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LONGWALL VENTILATION FIELD STUDIES: A COMPARISON OF BLEEDER AND BLEEDERLESS SYSTEMS

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ABSTRACT

Researchers at the National Institute for Occupational Safety and Health (NIOSH) conducted multiple ventilation research field studies with a cooperating trona mine and two coal mines, all using the longwall mining method. For these field studies, sulfur hexafluoride (SF_6) tracer gas was utilized to define airflow pathways and air velocitiesin a longwall system. The three field sites were chosen for their varying face lengths, ventilation design, and caving characteristics. The research studies indicated that the transport of ventilation air from the headgate towards the tailgate occurs in the main face airflow, inflow within the region of the shield legs, and inflow through the fracture zone in front of the gob. The research studies also characterized the rates and direction of transport in active panel gobs. The findings suggest that ventilation of trona mines operating with the longwall mining method have similar characteristics to the ventilation of coal mines. The results discussed in this paper define the pathway of ventilation airflow in an active longwall panel, and the findings contribute directly towards improving miner safety and health.

Keywords: Mine ventilation, longwall mining, coal, trona, and tracer gas.

INTRODUCTION

In longwall mining, ventilation is considered the most effective means for controlling gases and dust. Sufficient ventilation air on a longwall face is critical for the safety and health of crews working in the face area and for meeting statutory requirements for gas and dust concentrations. In addition, airflow into the void behind the shields and into the gob may be considered as beneficial for diluting the gases and rendering them harmless (Fig. 1). However, such airflows can remove ventilation airflow from the face, thus reducing the effectiveness of controlling both dust and gases. Ventilation researchers at the National Institute for Occupational Safety and Health (NIOSH) sought to identify flow paths of ventilation airflow on longwall panels with variations in roof caving characteristics and longwall face lengths. To achieve this goal, three field sites were chosen of varying face lengths and caving characteristics—228 m (750 ft) face length with bleeder ventilation (bleeder shaft) and caving up to the shields [1], 305 m (1,000 ft) face length with bleederless ventilation and caving up to the shields [2], and 381 m (1,250 ft) face length and bridging void-space behind longwall shields [3,4]. This paper summarizes the findings from the three similar field studies at mines with different characteristics and compares the ventilation systems at a gassy trona mine and two coal mines.

In addition to the field studies, the research team also investigated the important aspects of longwall ventilation using numerical modeling and scaled physical modeling. Numerical modeling research utilized computational fluid dynamics modeling and discrete fracture network modeling concepts [5]. The physical modeling research was conducted on a 1:30 scale physical model called "Longwall Instrumented Aerodynamic Model (LIAM)" [6-8]. The findings described in this paper contribute to the overall assessment of ventilation in longwall mines.

RESEARCH OBJECTIVE

The objective of this research was to develop an understanding of the role of gas dynamics in variable broken rock and investigate airflow exchanges between the face and the gob. This paper reports on results from three field studies using tracer gas to describe face air and gob area gas movements in a longwall panel. The studies were conducted on an active panel at both underground and surface monitoring sites. The studies used sulfur hexafluoride (SF_6) tracer gas released as a slug on the longwall face and in the front of the gob inby the face. The tracer gas technique has been widely used by researchers around the world to successfully investigate mine ventilation systems. Some of the original methods and applications of tracer gas in underground mines were developed by the U.S. Bureau of Mines and by NIOSH [9-12].

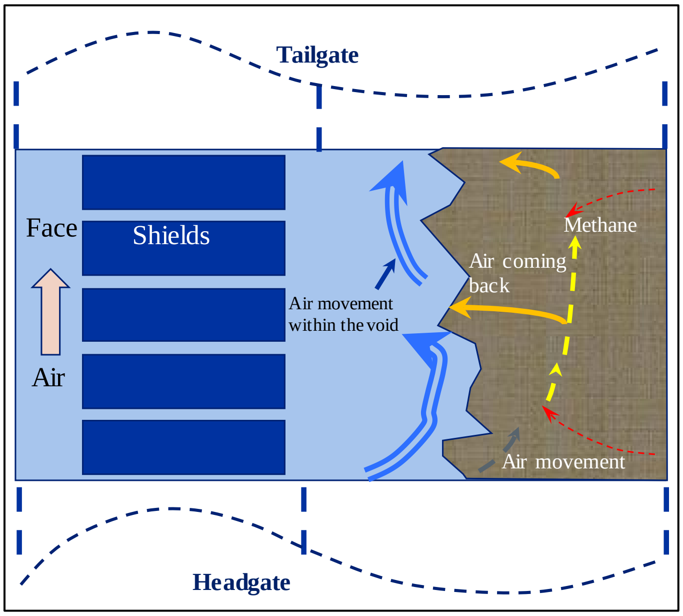

Figure 1. Schematic showing general layout of face ventilation in a longwall mine.

STUDY SITES

During a series of informal stakeholder meetings, a near unanimous concern was expressed related to the maintenance of effective ventilation airflow on longwall faces because of changing face length and caving characteristics. To study the longwall ventilation of mines with these varying characteristics, three sites were chosen. The sites are briefly described in this section and important characteristics for each site are listed in Table 1 (see APPENDIX).

Site A: Trona Mine with 224-m (750-ft) face, new field study site for NIOSH longwall ventilation study

Site A is a trona mine located in the Green River Basin, Wyoming, that uses the longwall mining method. The layout of the mine and the active longwall panel for the ventilation study are shown in Fig. 2. The face width is 224 m (750 ft) and panel length is 3,010 m (9,860 ft). The height of the mined face ranges from about 2.7 to 3.0 m (9 to 10 ft). Overburden depth is approximately 490 m (1,600 ft). The mine operator ventilates the mine with a main blowing fan and a bleeder shaft. A bleeder system is used for the longwall mining portion of the mine. The bleeder shaft is located near the study panel and provides a pathway to the surface for return airflow on the study panel. This bleeder shaft does not have an exhausting fan. Caving characteristics in relation to the study are described as normal, meaning the overburden caved up to the back of the shields immediately after the longwall shields advanced [1].

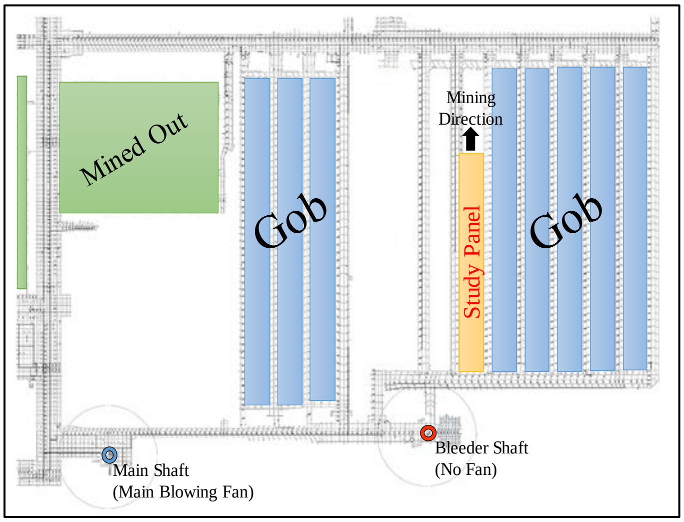

Figure 2. Site A mine map showing the study panel and previously mined-out areas at Site A.

Trona is classified as sodium sesquicarbonate and has the chemical formula $Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$. U.S. trona deposits of economic value are found in the western portion of the state of Wyoming (Fig. 3). There are as many as 40 separate beds in Sweetwater County, WY, of potential economic value. The mining of these Wyoming trona beds is done by underground methods. Room-and-pillar and longwall mining operations are both present in the Green River Basin. Trona mines are among the gassier types of metal/nonmetal mines, with certain operational characteristics, such as dilution of gob gas, that are closest to coal mines. Therefore, the researchers and the mine operator were very interested to investigate longwall ventilation in greater detail at this site. The underground trona mines in the Green River Basin are classified as gassy category III by the Mine Safety and Health Administration (MSHA), the primary federal mining regulatory agency in the United States. Methane emissions from some mines can exceed 30,000 m^3/day (1,000,000 cfd) due to the presence of organic matter in the Green River Formation oil shales. Trona mines are classified as category "3" in the MSHA regulatory scheme [13]. Some considerations for ventilating trona mines are discussed by Pritchard et. al [14]. The characteristics of longwall trona mines ultimately led to inclusion of this site in NIOSH's longwall ventilation research study.

Site B: Coal Mine with 305-m (1,000-ft) face

Site B is a coal mine located in the western United States. The mine operates in a bituminous coal seam and uses a U-type, bleederless ventilation system. The multiple panel district is ventilated by surface exhaust fans (Fig. 4). This mine had a bleederless ventilation configuration to minimize oxygen interaction within the worked-out area to reduce the potential for spontaneous combustion to occur. The overburden is variable and averaged 180 m (600 ft) in the vicinity of the longwall during the NIOSH field experiments. The overburden contains substantial thicknesses of shale and siliciclastic sedimentary units that influence mechanical failure characteristics during undermining. This appears to produce a tendency to hold up the roof in the vicinity of the face near the front of the gob. This leads to a caving characteristic with a bridging-void space present behind the longwall shields. This mine also utilizes multiple GGVs located near the active longwall face. The mine operator also has the capacity for nitrogen injection into the longwall gob, which occurred during the monitoring study [2]. A single large face release was done at this site; as one of the primary experimental questions was whether a large face release could be captured in GGVs.

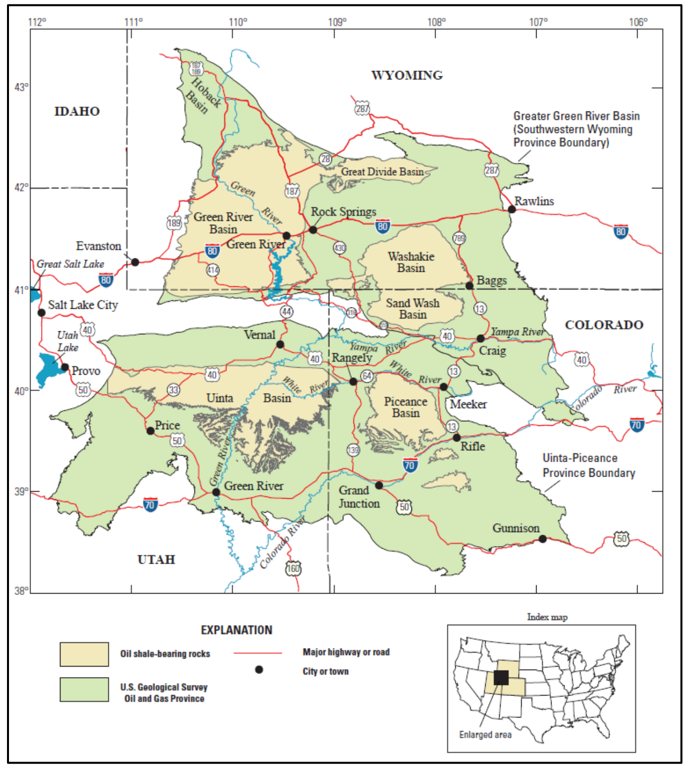

Figure 3. Green River Basin and associated major sedimentary basins in Wyoming, Utah, and Colorado, USA [15].

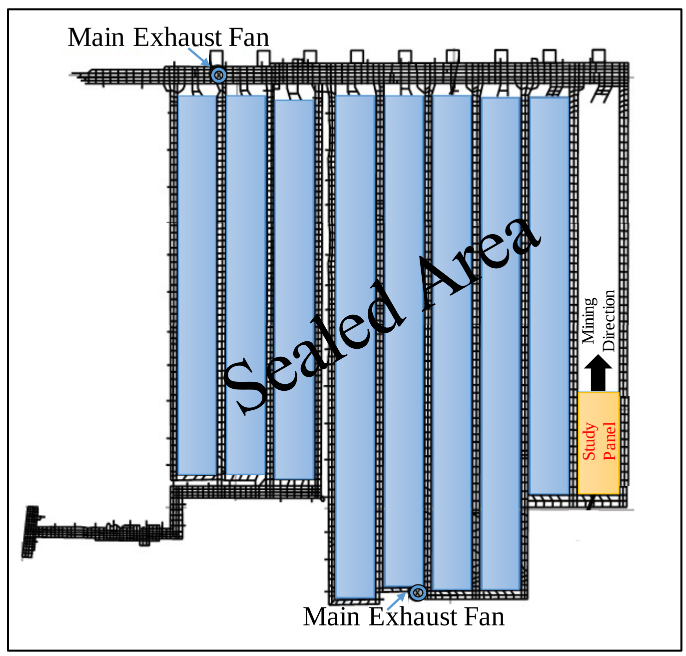

Figure 4. Site B mine map showing study panel and sealed area.

Site C: Coal Mine with 381-m (1,250-ft) face

Site C is a western U.S. coal mine located in the Bull Mountain Basin of Montana. This mine utilizes a bleederless design to ventilate its longwall panels, primarily due to the spontaneous combustion tendency of the mined coal bed that is part of the Tertiary-age Fort Union Formation. The mine layout and study panel are shown in Fig. 5. Airflow on the headgate side is in the inby direction towards the back of the panel. The overburden depth over the panel ranges from about 60 to 240 m (200 to 800 ft), making the panel design supercritical in terms of rock mechanics. The caving behavior at this mine is defined as normal, with gob caving up to the shields as the face retreated.

Nitrogen (N_2) injection is utilized on the active longwall panels by the mine operator. The N_2 is injected into the gob of the active panel from a surface plant which produces gas of > 95% purity. This gas is pumped underground to a pipeline located in the headgate entries of the active panel [3-4].

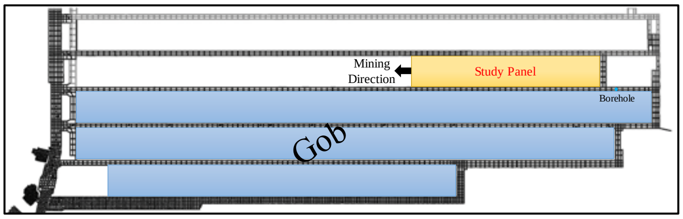

Figure 5. Site C mine layout and study panel.

TRACER GAS EXPERIMENTAL METHODOLOGY

The general concept of gas flow characterization experiments is to release a defined volume of a tracer gas into the ventilation airflow or longwall gob and then monitor all potential exit points for arrival of that gas. For these studies, SF_6 tracer gas was released in two separate monitoring experiments. One test was focused on airflow along the longwall face of the active panel, while the second test focused on gas transport in the mined-out portion of the same panel. This approach permitted the volumes of the tracer gas released and the duration of monitoring to be optimized for each test. The methodology for this tracer gas approach has been described in greater detail in previous publications by the U.S. Bureau of Mines and NIOSH [9-12]. In this paper, Site A and C had two separate gas releases, while Site B had one gas release.

Gas Release

At these sites, tracer gas was released from lecture bottles, each containing roughly 34 L (1.2 ft^3) of high-purity SF_6 at 101.325 kPa and 0°C. The SF_6 gas was released in a rapid short-term fashion (slug), and its migration through the mine was tracked by sampling at different monitoring stations. For the face test, SF_6 was released for about two seconds near mid-height in the leg of the first shield on the headgate side. For the gob test, a larger quantity of SF_6 was released a few crosscuts inby the face on the headgate side. The SF_6 release volume for the gob test was much greater than that for the face test to achieve detectable and measurable gas concentrations in the gob. There was an exception to this approach at site B. At site B only one large release was done to see whether tracer gas could be captured in GGVs. These release volumes were determined by calculating the released mass and further corrected for underground ambient temperature and pressure conditions using ideal gas law conversions.

Gas Sampling

The tracer gas samples were collected in evacuated 15-ml glass vials at each monitoring station by manual sampling of ventilation air drawn through polyethylene tubing. The tubing was 0.95 cm (0.38 in.) ID and 1.3 cm (0.5 in) OD in size and was attached to permissible Aircheck 224-44XRM vacuum pumps (SKC, Inc.). The time of sampling was corrected for the transit time through the tubing lines using the pump velocities and lengths of tubing. This sampling method has also been reported previously [16-17].

For the face test, the tubing inlets were positioned on the long axis of the centerlines of shields at 5%, 25%, 50%, 75%, and 95% of the face length. Sampling was also conducted at two additional near-face monitoring locations approximately one crosscut inby and outby the working face in the tailgate gateroad. The initial sampling interval was two per minute on each of the face test tubing lines for the first 30 minutes. Sampling became less frequent for the duration of the test to one sample every 10 min for the last 30 min. The overall duration of monitoring for the face test was approximately four hours.

For the gob test, samples were retrieved at several locations around the active panel including headgate inby and outby the face, tailgate inby and outby the face, headgate and tailgate bleeder entry, and bleeder shaft on the surface if present. Depending on the monitoring location, the samples were collected more frequently at an interval of every 15 minutes to less frequently at an interval of every 45 minutes. The gob test ran for five days, one shift per day.

Gas Analysis

Samples collected during the field studies were analyzed for SF_6 concentrations by gas chromatography (GC). Samples were drawn from the bottle samples and analyzed using a modification of NIOSH Method 6602 using a Shimadzu GC8 with an electron capture detector [18]. The limit of quantification for the GC method is about 1 ppb SF_6 in air.

RESULTS AND DISCUSSION

Site A: Trona Mine with 224-m (750-ft) face

Face Test. The face test was conducted during a daylight nonproduction shift on the first day of the field study. During the duration of this test, the shearer was positioned at the zero entry. The tracer gas (SF_6) was released for about two seconds near the leg of the first shield on the headgate side (Fig. 6). The released volume of SF_6 was 0.35 L (0.012 ft^3), determined by the released mass and corrected for underground temperature and pressure conditions.

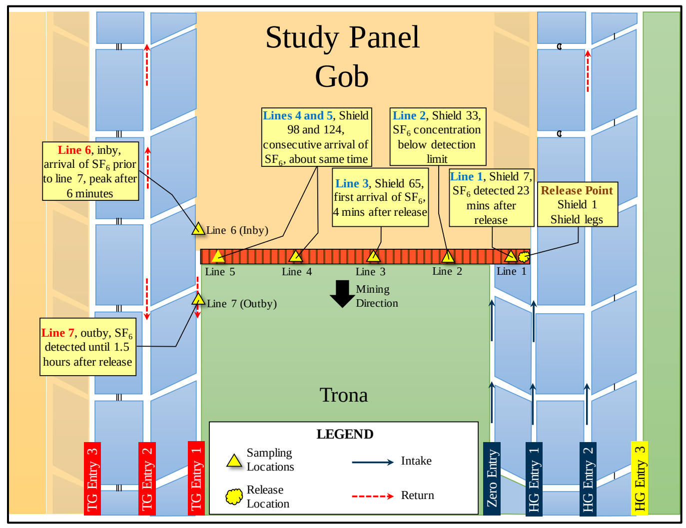

Figure 6. Site A face test, ventilation configuration, and sampling locations.

The sampling locations and tracer gas arrivals are shown in Figure 6. The sampling location closest to the release point was line 1; however, tracer gas was not measured here until 23 minutes after release. Such behavior is thought to be representative of tracer gas residing in the gob for a period before flowing back on the face. On line 2, a detectable amount of tracer gas was not seen throughout the duration of the sampling period. The lack of tracer gas at line 2 may be the result of the influx of fresh air in the zero entry. Line 2 was the first sampling location on the face inby the zero entry. The intake airflow in zero entry was measured at 33.5 m^3/s (71 kcfm), and this air mixed with the existing intake air from headgate entry number 1. Tracer gas movement at line 2 was likely affected by the flow of gas in the zero-entry entering the face airflow. The first measured arrival of tracer gas was seen at line 3, approximately four minutes after the release of gas. The first peak (movement of released slug) also appears first at this location. This behavior of tracer gas suggests that a portion of air from the release location traveled in a region behind the shield line and reached the mid-face region first. The tracer gas arrived at lines 4 and 5 at approximately the same time, four minutes after the release. The last occurrence of SF_6 was measured 20 minutes after release for both locations. Such gas behavior indicates transport from the release point to the tailgate end of the face through an undefined pathway. The gas stayed on the face for 20 minutes at lines 4 and 5 on the tailgate side of the face.

Line 6 was located one break inby the face in the former number 1 tailgate gateroad. Line 7 was located one break outby the face. The tracer gas arrived at line 6 prior to arriving at line 7. The concentrations measured for these arrivals and peaks were higher for line 6 than line 7. On line 6, the peak was recorded six minutes after the time of release. The determined concentrations for line 7 were intermittent and the peak was recorded 54 minutes after the time of release. At line 7, there were measurements of SF_6 above 1 ppb until 1.5 hours after the release, which may indicate residence time within a portion of the gob. Such behavior demonstrates rapid movement of tracer gas to line 6 and a longer duration of tracer gas at line 7.

Gob Test. The gob test was conducted for a duration of five days at Site A. The operator was mining on the evening 8-hr shift and NIOSH staff were monitoring during the daylight shift. Only one shift per day was monitored during the study. For this test, the tracer gas release was designed to be much greater than the face release to account for dilution in the gob; to achieve this, 92.1 L (3.25 ft^3) SF_6 was released two crosscuts inby the face on the headgate side, at crosscut 20 (Fig. 7).

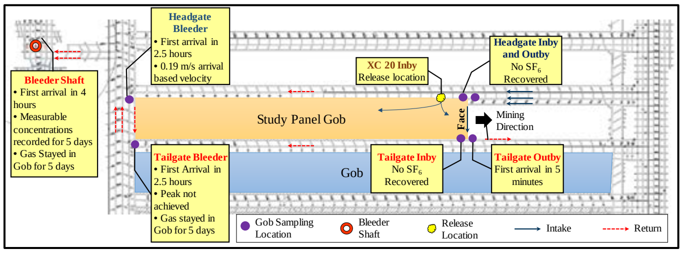

Figure 7. Site A gob test sampling locations and results.

First Arrival, 5 minutes after release: Tailgate Outby

The samples at this monitoring location were collected in tailgate entry #1 at crosscut 16, one break outby the face. Tracer gas arrived at this location five minutes after the release. The recorded concentrations throughout the duration of testing were quite low, on the order of 3 ppb. Low concentrations of tracer gas at the tailgate outby location show that only a small portion of tracer gas mixture moved along this path. Tracer gas was present on both day 1 and day 2 of testing. A possible explanation for such behavior is that the gas moved outby from the release location towards the face and eventually mixed with face air flowing towards the tailgate. However, the focus of this test was on gob gas transport and potential face air interaction. Without gas sampling on the face during this test, the exact path of near-face movement is not known. The lower concentrations recorded are due to high airflow on the face and tailgate outby. The velocity based on arrival times for this monitoring location is approximately ~0.91 m/s (~180 fpm). Caving was observed up to the shields during this testing.

No Gas Recovered: Tailgate Inby, Headgate Inby and Outby

During the duration of testing, tracer gas was not measured at the tailgate inby location. Based on the large quantity of air moving inby on the tailgate side and low concentrations of tracer gas on the outby side, it is highly probable that tracer gas was present at this location but that the concentration was below the detection limit of the gas chromatograph. The samples were collected in headgate entry number 1 at crosscut 17 on the inby side of the face and crosscut 16 on the outby side. No tracer gas was measured at this location during the duration of the testing. Based on the release location, it was considered unlikely for the gas to be present here since air was moving primarily from the headgate side to the tailgate side or towards the bleeders.

Gas arrived 2.5 hours after release: Tailgate Bleeder and Headgate Bleeder

The tailgate bleeder sampling was done at the intersection of the back-bleeder entries and tailgate entry number 2. The first arrival of tracer gas was recorded after approximately 2.5 hours of release time. The concentrations on day 1 at this location were lower compared to the concentrations at the headgate bleeder location, as the airflow was higher on the tailgate side. The air at the headgate bleeder sampling location moved towards the tailgate bleeder sampling location, as shown in Fig. 7. At this location, except for the first day, measurable concentrations on the order of 2 ppb were recorded for four days of sampling. This indicates that a portion of the gas stayed within the gob, though moving at a slow rate.

Fig. 7 shows the sampling location at the headgate bleeder in the back of the panel. SF_6 arrived at the inby bleeder location on the day of the release. The concentration was 24.6 ppb, which quickly increased to 467.4 ppb in the next two hours. For study days 2 and 3, the concentrations were mostly the same order of magnitude, around 10-15 ppb. For study days 4 and 5, the concentrations decreased to the 3-7 ppb range. On day 5, the last day of the study, SF_6 concentrations were on the order of 3 ppb suggesting that the tracer gas stayed within the gob. Using this data, the arrival-based velocity was calculated. The primary path of tracer gas movement from this release location was towards the back of the panel at a velocity of 0.19 m/s (37 fpm).

Gas arrived 4 hours after release: Bleeder Shaft

The gas samples were taken at the top of the bleeder shaft located at the back of the panel. The tubing inlet was approximately 3 m (10 ft) below the shaft collar. The arrival and peak of SF_6 at the surface site occurred on day 1. The gas arrived approximately four hours after the release of SF_6, and the peak concentration was observed approximately seven hours after the release. Decreasing concentrations were measured from this site for the rest of the monitoring period with an average concentration of approximately 2 ppb. The measurements at this location and the bleeder locations confirm that a portion of the tracer gas stayed within the gob, as was indicated from both sampling locations in the bleeders.

Site B: Coal Mine with 305-m (1,000-ft) face

At Site B, 80.7 L (2.85 ft^3) of SF_6 was released on the headgate side of the face (Fig. 8). There was a presence of void space behind the shields during the study, but the void dimensions were not known. The tracer gas sampling was conducted on the face, inby and outby the tailgate and on the surface at the top of the GGVs near the face. The GGVs at the study site are drilled deep enough to penetrate the longwall gob caved zone which may allow for increased connectivity to the void space behind the longwall shields, creating a potential pathway for the movement of tracer gas. The tracer gas arrived at line 1 (shield 57) and 2 (shield 119) at essentially the same time (2 minutes after release), with peak concentrations at line 2 (4 minutes after release) prior to line 1 (6 minutes after release). The sequence of arrivals and peaks at locations 1 and 2 is likely the product of multiple migration pathways in front of and behind the shield line from the release point to the shield 57 and 119 tubing inlets. Tracer gas arrived at lines 3 and 4 at the same time (6 minutes after release) and peaked in the same minute (6.5 minutes after release).

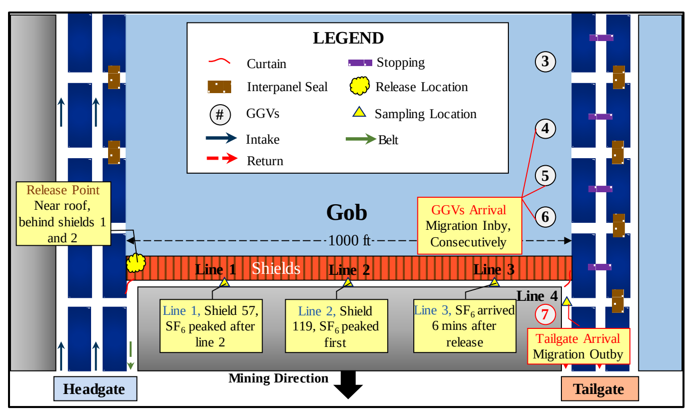

Figure 8. Site B ventilation configuration and sampling locations.

For the gob test, 160 L (5.7 ft^3) of SF_6 was released through a mine seal at headgate crosscut 73 between entries 2 and 3. Fig. 9 shows the monitoring locations for the gob test. The tracer gas first arrived at seal 75, within 30 minutes of the release. The peak concentration at this location was measured 3 hours after the release. As expected, the primary movement of the tracer gas slug was inby from the release location. However, some tracer gas was also retrieved at seal 70, 3.5 hours after the release. The slower transport time and decreased concentration at seal 70 versus 75 is thought to be related to the spread and dispersion of the tracer gas slug in the gob. The sampling location at seal 65 saw much less SF_6 concentrations, 36 ppb compared to 3,200 ppb at seal 75. Data from inby the set of seal locations 87, 92, and 97 showed that the tracer gas did not arrive during the first shift after the release. On Day 2 of the monitoring, the tracer gas was detected at all three sampling sites. The peak concentration at seal 87 was measured 24 hours after the release on Day 2, and peak concentrations at seals 92 and 97 were measured on Day 3. Data was also collected at the borehole near the back of the panel. The tracer gas arrived on Day 2 of the monitoring period but continued to rise over the rest of the duration of the test, and the peak could not be recorded during the monitoring period as the concentration was on the rise during the last day. Gob test results suggest rates of movement of the tracer gas on the headgate side of the gob. Gas transport from seal 73 to seal 97 indicates an average velocity of 0.019 m/s (3.7 fpm). The gob tracer gas test did document the slight movement of tracer gas towards the active panel face from a location inby the face near the headgate gateroad. This behavior was observed despite the predominant pattern of tracer gas movement toward the back of the panel.

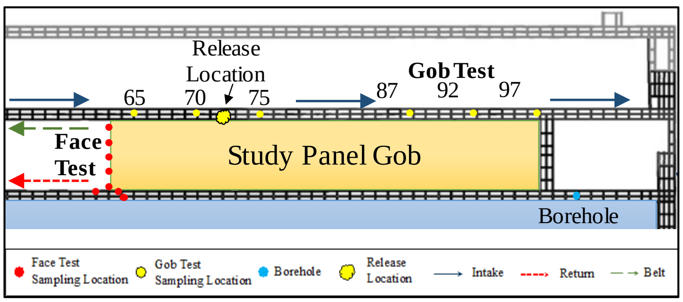

Figure 9. Site C gob test sampling locations.

SUMMARY AND CONCLUSIONS

The findings from the three tracer gas studies at trona and coal longwall mines are summarized in Table 2 (see APPENDIX). The findings suggest that ventilation of trona mines operating with the longwall mining method have similar characteristics to the ventilation of coal mines. The three tracer gas studies investigated the potential airflow losses of ventilation air off longwall faces. Additional ventilation pathways of movement were characterized, and interaction of the front of the gob and longwall face was also addressed by this extensive research effort. The three field studies complemented each other to improve the understanding of longwall mine ventilation. The research studies indicated that transport of ventilation air from the headgate towards the tailgate occurs in the main face airflow, in movement within the region of the shield legs, and in movement through the fracture zone in front of the gob. The research studies also characterized the rates and direction of transport in active panel gobs.

Sufficient ventilation air on a longwall face is critical for the safety and health of crews working in the face area and to meet statutory requirements for gas concentrations. NIOSH conducts research to minimize risks of mine disasters, such as those that may arise due to inadequate ventilation on longwall mining faces. Therefore, quantitative assessments like those discussed in this paper can allow the operator and regulatory agencies to improve the longwall design parameters for controlling gas on the face and in the gob, and hence, improving the overall health and safety of miners working in longwall mines.

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DISCLAIMER

The findings and conclusions in this paper are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. Mention of any company or product does not constitute endorsement by NIOSH.

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APPENDIX

Table 1. Important characteristics of the three field study sites.

Characteristic	Site A (Longwall Trona Mine)	Site B (Longwall Coal Mine)	Site C (Longwall Coal Mine)
Face width	224 m (750 ft)	305 m (1,000 ft)	381 m (1,250 ft)
Panel length	3,010 m (9,860 ft)	3,650 m (12,000 ft)	6,250 m (20,500 ft)
Mining height	2.7 to 3.0 m (9 to 10 ft)	2.1 m (7 ft)	2.2 m (7.2 ft)
Average overburden depth	490 m (1,600 ft)	180 m (600 ft)	Varies between 60 to 240 m (200 to 800 ft)
Bleeder/Bleederless	Bleeders (bleeder shaft)	Bleederless	Bleederless
Gob Gas Ventholes (GGVs)	No	Yes	No
N_2 injection	No	Yes	Yes
Blowing/Exhausting Ventilation	Blowing	Exhausting	Blowing
Caving characteristics	Normal (caving right up to the shields)	Bridging-void space	Normal (caving right up to the shields)

Table 2. Comparison of Trona Mine (Site A) versus Coal Mine (Sites B and C) Ventilation Systems.

Characteristic	Trona Mine (Site A)	Coal Mine (Site B)	Coal Mine (Site C)
Face ventilation	Tracer gas arrivals and peaks suggested movement either in shield legs or the active panel gob from headgate corner to mid-face location and to the inby tailgate location. Persistence of SF_6 on the face for 2 hours indicated residence time within a portion of the gob near the face.	The tracer gas arrival and peak time implied that the movement of air at the face was influenced by void space and gob permeability. This mine had a persistent void space with bridging caving behavior behind the shield line which adds to further redirection of airflow from the face.	Tracer gas arrived and peaked at shield 47 before shield 9. The tracer gas arrived at other locations on the face in the order of distance traveled. Tracer gas arrived within 5 minutes of release at the tailgate inby location. The data indicated that the movement of air occurred both in the main face airflow and in movement through the gob.
Gob ventilation and rate of transport	The tracer gas indicated a rapid path of movement, 0.19 m/s (37 fpm), from inby the face on the headgate side to the bleeder locations and bleeder shaft. The existence of tracer gas for more than 5 days also indicated the residence time of gas in the gob. The first arrival of tracer gas at the tailgate outby location suggested movement of a small portion of gas outby and mixing with the face airflow.	The tracer gas released on the face was recovered at the GGVs. The arrival-based velocities at different GGVs indicate the transport rate between 0.001 m/s (0.2 ft/min) and 0.007 m/s (1.3 ft/min).	The primary pathway of gob transport was inby towards the back of the panel, but a small portion of tracer gas moved outby towards the face as well at a slow rate. The velocity for tracer gas movement parallel to the headgate gateroad was about 0.019 m/s (3.7 fpm).
Gas management	The Site A trona mine did not use nitrogen injection, GGVs or exhaust bleeder fans for gas management. The mine used a bleeder shaft without a fan behind the active panel and a blowing main ventilation fan. NIOSH researchers did not conduct gas compositional analysis (except SF_6) on the air samples collected from the mine.	Site B used GGVs and nitrogen injection for gas management. The GGVs were drilled and completed near the mined coal bed, terminating about 15 m (50 ft) from the caved material from the tailgate entry laterally. The mine had a bleederless ventilation system that was acted upon by multiple main surface exhausting fans.	Site C used a Nitrogen injection system on the active longwall panel. N_2 is produced on the surface and transported through a main line to the active panel gob, where additional lines are connected to extend the injection points along the tailgate seals. The mine uses a bleederless design, due to the spontaneous combustion tendency of the mined coalbed.