-7

Mine Safety and Health Administration (MSHA)

Request for information to improve the health and safety of miners and to prevent accidents in underground coal mines

RIN 1219-AB85

Docket Number MSHA-2014-0029

Submitted by

R. Karl Zipf, Jr., Ph.D., P.E., Research Professor, Colorado School of Mines

rkarlzipfjr@gmail.com 412-992-6085

A. Requirements for developing and implementing roof control and mine ventilation plans

A1. What health and safety benefit could result from requiring mine operators to designate a mine management employee, who is a credentialed professional, to be responsible for development and implementation of approved roof control and ventilation plans?

In principle, having someone on the management team who is personally and professionally responsible for roof control and ventilation plans should result in higher quality, more conservative, and safer plans. In practice though, other factors may influence the decisions of a licensed professional engineer with respect to roof control and ventilation plans. Anecdotal evidence suggests that hastily created and approved plans can result in disaster. The Crandall Canyon roof control plan was created quickly by a reputable consulting company in response to the mining company's needs and approved quickly by MSHA also in response to the mining company's desires. The result was disaster. The Upper Big Branch ventilation plan was also created in haste and rushed through MSHA approval. Again, the result was disaster.
I favor having licensed professional engineers certify roof control and ventilation plans, but such certification itself is no guarantee against a flawed plan and disaster. Mining professionals must have the courage and be encouraged to speak up honestly when a proposed roof control or ventilation plan is potentially dangerous. They may need protection from unscrupulous operators who might choose to fire such employees or consultants because they did not deliver the desired answers.

A2. What knowledge, skills, abilities, or licensure would this credentialed professional need in order to develop, implement, and monitor roof control and ventilation plans?

Roof control and ventilation plans should be developed and certified by a licensed Mining, Civil or Mechanical Engineer with demonstrated experience at the particular mine or with the particular hazards present at the mine. This person could either be a direct employee of the mining company or a consulting engineer. These professionals must be encouraged to speak up honestly when proposed plans are not safe, and they may need some protections from retaliation by unscrupulous operators.

A3. Please comment on the recommendation to increase the minimum quantity of air. What are the advantages, disadvantages, impact on miner health and safety, and costs associated with an increase in the minimum quantity of air for longwall mines? How could this minimum quantity of air be determined and where would it be measured?

I do not support a mandate of 75,000 CFM on longwall faces. The amount of air required to dilute methane concentration to less than 1% at the tailgate depends on the methane emission rate, methane production from gob vent boreholes, and the coal production rate. Increased face ventilation is but one option to consider when developing a ventilation plan to keep tailgate methane at less than 1%.
The amount of air on the longwall face should be measured at a minimum of three locations along the face that are approximately evenly spaced.

A4. What is the most effective way to control methane, oxygen, and respirable dust levels to assure the health and safety of miners?

The use of progressively sealed (or bleederless) ventilation systems along with nitrogen injection is the best way to control methane and oxygen in longwall gobs to prevent explosions and improve mine safety. The required use of bleeder ventilation systems at most longwall mines in the US has become an increasingly dangerous practice as our modern longwall panels have become wider, longer and more productive. This US practice also contrasts with mining practices around the world (Australia, Germany, Poland, and Great Britain) where the use of progressively sealed (bleederless) longwall ventilation systems is the norm.

The use of bleeder ventilation systems in US coal mines originated from room-and-pillar mining with full or partial pillar extraction within panels during retreat mining. This mining method was common in the US prior to the 1970s, but has diminished in use since then with the growth of modern longwall mining. Typical room-and-pillar panels were up to about 600 feet wide and about 1,000 feet long. They usually contained numerous pillar remnants such that the gob contained extensive void spaces and was therefore highly permeable, especially compared to the tightly caving gobs of modern longwall panels. Because of this permeable gob, a bleeder ventilation system for a mined-out room-and-pillar panel can function as intended to sweep methane out of the gob and prevent formation of any explosive mixtures of methane-air within the gob. Present MSHA ventilation regulations treat a longwall mine gob the same as a room-and-pillar mine gob and expect the bleeder system around a longwall mine gob to perform as well as one around a room-and-pillar mine gob. Recent studies by researchers at Colorado School of Mines (Brune et al., Grubb et al., Worrall and Marts) demonstrate that this belief is incorrect.

In the 1980s, typical longwall faces were 500 to 800 feet wide, and panels were 2,000 to 5,000 feet long. Today, longwall faces are typically 1,000 to 1,500 feet wide, and panels can be 10,000 to 20,000 feet or longer. Longwall mining often extracts 100% of the coal thickness, and caving of the overlying rock is complete. Compared to a mined-out room-and-pillar panel, a mined-out longwall panel contains little void space, except around the panel edges. The permeability of a mined-out longwall panel gob is much less than a mined-out room-and-pillar panel gob.

This difference in gob permeability means that it is not possible for a bleeder system to perform its intended function of sweeping methane out of large longwall mine gobs and preventing the development of an explosive mixture somewhere within the gob. As proof of this statement, consider the longwall tailgate area with an atmosphere of ≥99% air and <1% methane. Gob vent boreholes may be located a few hundred feet behind the longwall face and may terminate about 30 to 50 feet above the coal seam in the longwall gob. These gob vent boreholes frequently produce 90 to 100% methane. Since the tailgate and the gob vent borehole communicate, it is an absolute certainty that an explosive mixture of 5 to 15% methane-in-air exists somewhere between these two points. The only questions are exactly where it exists and what happens if it is ignited. The existence of this explosive gas zone (EGZ) is not due to an improperly functioning bleeder system, rather, it is an inherent engineering problem with all bleeder systems around mined-out longwall panel gobs.

With a bleeder ventilation system, computational fluid dynamics (CFD) models show that an explosive gas zone (EGZ) always exists within and around a longwall panel gob, no matter what the ventilation system layout or the ventilation air quantities. Figure 1 from Gilmore et al. (2015) and Brune et al. (2015) shows the EGZ location in a typical longwall panel gob. The color coding follows a scheme based on Coward's triangle shown at the lower right in this figure. Red indicates an explosive methane-air mixture in the 5 to 15% range. Orange indicates mixtures that are close to entering the explosive range. Blue indicates methane-lean, oxygen-rich mixtures similar to fresh air that can become explosive with the addition of methane. Yellow indicates methane-rich, oxygen-lean mixtures that can become explosive with the addition of air. Green indicates low oxygen mixtures that cannot become explosive with methane addition. The computational fluid dynamics models show that an extensive EGZ exists deep within the mined out longwall panel and around its perimeter. This EGZ is especially prominent along the headgate side of the mined-out longwall panel and in the start-up room entry.

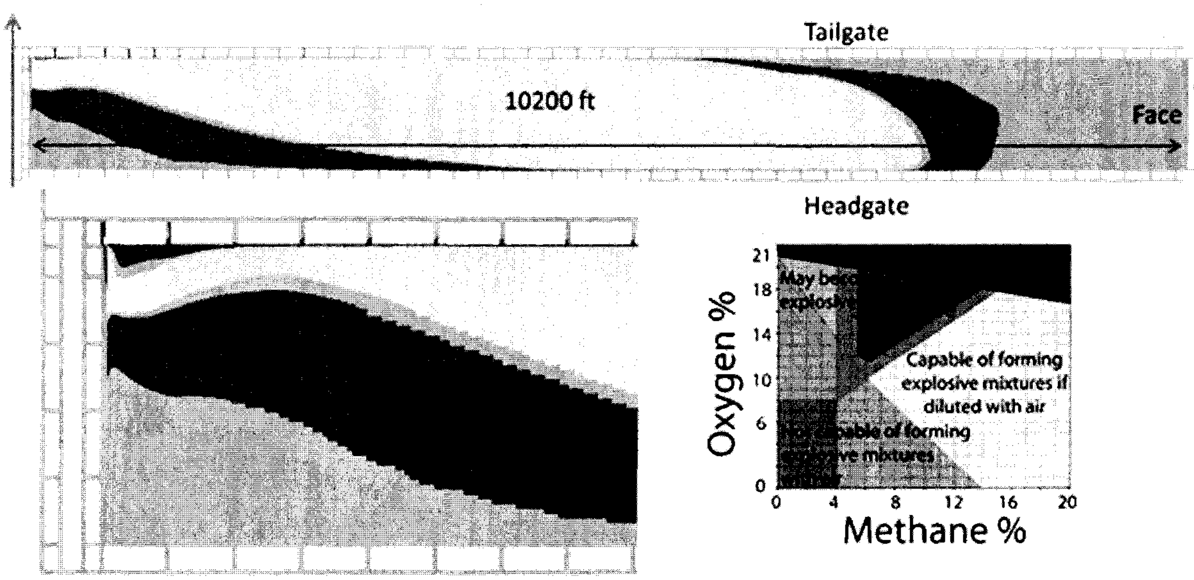

Figure 1 – Explosive gas zone (EGZ) in red surrounding a longwall gob. The image at lower left shows detail near the start-up entries of the longwall panel. The color coding is scheme is based on Coward's triangle shown in lower right. Airflow across the back bleeder entries is about 17,000 cfm in this case. (From Gilmore et al., 2015 and Brune et al., 2015)

Figure 2 shows the ventilation airflow quantities around the perimeter of the mined-out longwall panel used in these CFD models of airflow in the entries and through the longwall gob. The quantities are typical of current ventilation practice. 100,000 cfm is brought into the panel up the headgate; 75,000 cfm flows across the longwall face, and 25,000 cfm flows into the headgate entries inby the face. 25,000 cfm is brought into the panel up the tailgate. About 35,000 cfm leaks from the face and migrates through the gob toward the headgate entries behind the face. 65,000 cfm flows down the middle tailgate entry between the mined-out longwall panels. Therefore, the bleeder fan located beyond the tailgate side of the panel withdraws 125,000 cfm from the mine.

The amount of air flowing down the tailgate between two longwall gobs is 65,000 cfm, and the amount of air flowing down the headgate side toward the start-up room is 60,000 cfm. These quantities do not vary much for bleeder ventilation systems used in practice in the US. Regulators located on the headgate side near the start-up room and at the entrance to the bleeder entries can affect airflow through the longwall gob. These regulators are the primary controls on the behavior and effectiveness of the bleeder system. In this particular model variant, 17,000 cfm flows across the start-up room from the headgate side to the tailgate side. Another 20,000 cfm flows through the headgate side regulators and enters the bleeder entries. The remaining 20,000 cfm flows from the headgate entries before the start-up room into the gob and migrates toward the tailgate. The effect of this flow is to create the blue triangle of oxygenated, fuel-lean atmosphere near the start-up room on the headgate side of the panel.

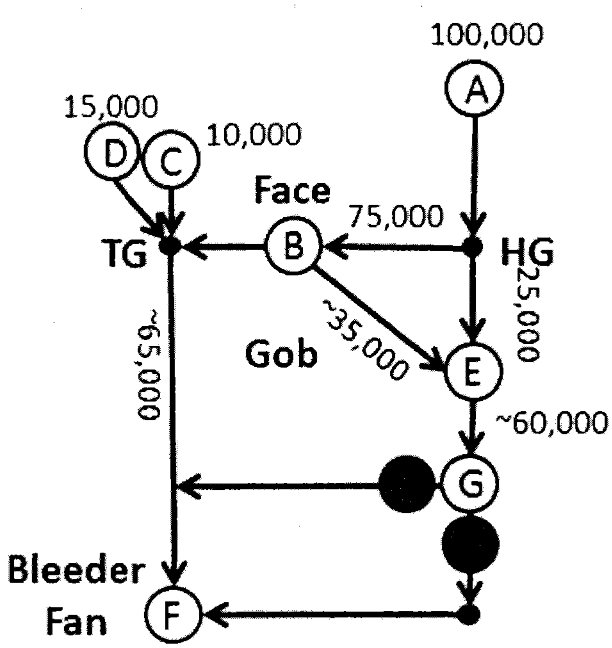

Figure 2 – Typical ventilation airflow distribution for the CFD models of airflow through the entries and through the longwall gob (Gilmore et al., 2015).

Changing the airflow across the start-up room by changing the regulator settings changes the location and volume of the explosive gas zone (EGZ) in the longwall gob but does not eliminate its presence. Figure 3 shows calculations of the EGZ location for three different regulator settings that cover a range of practical possibilities. Increasing the airflow across the start-up room, as shown in Case 2a, moves the EGZ closer to the headgate side of the longwall gob. In this case, air flow from the headgate into the longwall gob is zero. However, the EGZ still exists along the entire length of the longwall gob on the headgate side. Decreasing the airflow across the start-up room to zero, as shown in Case 2c, moves the EGZ closer to the tailgate side of the longwall gob. However, the EGZ still exists along the entire tailgate side of the panel.

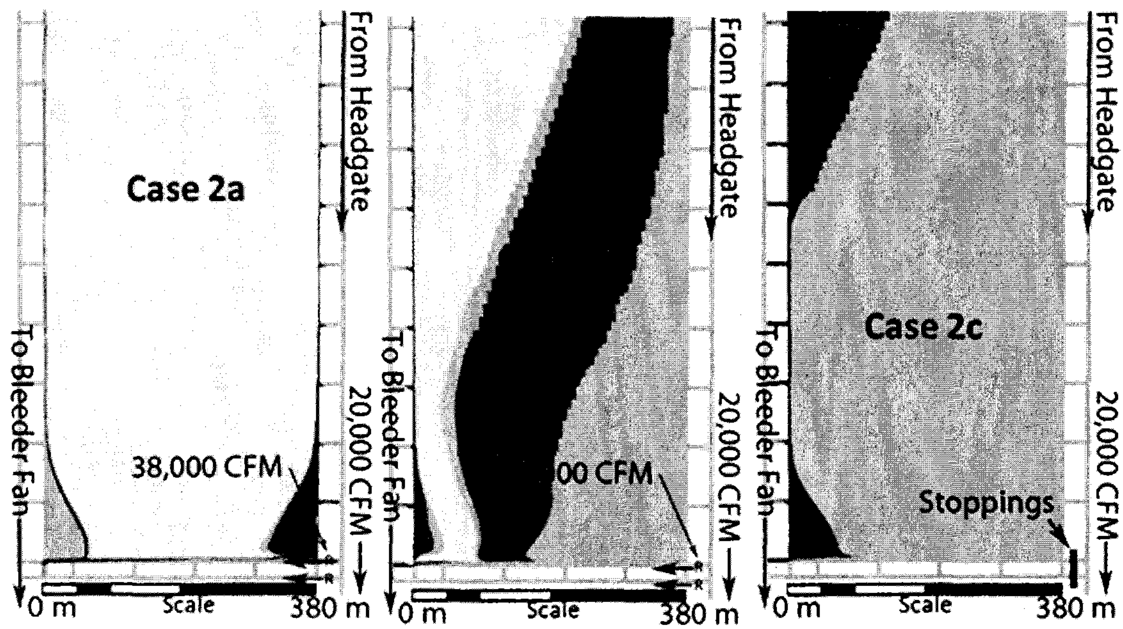

Figure 3 – EGZ extent near start-up room in longwall gob for three different regulator settings. Case 2B is the same as shown in Figure 1. Case 2A is for increased flow across the start-up room, and Case 2C is for no flow across the start-up room. (From Gilmore et al., 2015 and Brune et al., 2015)

A better ventilation approach for most longwall mines, whether the coal is prone to spontaneous combustion (spon com) or not, is a U-type ventilation system in conjunction with progressive sealing of the longwall gob. With this approach (also known as a bleederless system), the EGZ is moved well behind the longwall face, as shown in Figure 4 top, where it presents less danger to mining personnel. The EGZ can be minimized, as shown in Figure 4 bottom, through the use of nitrogen injection through the headgate side seals into the longwall gob behind the face on the headgate side. With a back return (not shown), it is possible to push the EGZ further behind the longwall face on the tailgate side and to complete a contiguous zone of nitrogen between headgate and tailgate that separates the fresh air from the methane-rich center of the gob, thereby completely eliminating the EGZ fringe. This nitrogen-rich zone behind the face is called a "dynamic seal."

Unfortunately, the existence of the EGZ in longwall panel gobs is inherent with the use of a bleeder ventilation system, even with a properly operating bleeder ventilation system. Changing the ventilation system design or ventilation airflows cannot eliminate the existence of the EGZ, rather it can only move its location. The use of a U-type ventilation system with progressive sealing is the recommended approach for eliminating the danger posed by the EGZ, whether the mine is spon com prone or not. Furthermore, with nitrogen injection in combination with a back return, it is possible to eliminate the EGZ completely and remove any danger of fire and explosion within longwall gobs.

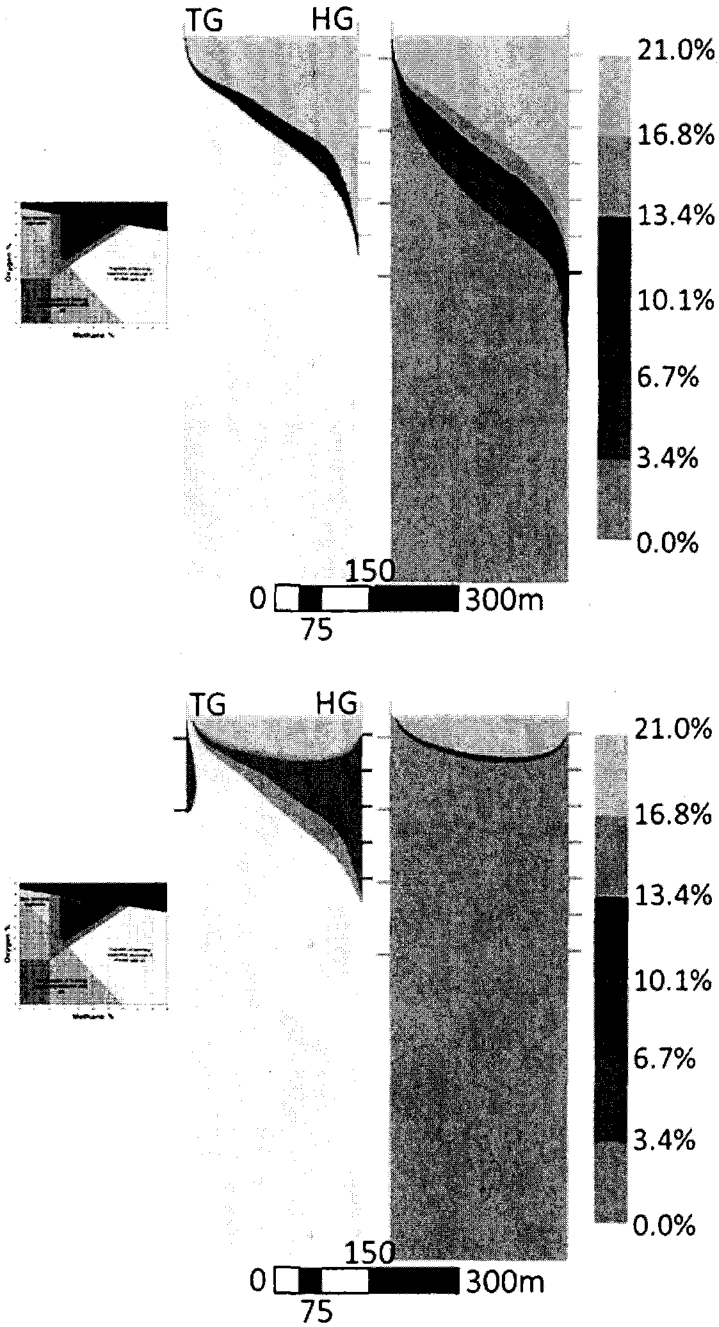

Figure 4 – CFD model showing atmospheric composition in progressively sealed longwall gob. Longwall face is at the top edge, and the start-up room is at the bottom edge. The tailgate is along the left side, and the headgate with gob isolation stoppings is along the right side. The EGZ zone is shown in the leftmost figures, and the oxygen concentration is shown in the rightmost figures. In the top figures, nitrogen injection is not used, and an EGZ forms in the longwall gob that touches the headgate about 6 cross-cuts behind the face. In the bottom figures, nitrogen is injected at the first two cross-cuts behind the face, and the EGZ is eliminated. These models do not use a back return at the tailgate. Other CFD models show that a back return pushes the EGZ further behind the face on the tailgate side. (Marts et al., 2015).

A5. Please comment on equipment doors: Their use, location, approval, advantages, disadvantages and impact on miner health and safety. Also comment on the use of equipment doors in travelways, including the use of an interlock system. What are the advantages, disadvantages, impact on miner health and safety, and costs of using interlock systems on equipment doors?

The use of equipment doors should be avoided insofar possible. When both doors are open, a short circuit in the ventilation system results, and less fresh air is delivered to the working faces. This condition is potentially dangerous. Interlocks can prevent the both doors open scenario simply and reliably. In addition to safety interlocks, the atmospheric monitoring system (AMS) should include pressure sensors, air velocity monitors or air direction monitors near the equipment doors. Finally, sets of doors should never be used in lieu of overcasts to separate different types of airways.

B6. Continuous remote monitoring systems, such as AMS and tube bundle systems, can be used to detect unexpected ventilation system changes or methane inundations. Please comment, including rationale, on whether and under what circumstances MSHA should require the use of a continuous remote monitoring system. Please include impact on miner health and safety, impact on mining method, and any other related impact. What would be the costs to add monitoring systems or to extend existing systems in mines?

Between 1976 and 2010, explosions caused by methane and coal dust accumulations in underground coal mines in the U.S.A. killed 186 coal miners and seriously injured uncounted others. Twelve explosions involving methane alone occurred between 1986 and 2006 in the abandoned and sealed areas of coal mines, resulting in 21 fatalities. A total of 25 explosions involving methane and coal dust occurred in the active areas of coal mines, resulting in 165 deaths. Select explosion examples include 1) Scotia Mine in 1976 with 26 dead, 2) McClure #1 Mine in 1983 with 7 dead, 3) Pyro Mining #9 Slope in 1989 with 10 dead, 4) South Mountain #3 Mine in 1992 with 8 dead, 5) Willow Creek Mine in 2000 with 2 dead, 6) Jim Walter #5 Mine in 2001 with 13 dead, and 7) Upper Big Branch Mine 2010 with 29 dead.

Krog and Schatzel (2007) documented 1,589 friction ignitions that occurred in U.S. coal mines from 1983 through 2005. These ignitions occurred at both continuous miner and longwall faces in a wide number of coal seams throughout all coal basins. Frictional ignitions are potential precursors to a larger coal mine explosion, and any such ignition has the potential of multiple fatalities, fires and destruction of ventilation controls that will compromise the ability to dilute and render harmless further accumulations of methane.

The occurrence of frictional ignitions and coal mine explosions may be symptomatic of inadequacies with current methane monitoring and detection requirements and with mine ventilation system performance monitoring. Under current regulations, an accumulation of methane gas or a change in the ventilation system can go undetected due to inadequate checks at certain locations or infrequency of checks.

In addition to potential inadequacies in the current monitoring regimen, several mechanisms exist that can generate large influxes of methane that can overwhelm the ventilation system and lead to unanticipated accumulations of this gas: 1) barometric pressure changes, 2) large roof falls in the gob or coal mine bump, and 3) mining into cracks and methane feeders.

In less than a few hours, barometric pressure can decrease 1 to 2 inches of mercury during severe storms, which is about 3 to 7% of normal atmospheric pressure. Consequently, about 3 to 7% of the atmosphere in a mined-out gob and sealed areas will expand into nearby entries in the ventilation system in about this same time frame. If this occurs between the periodic manual methane checks by mine examiners and no continuous AMS is available, a potentially disastrous situation can arise.

In most longwall coal mines, the mined-out area may experience large roof falls in the gob that can suddenly expel some unknown volume of the gob atmosphere into the nearby ventilation system. Such events are suspected to have caused the fires and explosions at Willow Creek in 1998 and again in 2000 resulting in 2 fatalities, as well as Buchanon mine in 2005 and 2007. Certain coal mines in the U.S. suffer from coal mine bumps that can also push gases from the gob into the active areas of the mine ventilation system.

During mining with either continuous miners or longwall shearers, it is possible to encounter cracks or methane feeders that can release quantities of methane into the ventilation system. These cracks may be connected to gas sources in nearby rock strata. In extreme cases, a methane outburst can occur, which can suddenly release large quantities of methane.

The ventilation system must have sufficient capacity to dilute the gas, render it harmless and carry it away. For this reason, an adequate system is needed to detect the methane gas in time to de-energize mining equipment or take other corrective actions. Present methane monitoring schemes, relying on periodic handheld methane checks cannot adequately protect U.S. coal miners as evidenced by the large number of frictional ignitions and coal mine explosions that have occurred over the past few decades. Just in 2012 alone, more than a dozen face ignitions occurred in U.S. underground coal mines based on MSHA accident statistics.

Remote, continuously-monitoring detection systems for dangerous gases such as methane, carbon monoxide, and other gases and of the ventilation such as air velocity, air direction and pressure should be required for all key locations in most large coal mining operations. The purpose of such monitoring systems is to ensure that the ventilation system performs as designed in the approved ventilation plan and that it dilutes and renders harmless potentially dangerous gases everywhere in the system at all times. With continuous monitoring, trends become visible and gradual changes over time in ventilation system performance and gas concentrations can be observed. The use of continuous monitoring systems for atmospheric and ventilation system monitoring is long overdue in US coal mines, and implementing these systems would be a major step forward in preventing another Upper Big Branch disaster from occurring.

Recognizing that the methane inflow to each mine is different and may change over time, a three-level system is suggested for placement of additional continuous methane monitors based upon methane emissions into the mine. These new monitoring requirements are <u>in addition</u> to existing requirements for pre-shift, on-shift and weekly examinations, machine-mounted methane monitors, and sealed area monitoring.

All underground coal mines should deploy methane monitors at the exhaust and bleeder fans (Level 1). If methane emissions exceed 500 cfm at a main exhaust or bleeder fan or if methane concentrations exceed 0.25% at a main exhaust fan or exceed 0.50% at a bleeder fan in any 15-minute period, then additional Level 2 methane monitors are recommended. If the methane emissions or methane concentrations exceed 200 cfm or 0.25%, respectively in any 15-minute period upstream of an air regulator, return air junction, in return air near a longwall tailgate or in a belt entry from a working section; or exceed 500 cfm or 0.50%, respectively in any 15- minute period upstream of a travelable bleeder air junction, then additional Level 3 methane monitors are recommended.

Recommended three-level system for methane monitoring

Level 1:

- all main exhaust fans
- all bleeder fans

Level 2:

- in return air streams upstream of regulators
- in return air streams upstream of major junctions
- in belt entries near the mouth of working sections
- in travelable bleeder air streams upstream of junctions
- in return air streams near a longwall tailgate

Level 3:

- in return air streams near the last permanent stopping of each working section if more than 3,000 feet from the return air regulator
- at 5 locations along a longwall face under the shields and close to the face
- down-stream of each set of permanent seals or at least every 10th seal in a set

Similarly, a three-level system for monitoring the ventilation system performance is recommended, where the number and placement of monitors depends on the methane output and/or the total airflow of the mine. Low methane emission mines with low total airflow have lower continuous monitoring requirements in this recommended system. Level 1 monitoring is required when the total mine airflow exceeds 200,000 cubic feet per minute (cfm) and methane liberation exceeds 200,000 cubic feet during a 24-hour period. Level 2 monitoring is required in addition to Level 1 monitors when the total airflow or methane liberation exceeds 500,000 cfm and 500,000 cubic feet in a 24-hour period, respectively. Level 3 monitoring is required in addition to Level 2 monitors when the total mine airflow and methane liberation exceeds 1,000,000 cfm and 1,000,000 cubic feet in a 24-hour period, respectively.

Recommended three-level system for ventilation system monitoring

Level 1:

- air velocity & pressure at all main fans or at main returns

- air velocity & airflow direction at all separated belt entries at the point of lowest measured air velocity
- atmospheric barometric pressure
- temperature and humidity on surface

Level 2:

- air velocity at development panel regulators or in the drift directly prior to the regulator
- air velocity & pressure at bleeder fans
- air velocity at longwall intakes

Level 3:

- pressure differential at every 10,000 ft. of mains
- air velocity at major facilities with airflow over 20,000 cfm

In addition to the methane and ventilation system monitoring, fire detection sensors should be incorporated into this system.

Recommended locations for additional fire detection sensors

- conveyor belt entries regardless of the use of ventilation airflow
- unattended underground equipment
- permanent underground diesel fuel storage areas
- battery charging stations
- underground shops or maintenance areas
- trolley and/or track entries
- mined-out, caved areas, such as gobs or sealed areas

With the above scheme, all longwall mines and many room-and-pillar mines in the US would need to install a continuous remote monitoring system for dangerous gases and the ventilation system. However, most small operations would not.

An atmospheric monitoring system (AMS) for gases and ventilation can be added to existing systems used at most large mining operations to monitor continuously the status and health of most major mining machinery such as operating state, power consumption, temperature, oil pressure, RPM, vibration, etc. Adding additional sensors to these existing systems to monitor gases and ventilation parameters is relatively simple. The task may involve the addition of another PLC or computer to continuously monitor the gas and ventilation sensors, record the data, and issue warnings.

An AMS using electronic sensors is recommended over a tube bundle system (TBS) for most continuous remote monitoring requirements in the active areas of underground coal mines. An AMS with electronic sensors provides real-time data about mine gases and the ventilation system, and this real-time information is necessary for explosion prevention in the active areas of mines. In contrast, TBSs do not provide real-time atmospheric composition data due to the delay time in the sample tubes, nor do they provide data about the ventilation system such as air velocity, air direction and pressure. TBS are useful in providing atmospheric data from sealed areas or bleeder systems where the use of electronic sensors is not feasible; however, other technologies based on fiber optic sensors may solve that problem in the near future.

Requiring a continuous remote monitoring and recording for dangerous gases and the ventilation system condition would likely have prevented explosion disasters such as Upper Big Branch (2010), Jim Walter Resources (2001) and Willow Creek (1998, 2000) from occurring. In many explosion disasters, the root causes most often cited as a contributing factors are inadequate ventilation and failure to detect an explosive accumulation of methane. Evidence from recent disasters also suggests that machine-mounted methane monitors and periodic methane checks with hand-held methane meters were inadequate for detecting hazardous methane accumulations before an ignition occurred. The solution for preventing explosion disasters appears to be regulations requiring continuous monitoring for methane and ventilation parameters at many more points throughout the ventilation system.

The costs for adding addition gas and ventilation-related sensors plus additional PLCs and computers to existing mine-wide monitoring systems that continuously monitor and record the status and health of mining machinery should be less than several hundred thousand dollars. The investment in mining equipment and development for a typical longwall mine is a least several hundred million dollars. Thus, the additional capital cost for the safety-related monitoring system is relatively small.

Requiring continuous remote monitoring and recording for dangerous gases and the ventilation system condition could have an adverse impact on coal production and productivity, early in the transition period, due to delays caused by alarms raised by this new system. More methane sensors producing more data are more likely to detect potentially hazardous methane concentrations that result in production delays. However, with the additional performance data, mining companies will learn to manage their ventilation systems better resulting in safer coal mines. Delays will happen early in the transition period; however, they are expected to diminish as experience is gained.

Requiring most underground coal mines to have more extensive continuous remote monitoring and recording systems will also require changes to MSHAs enforcement policies. Access to a continuous record of methane concentration and ventilation performance data should not enable MSHA to levy fines for every brief encounter of methane over 1.0%. Modified regulations may need to consider both the sensor location and the duration of adverse readings, recognizing that occasional aberrant data will be collected. One suggestion is that no methane concentrations at Level 2 and Level 3 monitors be allowed over 1.0% for more than 15 minutes at a time and no more than 60 minutes total per day, and no methane concentrations at these monitors be allowed over 2% at any time.

B7. Where should continuous remote monitoring systems be installed in underground coal mines? Please be specific as to locations and provide rationale, including the impact on miner health and safety.

The following tables and figures summarize recommended additional locations for methane, ventilation system, and fire detection sensors (CO and smoke). These safety-oriented sensors should be added onto existing monitoring systems already deployed by most large coal mining operations to monitor continuously the status and health of most major mining machinery. The system itself, consisting of controllers, computers, data management systems, and display screens should be located in the mine office (dispatcher's office) where trained and qualified monitoring staff can react to alarms as needed. The potential impact of this more extensive monitoring system is to detect increasing methane concentrations, unintended changes in the ventilation system, or a developing fire in time to correct the situation before a disaster occurs.

Tables 1 and 2 summarize the criteria and recommended locations for methane and ventilation system sensors depending on the monitoring level required – either 1, 2, or 3. Table 3 summarizes the recommended locations and type for fire sensors to be deployed in all mines.

Table 1. Summary of the three-level system for continuous monitoring of methane with AMS

Monitoring Level	Criteria	Recommended locations of required continuously-recorded methane monitors
1	In all underground coal mines,	methane monitors are required as follows: **1)** all main exhaust fans, and **2)** all bleeder fans.
2	**1)** if from a main exhaust fan, methane emission is > 500 cfm, or methane concentration is > 0.25% in any 15-minute period, or **2)** if from a bleeder fan, methane emission is > 500 cfm, or methane concentration is > 0.50% in any 15-minute period;	then, additional methane monitors are required as follows: **1)** in return air streams upstream of regulators, and **2)** in return air streams upstream of major junctions, and **3)** in belt entries near the mouth of working sections, and **4)** in travelable bleeder air streams upstream of junctions, and **5)** in return air streams near a longwall tailgate.
3	**1)** if upstream of a return air regulator, methane emission is > 200 cfm, or methane concentration is > 0.25% in any 15-minute period, or **2)** if upstream at a return air junction, methane emission is > 200 cfm, or methane concentration is > 0.25% in any 15-minute period, or **3)** if in a belt entry from a working section, methane emission is > 200 cfm, or methane concentration is > 0.25% in any 15-minute period, or **4)** if upstream travelable bleeder air junction, methane emission is > 500 cfm, or methane concentration is > 0.50% in any 15-minute period, or **5)** if in return air near a longwall tailgate, methane emission is > 200 cfm, or methane concentration is > 0.25% in any 15-minute period;	then, additional methane monitors are required as follows: **1)** in return air streams near the last permanent stopping of each working section if more than 3,000 feet from the return air regulator, and **2)** at multiple locations (i.e 5) along a longwall face under the shields and close to the face, and **3)** down-stream of each set of permanent seals or at least every 10^{th} seal in a set.

Table 2. Summary of the three-level system for continuous monitoring of ventilation with AMS

Monitoring Level	Criteria	Recommended locations of required monitors
1	**1)** if mine total airflow exceeds 200,000 cfm, and/or **2)** if mine liberates more than 200,000 cubic feet of methane or other explosive gases during a 24-hour period	Monitors are required as follows: **1)** air velocity and pressure at all main fans or at main returns and **2)** air velocity and airflow direction at all separated belt entries at the point of lowest measured air velocity **3)** atmospheric barometric pressure, temperature, and humidity on surface
2	**1)** if mine total airflow exceeds 500,000 cfm, and/or **2)** if mine liberates more than 500,000 cubic feet of methane or other explosive gases during a 24-hour period	then, additional monitors are required as follows: **1)** air velocity at development panel regulators or in the drift directly prior to the regulator, and **2)** air velocity and pressure at bleeder fans, and **3)** air velocity at longwall intakes
3	**1)** if mine total airflow exceeds 1,000,000 cfm, and/or **2)** if mine liberates more than 1,000,000 cubic feet of methane or other explosive gases during a 24-hour period	then, additional monitors are required as follows: **1)** pressure differential at every 10,000 feet of mains **2)** air velocity at major facilities with airflow over 20,000 CFM

Table 3. Summary of fire detection locations, regulations, and sensors for AMS system.

Location	Mandatory Sensor	Alternative and/or Recommended Sensor	Location Specifics
Conveyor belt entries when the ventilation airflow in the entry is used to ventilate a working section	CO	Smoke	Located at distances no greater than 100 feet downstream of a conveyor belt drive and/or belt take-up, transfer point or tailpiece; at subsequent intervals not to exceed 1000 feet
Conveyor belt entries regardless of the use of ventilation airflow	CO	Sensors responding to radiation, smoke, gases, or other indications of fire as long as such sensors provide protection equivalent to CO sensors	Located at distances no greater than 100 feet downstream of a conveyor belt drive and/or belt take-up, transfer point or tailpiece; at subsequent intervals not to exceed 1000 feet
Unattended underground equipment	Heat	Optical flame sensor and CO or smoke sensor	CO or smoke sensor near the roof in the entry downstream of the equipment at a distance of 150 to 200 feet
Permanent underground diesel fuel storage areas	None	Heat or optical flame sensor for primary and CO or smoke sensor as backup	CO or smoke sensor near the roof in the entry downstream of the equipment at a distance of 150 to 200 feet
Mobile diesel-powered equipment and fuel transportation units	None	On-board heat or flame sensor	Some method to keep track of location for AMS
Battery charging stations	None	CO or smoke sensor	Near the roof at locations both near the exhaust that goes into the return and in the entry just downstream of the battery charging area
Underground shops or maintenance areas	None	Heat or optical flame sensor for primary and CO or smoke sensor as backup	CO or smoke sensor near the roof in the entry downstream of the area at a distance of 150 to 200 feet
Trolley and/or track entries	None	CO or smoke sensors	Spaced along such entries at intervals not to exceed 1000 feet.
Mined-out, caved areas, such as gobs or sealed areas	None	Tube bundle system	Analysis at central, above-ground location for CO, CO_2, O_2, and CH_4

Figure 1 is a schematic for a typical longwall mine with a bleeder system, a sealed area and two continuous miner development sections. The figure shows the ventilation system including a main mine fan and bleeder fan, intake, return and belt entries, plus seals, stoppings, overcasts and regulators. The figure also shows Level 1, Level 2 and Level 3 monitoring sensors for methane, air velocity, air direction and pressure differential plus various fire sensors. Figures 2 through 7 show details of key parts in this schematic including longwall tailgate area (Figure 2), gateroad development area (Figure 3), mains development area (Figure 4), bleeder entries (Figure 5), near a battery charging station (Figure 6), and near seals and a diesel fuel storage area (Figure 7).

To summarize the number of sensors required in this schematic (Figure 1), all mines would have weather sensors recording the barometric pressure, temperature and humidity at the surface near the mine intakes. All mines would have additional fire sensors, and in this example, 10 carbon monoxide and 5 heat and flame sensors are required. If the mine were prone to spontaneous combustion, a tube bundle system is shown in Figure 1 to monitor 12 points in sealed areas and the bleeder entries of active gobs.

The total number of methane, air velocity, air direction and differential pressure sensors required depends on the monitoring level required. All mines would have Level 1 monitors, and in the example mine shown in Figure 1, 2 methane sensors, 2 air velocity sensors, 1 air direction sensor, and 2 differential pressure sensors are required. If the mine required Level 2 monitoring, then an additional 13 methane sensors, 7 air velocity sensors, 3 air direction sensor, and 2 differential pressure sensors are required. If the mine required Level 3 monitoring, then another 14 methane sensors, and 2 more differential pressure sensors are required.

In the worst case (Level 3 monitoring required), the example mine shown in Figure 1 requires about 66 total sensors for the weather (3), fire (15), methane (29), air velocity (9), air direction (4), and differential pressure (6). The total cost for the 66 sensors shown for this example mine is not expected to exceed several hundred thousand dollars, which is small relative to the total investment in a longwall mining operation.

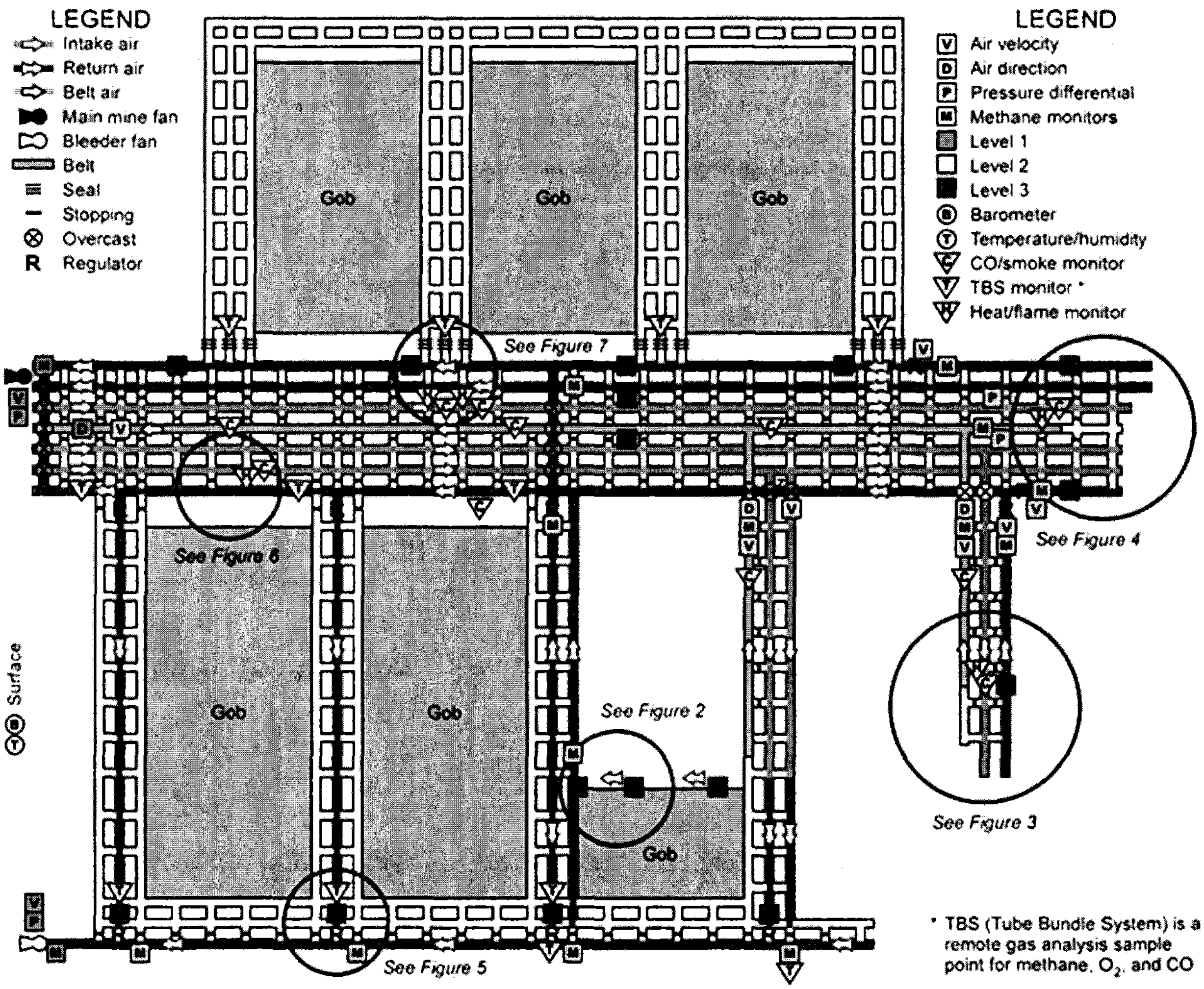

Figure 1 – Schematic of typical underground coal mine showing proposed AMS fire, methane and airflow monitoring locations.

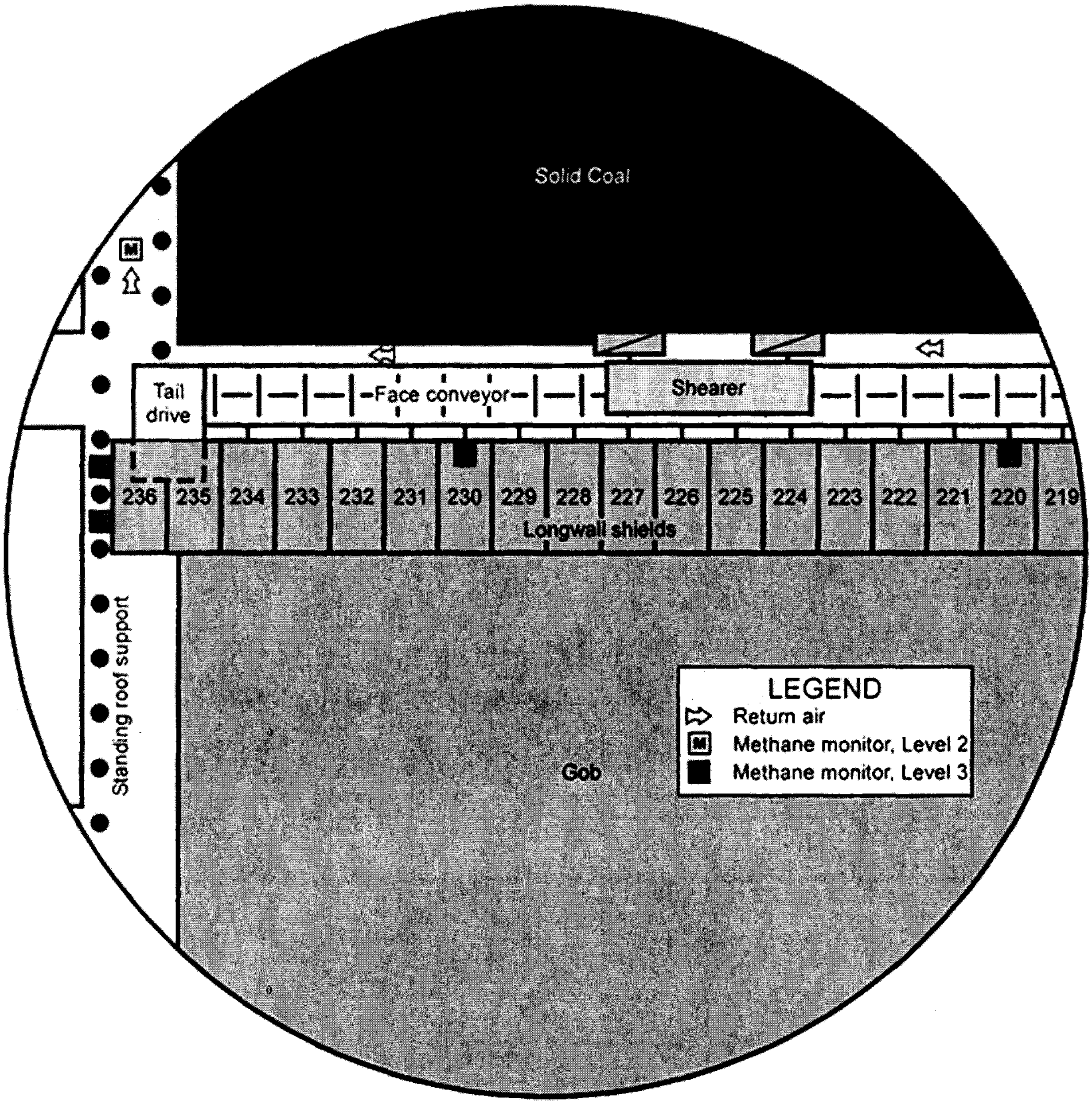

Figure 2 – Schematic of longwall tailgate area showing proposed methane monitors.

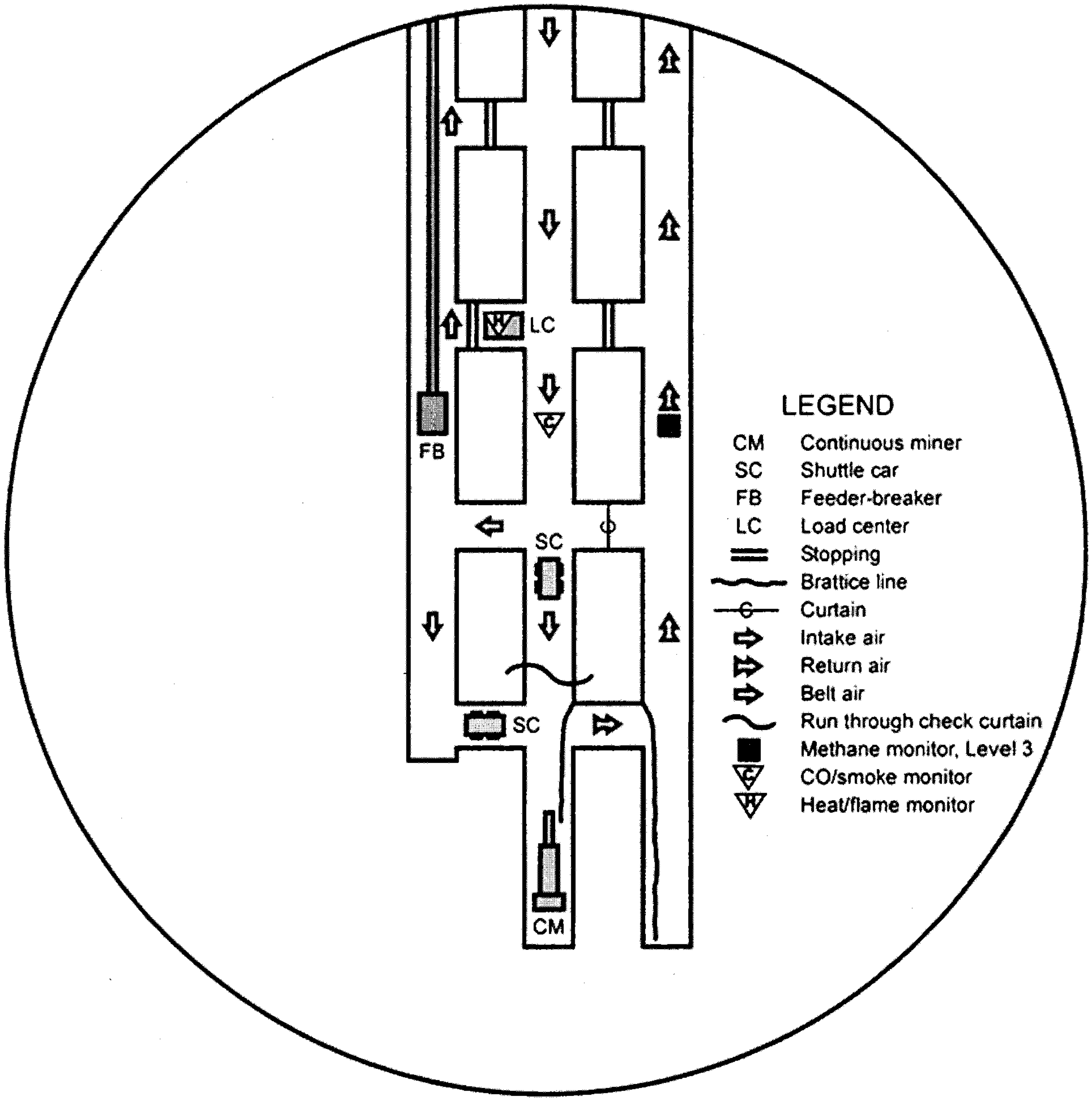

Figure 3 – Schematic of gateroad development area showing proposed methane CO/smoke, and heat/flame monitoring locations.

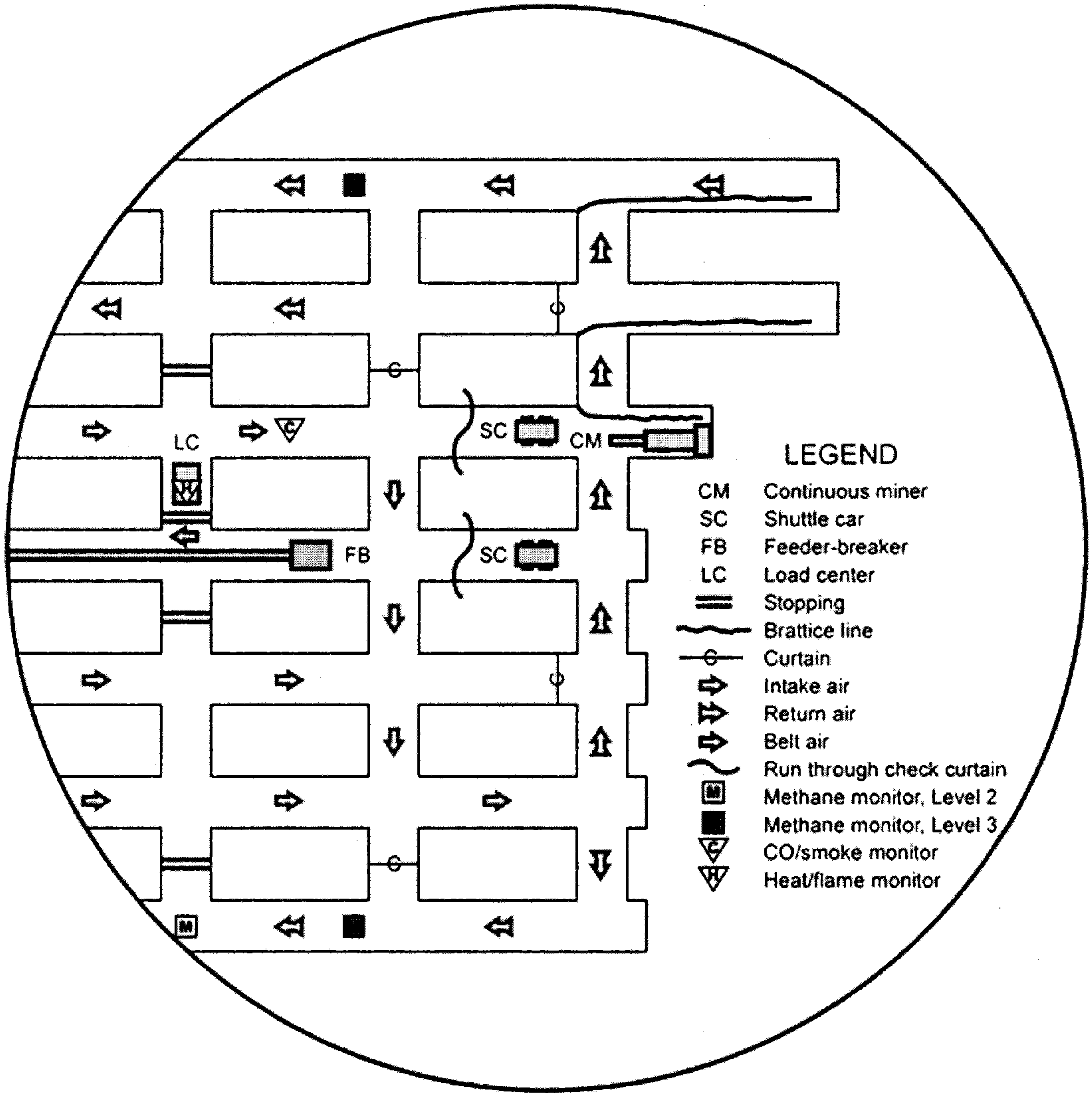

Figure 4 – Schematic of room-and-pillar development area showing proposed methane, CO/smoke, and heat/flame monitoring locations.

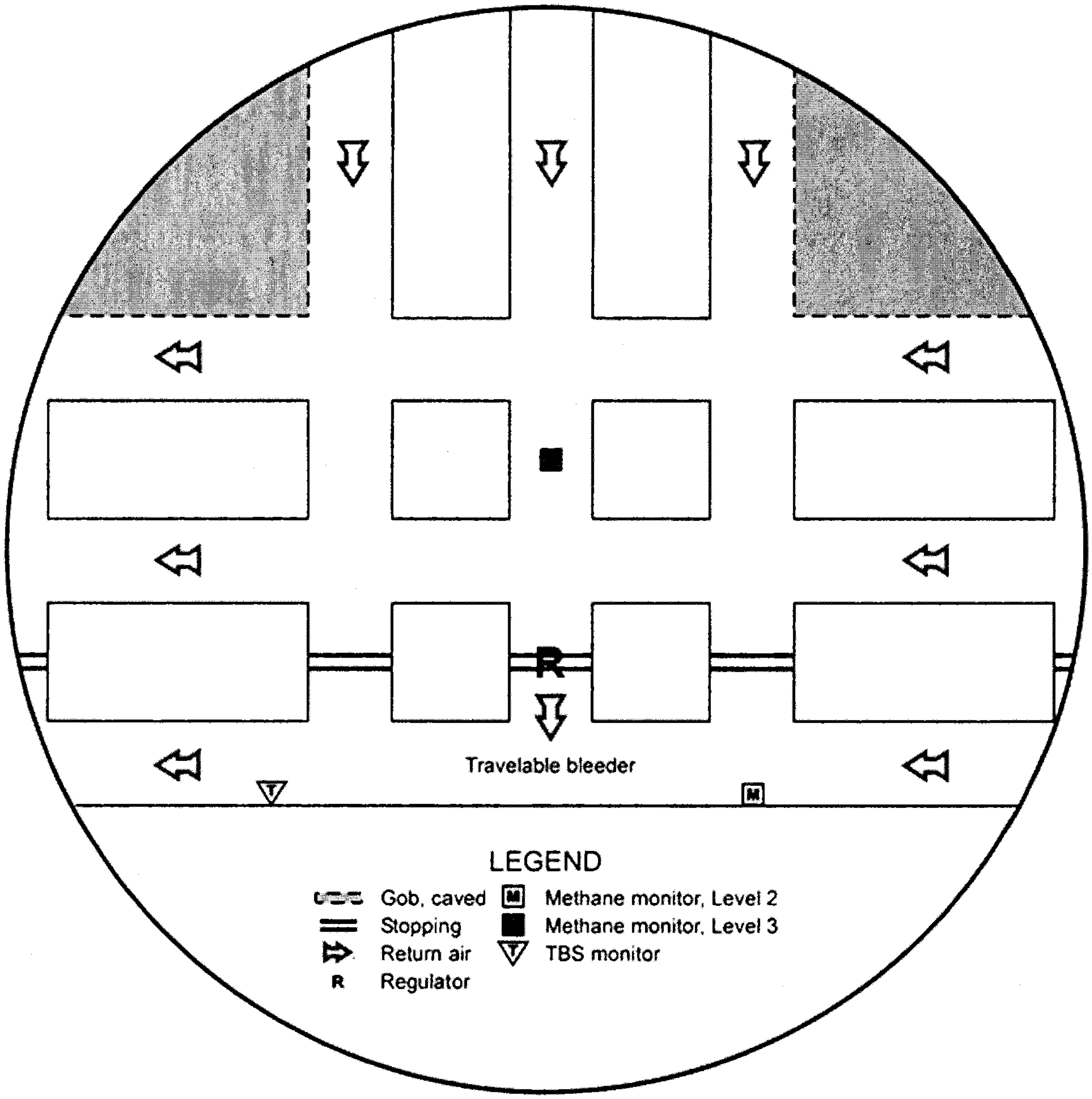

Figure 5 – Schematic of bleeder area airstreams showing proposed tube bundle and methane monitor locations.

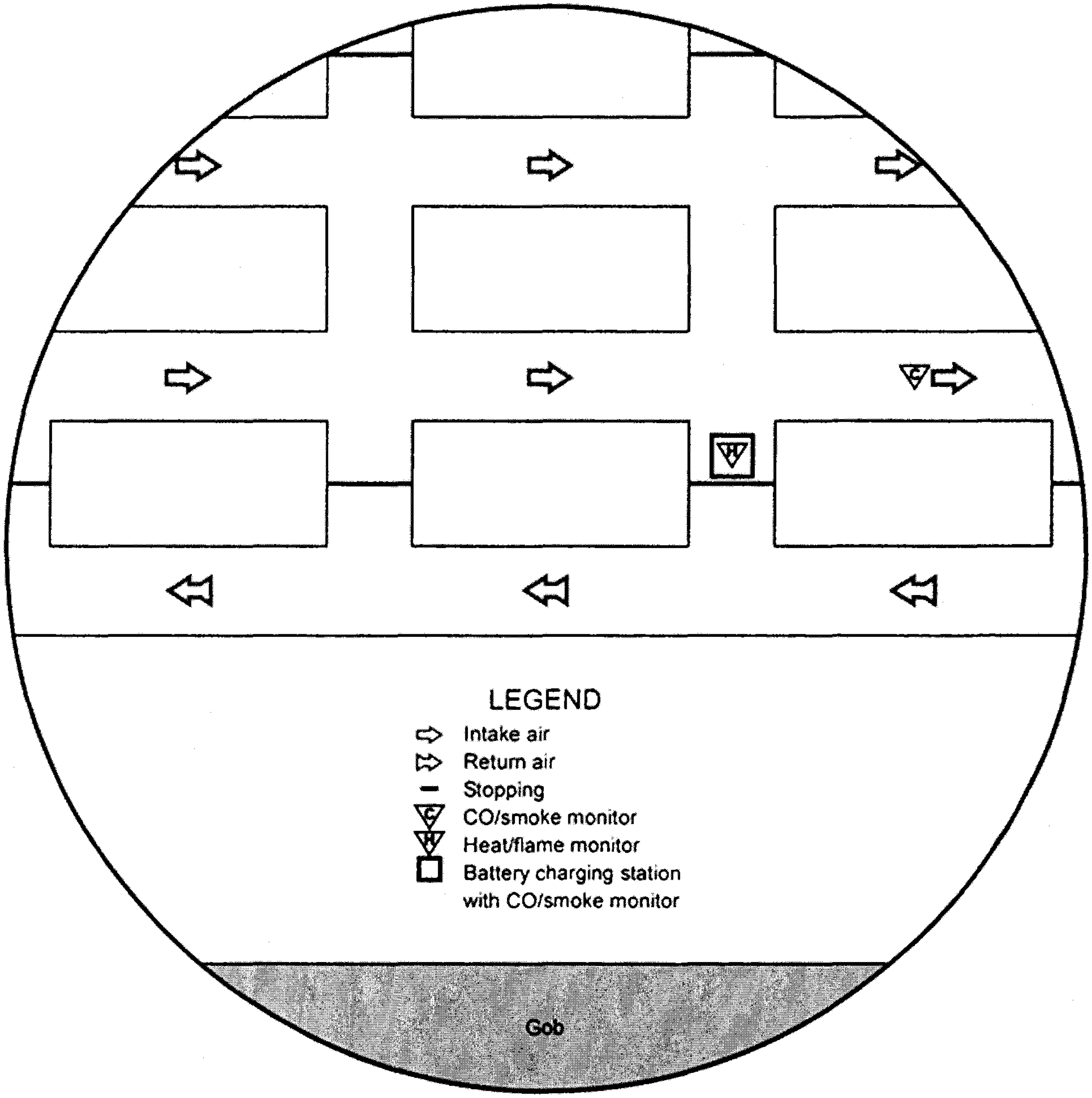

Figure 6 – Schematic of location of battery charging station and heat/flame monitor.

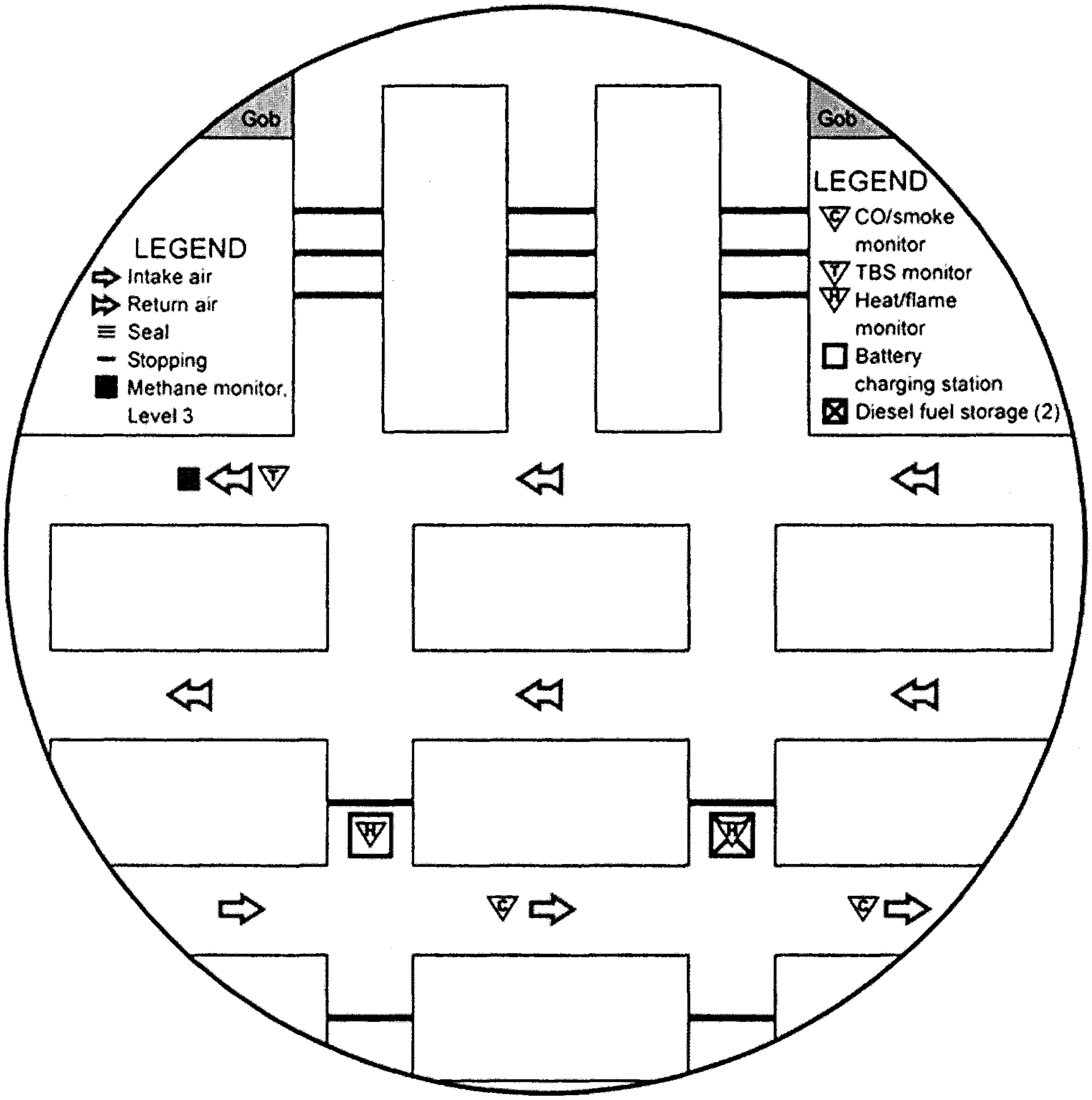

Figure 7 – Schematic of intake and returns showing diesel fuel storage area, battery charging station, and permanent seals and associated CO/smoke, heat/flame, methane, and TBS monitoring locations.

B8. Under what conditions should additional gas monitoring sensors and sensors that measure air velocity and direction be used to monitor the longwall face and its tailgate corner to minimize accumulations of methane, other gases, and dust? Where should these sensors be located?

Figures 1 and 2 above show the suggested additional monitors for methane and ventilation of a longwall face. Most longwall mines would likely need a Level 2 methane monitor located in the tailgate airstream just ahead of the approaching longwall face. Most mines would also need Level 2 ventilation system monitors including air velocity sensors in the longwall intake air, along with air velocity, air direction and methane monitors along the longwall belt near the panel mouth. If potentially large quantities of methane are detected or anticipated, then the mine may need several Level 3 methane monitors along the longwall face above the walkway under the shields about 1 foot from the canopy. The intent of these methane detectors is to provide early warning of a developing methane inundation due to barometric pressure change, roof fall in the gob or some other cause, before the flood of methane is ignited by the shearer. Existing methane monitors mounted on the shearer body as per the current regulations may have failed to detect these incoming methane bodies in time, which may have led to explosion disasters such as Upper Big Branch, Willow Creek and others.

With the addition of the Level 3 early warning methane sensors along the longwall face, MSHA may need to adjust its enforcement policies for these sensors. It is reasonable to expect that these monitors may record methane concentrations greater than 1% at certain times for some unknown period of time. Suggested allowable methane concentration at these sensors are

1) less than 2% at all times,
2) between 1 and 2% for no more than 15 minutes at a time and no more than 60 minutes total per day.

B9. What are the advantages, disadvantages, and costs of continuously monitoring the underground coal mine environment for accumulations of gases, air velocity, and airflow direction?

The continuous monitoring system should verify that the ventilation system including air velocity and air direction in each ventilation circuit is performing at all times as designed in the approved ventilation plan and that it is diluting potentially dangerous gases to acceptable concentrations. The advantage of a continuous monitoring system is mine safety. With more rigorous continuous atmospheric monitoring systems in place, explosion disasters such as Upper Big Branch can be eliminated from US coal mines. The disadvantage of continuous monitoring is 1) accountability due to a record of ventilation system performance and 2) production interruptions due to false alarms.

A continuous record of ventilation system performance along with the associated record of methane concentration at many points throughout the ventilation system could become a tool to hamper underground coal mines, if the data were overused by MSHA. With increased monitoring, we will likely observe and record methane concentrations greater than 1% and potential problems with the ventilation system. The coal industry and MSHA need to use this

data constructively to improve the safe operation of ventilation systems. The data should not become a tool for MSHA to prosecute coal mine operators for every observed problem with the ventilation system. If a problem is observed, companies should be allowed to address it promptly without fear of a citation.
Continuous monitoring systems could adversely affect mine productivity. Problems with ventilation system performance and high methane concentrations will be detected, and these readings could temporarily shut down production until the problem is addressed. These problems will occur early during the transition to continuous monitoring systems, but they will likely decrease as the coal industry gains experience with the systems.

B10. How could continuous remote monitoring technology be linked to communication and tracking technology to form an integrated monitoring system? Please explain.

Continuous remote monitoring systems for gases and the ventilation system should be added onto existing systems used at most large mining operations to continuously monitor the status and health of most major mining machines such as shearers, stage loaders, conveyor drive motors, and power centers. If the system detects something dangerous such as high methane concentration or air velocity decrease, the system attendant such as the dispatcher should notify personnel for appropriate action. The dispatcher could utilize the miner communication and tracking technology system if the situation warrants.

B11. How can integrated monitoring systems be linked to machine-mounted monitors? What are the advantages, disadvantages, impact on miner health and safety, and costs of integrated monitoring systems?

The continuous remote monitoring system for gases and the ventilation system should be built onto existing monitoring systems for production equipment. The existing machine-mounted monitors for methane should be linked into this same system.

B12. What types of continuous remote monitoring systems can continue to safely operate and function after an explosion, fire, or any other mine accident? How long can such systems operate after an explosion or fire, since power is likely to be de-energized due to the emergency? What can be done to improve the survivability and reliability of continuous remote monitoring systems after an explosion or fire?

No continuous remote monitoring systems can continue to safely operate and function after an explosion. With a system based on conventional electronic sensors as described previously, the system will not operate after an explosion due to power loss to the sensors. With a tube bundle system, the sample pumps and the analyzer will continue to function because they are located on the surface and would remain functional after an explosion. However, the explosion would likely destroy the sample lines somewhere inside the mine. Responsible personnel would have no idea where the sample was actually collected. It is possible to protect the sample lines by burial in the mine floor, but this expense is not recommended. The recommended approach is to use conventional electronic sensors to continuously monitor gases and ventilation and prevent an explosion from ever occurring.

B13. What types of technologies exist to remotely determine methane-air mixtures and other gas, dust, and fume levels in bleeders and bleederless ventilation systems, other than traditional AMS and tube-bundle systems? Please be specific and note if this technology is practical and feasible.

A tube bundle system is the most practical system for remotely monitoring methane and other gases in bleeders and bleederless ventilation systems in areas of the mine where power is not available or not permissible. Sensors based on fiber optic technology may become commercially available in the near future.