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Mine Ventilation Pathway Simulation on a Hypothetical Shale Gas Well Breach Utilizing the Longwall Instrumented Aerodynamic Model (LIAM)

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Abstract

Researchers from the National Institute for Occupational Safety and Health (NIOSH) evaluated the impact of potential shale gas well breaches and subsequent gas inflow on selected mine ventilation systems of operating longwall panels using a 1:30 scaled Longwall Instrumented Aerodynamic Model (LIAM) and Sulfur hexafluoride (SF_6) as a tracer gas. A series of tests were performed at 340, 400, and 500 cfm inflow levels utilizing different mine ventilation scenarios. Results suggest that the breached gas can be diluted to meet statutory levels when the longwall panel is adequately ventilated. The results enhance the understanding of the gas inflow and mine ventilation system interaction and provide critical information to the industry and regulatory agencies for improving miners' safety.

INTRODUCTION

In the tristate area of Pennsylvania, West Virginia, and Ohio, unconventional shale gas wells have been drilled through current and future coal reserves. Impacts on the mechanical integrity of these wells becomes a concern when mining occurs in and around these wells. The shale gas wells can potentially penetrate the coal seams and the coal seams are subsequently mined. Therefore, it is imperative that the coal and shale gas industries to know what the impacts of longwall mining may be on the shale gas wells, what the potential deformation may be, and what stresses are imposed on the gas wells.

In 2012, the Pennsylvania Department of Environmental Protection (PADEP) recognized that the 1957 Pennsylvania Gas Well Pillar Regulation (Commonwealth of Pennsylvania, 1957) was created with limited data from modern day longwall mining and called for research to revise the outdated regulation. Therefore, given the posed questions and the need for further guidance given modern mining technologies and practices, the National Institute for Occupational Safety and Health (NIOSH) initiated research to address these issues.

To this end, several research efforts have focused on predicting the potential quantity of methane that could enter an underground coal mine environment if a shale gas well casing should be breached. One such area is gas permeability in ground strata. Measurements of the permeabilities of the ground strata under varying depths of cover are being conducted. Current research shows that shallow cover conditions (<500 ft depth to the mined coal seam) have the highest permeability compared to deep cover sites [1, 2]. Researchers have modeled and predicted the ground permeabilities which are well aligned with the field measurements [3]. Based on the collected field measurements, researchers modeled and predicted quantities of methane that may infiltrate an underground coal mine during a potential shale gas well breach [3–6].

Managing mine ventilation systems for longwall operations is a complex and time-consuming daily process for mine engineers and ventilation managers. Understanding the possible impacts to the mine ventilation system is paramount to mine management in order to provide an adequate ventilation design and planned response options. Given the predicted quantities of methane that may infiltrate into an underground coal mine during a shale gas well breach, physical modeling provides critical information by simulating mine ventilation performance through controlled conditions. A possible unplanned shale gas inflow from a hypothetical breached gas well casing presents a scenario potentially detrimental to a mine ventilation system, mine production, and miners' safety. The results from the Longwall Instrumented Aerodynamic Model (LIAM) experiments and tracer gas studies provide ventilation engineers the necessary information for adequate ventilation design planning and the basis for developing event response protocols for breach gas mitigation plans and required agency approvals.

The LIAM (Figure 1) was designed and constructed as a 1:30 scale physical model to simulate a portion of a longwall operation. The LIAM design is a three-entry headgate and tailgate longwall panel design commonly utilized in Pittsburgh Coal Seam longwall operations [1]. Hotwire anemometers provide velocity readings in the LIAM entries and mined gob areas. The differential pressure across the face is recorded and two thermocouples record air temperature. Depending upon the design test scenario, the LIAM utilizes a main mine fan and/or a bleeder fan. Mine fans and entry regulators are adjusted to ventilation specifications for each test scenario. Theatrical smoke is used for visualization of airflow paths on the longwall face and behind the shields, eddy currents, and gob-face interactions in order to validate that airflow pathways correspond to the design test scenario. Sulfur hexafluoride (SF_6) is utilized as a surrogate for methane for the tracer-gas-based analysis of the breached gas [7, 8].

METHODOLOGY

Scenarios for LIAM experimental testing are designed to utilize cooperating mine ventilation data and NIOSH researchers' assumptions for inflow values generated from Discrete Fracture Network (DFN) and Computational Fluid Dynamics (CFD) models. These models predicted the potential inflow quantities and locations. The mine ventilation plan used is typical of longwall mines in the Pittsburgh Coal Seam. The LIAM is configured with airflow quantities and ventilation controls commonly approved by the Mine Safety and Health Administration (MSHA). Shown in Figure 2, the LIAM is geometrically designed to represent a single longwall panel with a three-entry headgate and a three-entry tailgate configuration with two-bleeder entries with exhausting ventilation [9]. Other mine ventilation configurations can be simulated on the LIAM. Concentrations of SF_6 are determined by gas chromatography (GC) using NIOSH method 6602 [10]. The method uses Ultra P5 as a carrier gas (95% methane, 5% argon) and produces a limit of measurement of 1.0 ppb in air.

Figure 1. The LIAM is shown in the NIOSH PMRD laboratory

In this paper, four test scenarios are presented. Each scenario is represented by a test series. Table 1 lists the inflow rates and insertion points for each test series. Test Series A has an inflow value of 340 cfm inserted into the LIAM at the mine roof at 30 location points (8 insertion points located in the tailgate corner gob behind the tailgate shields and 22 insertion points located inby the tailgate pillar extending towards the tailgate bleeder evaluation point, BEP). Test Series B has an inflow value of 400 cfm inserted at the mine roof at 30 location points (14 insertion points located in the tailgate corner gob behind the tailgate shields and 16 insertion points that were located inby the tailgate pillar extending towards the tailgate BEP). Test Series B is also based upon work conducted by Ajayi et al.[11] in which most of the predicted inflow values ranged from 1 to 400 cfm. Consequently, the highest predicted inflow value, 400 cfm, was chosen for this series of tests. Test Series C has an inflow value of 400 cfm inserted at the mine roof at 30 location points (6 insertion points located in the tailgate corner gob behind the tailgate shields and 24 insertion points located inby the tailgate pillar) and was predicted by

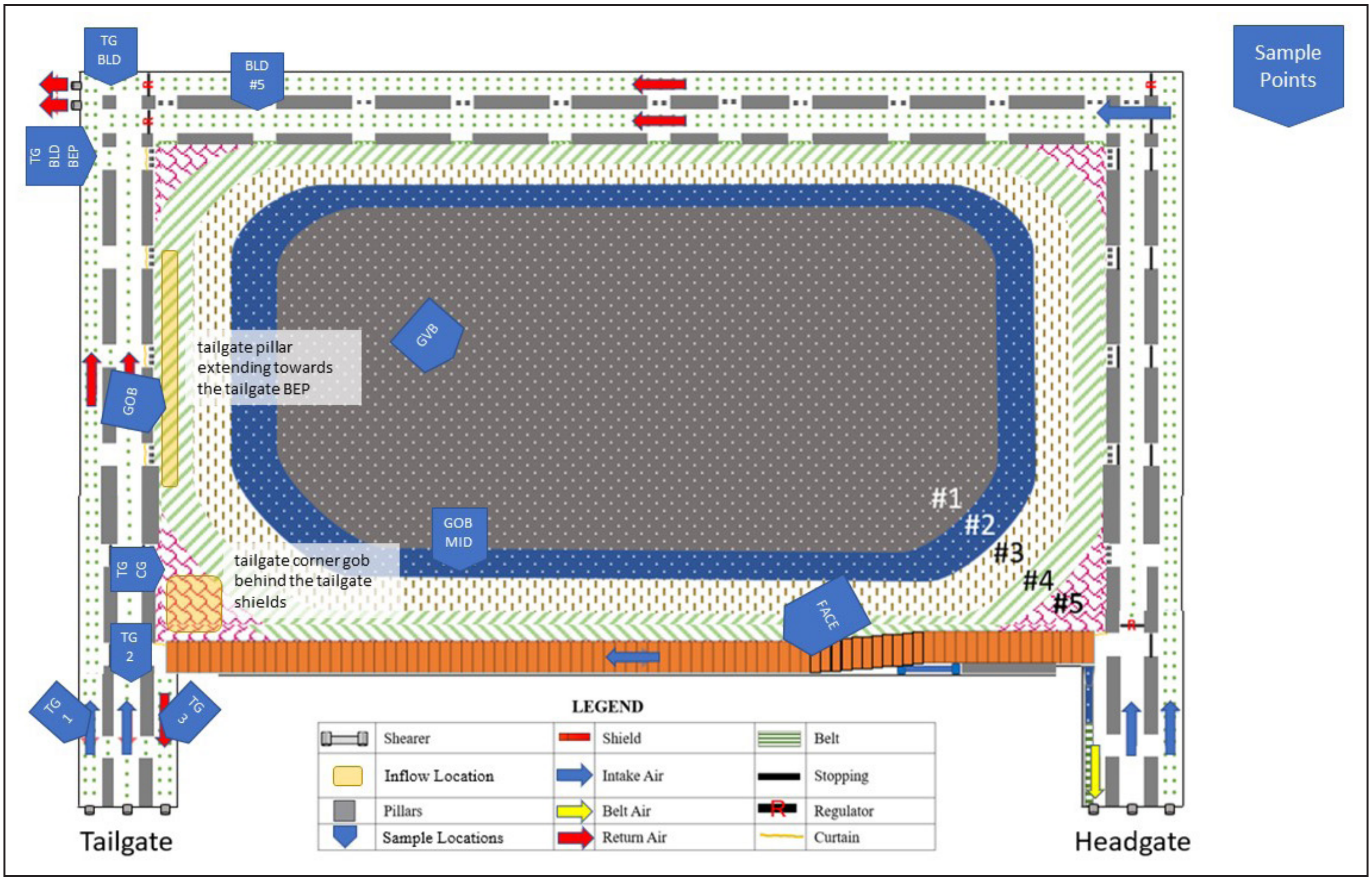

Figure 2. Insertion points and sample locations are shown on the LIAM

Table 1. Inflow rates and insertion points for the various test series

Test Series	Inflow Rate (cfm)	Insertion/Breach Points
A	340	8 in the tailgate corner gob behind the tailgate shields 22 inby the tailgate pillar extending towards the tailgate BEP
B	400	14 in the tailgate corner gob behind the tailgate shields 16 inby the tailgate pillar extending towards the tailgate BEP
C	400	6 in the tailgate corner gob behind the tailgate shields 24 inby the tailgate pillar
D	500	8 in the tailgate corner gob behind the tailgate shields 22 inby the tailgate pillar extending towards the tailgate BEP

Watkins [12] through a CFD model. The researchers chose the insertion points based upon the CFD plume graph. The location Test Series D has an inflow value of 500 cfm inserted at the mine roof at 30 location points (8 insertion points located in the tailgate corner gob behind the tailgate shields and 22 insertion points were located inby the tailgate pillar extending towards the tailgate BEP). The sampling and insertion locations are shown in Figure 2.

Breached gas inflow values (340, 400, and 500 cfm) were used in the testing scenarios and for simulating breached gas moving through the mine roof fractures into the mine ventilation system. During testing, SF_6 is inserted into the LIAM at the mine roof level for 15 to 16 minutes. A mass flow controller regulates the inflow. At each sample location, a vacutainer tube sample is taken every 30 seconds for the first 5 minutes and then every 60 seconds for the next 10 minutes, and then at 17.5, 25, and 40 minutes. Samples are analyzed by gas chromatography and results are converted to methane concentrations in ventilation air using conventional tracer gas methods for the test inflow rates. Critical sampling locations were determined by locations in an operating longwall panel where electrical power would be energized or where miners would be working. Agency-approved mine ventilation plans dictate specific maximum methane values acceptable in the operating longwall panel. Identified critical sample locations are at the operating longwall face, the headgate entries, the belt entry, the tailgate entries, the tailgate drive, the tailgate bleeder evaluation point (BEP), the bleeder entries, and the mine fans.

RESULTS

The velocities for each of the test series are summarized in Table 2. Those values without a standard deviation consist of only one measurement. However, there is good reproducibility seen at each location between the series. Therefore, the effects of varying breach in-flow rates on the ventilation system should be readily seen.

SF_6 Concentrations

The SF_6 samples were collected at the following locations: tailgate #1 entry (TG#1), tailgate #2 entry (TG#2), tailgate #3 entry (TG#3), the tailgate bleeder entry (TG BLD), the tailgate corner gob (TGCG), the tailgate bleeder BEP (TG BLD BEP), the gob vent borehole (GVB), the gob tailgate bock end corner (GOB), the gob mid face (GOB MID), the face (FACE), and bleeder entry #5 near the tailgate corner (BLD #5). Due to the critical nature of the locations, these positions were chosen for a complete understanding of the mine ventilation systems ability to dilute and render harmless gas from a breach gas well scenario. When examining the data, results from samples 5–19 (taken at 2.5 min – 14 min once the system has reached steady state) are averaged. Table 3 lists the average SF_6 measured at each sampling location for each test series. The blank fields indicate that no samples were taken at that sampling location during the test series. These were locations in which the researchers were confident no SF_6 would travel to or be found. However, they were later added to confirm zero (0) parts per billion (ppb) SF_6 at these locations.

As can be seen, the bulk of the SF_6 was found in the tailgate bleeder BEP and the tailgate bleeder. Minimal to no SF_6 is measured in the tailgate entries #1–3. Very little, 0–4 ppb, SF_6 is measured in the GVB, GOB, GOB MID, and FACE sample locations. Following, each test series will be examined in more detail.

Test Series A

For Test Series A, the individual test averages are shown in Table 4. There are some instances in which SF_6 concentration measurements spike. One such instance is the sample at minute 14 at GOB MID location shown in Figure 3. This individual measurement of 74.5 ppb increased the average value in Test #3 to 8 ppb. This is an example of a location in the gob that generally sees minimal air movement but where gas can occasionally find its way through the panel gob to that location before becoming diluted and dissipating. A similar phenomenon was observed in the average value of Test 3 for the GOB location (Table 4). The LIAM is configured to replicate permeability distributions for Pittsburgh coal bed mines at typical mining depths. Gas movement from the gateroads through the gob towards the borehole locations is a path of decreasing permeability. This is reflected in limited gas movement towards this location and potentially few data showing the presence of tracer gas with the effects of discrete sampling intervals.

Sample location TG BLD in Figure 4 depicts samples ranging in concentration from 20 ppb to 60 ppb SF_6. This location is inby the BEP on the tailgate side of the longwall panel and is affected by dilution from bleeder air

Table 2. Summary of velocities in each test series

	No. of tests	Sample Location Average Velocities (fpm) ± standard deviation										
Test Series	in series	TG#1	TG#2	TG#3	TG BLD	TGCG	TG BLD BEP	GVB	GOB	GOB MID	FACE	BLD #5
A	3			49.9 ±0.4	80.2 ±0.4	13.8 ±0.2	93.2 ±1.7		12.4 ±0.8	8.2	359.9 ±1.8	
B	3	15.4 ±1.2	14.8 ±0.5	29.4 ±0.4	76.4 ±0.6	14.9 ±0.0	100.1 ±1.0	604.1 ±3.4	10.9 ± ±0.2	13.3 ±0.1	343.2 ±1.9	
C	3	15.3 ±1.6	14.4 ±1.0	29.2 ±0.1	75.8 ±0.3	16.5 ±0.2	99.8 ±0.3	600.7 ±1.1	11.1 ±0.1	13.2 ±0.1	341.0 ±2.8	
D	2	13.0 ±1.9	12.8 ±1.0	28.2 ±1.0	73.6	15.9 ±1.6	98.9	607.9 ±11.7	11.6 ±1.5	11.8 ±1.6	340.0 ±6.2	79.5 ±1.8

Table 3. The average SF_6 measured at each sample location for all test series

	Inflow	No. of tests	Sample Location Average SF_6 (ppb)								
Test Series	Rate (cfm)	in series	TG#3	TG BLD	TGCG	TG BLD BEP	GVB	GOB	GOB MID	FACE	BLD #5
A	340	3	0	33	2	271		2	4	0	
B	400	3	0	77	0	332	1	3	0	0	
C	400	3	2	36	1	251	0	0	0	0	
D	500	2	1	83	65	355	0	0	2	0	0

Table 4. Test Series A average SF_6 concentration measurement at each sample location

	Sample Location Average SF_6 (ppb)						
Series A	TG#3	TG BLD	TGCG	TG BLD BEP	GOB	GOB MID	FACE
Test 1	0	40	3	290	1	3	1
Test 2	0	28	2	259	0	2	0
Test 3	0	30	1	266	6	8	0
Series Average	0	33	2	271	2	4	0

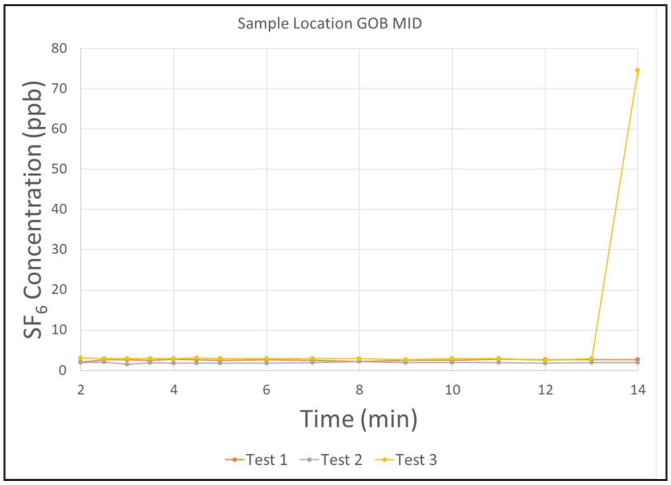

Figure 3. Individual sample results for the GOB MID location in Test Series A

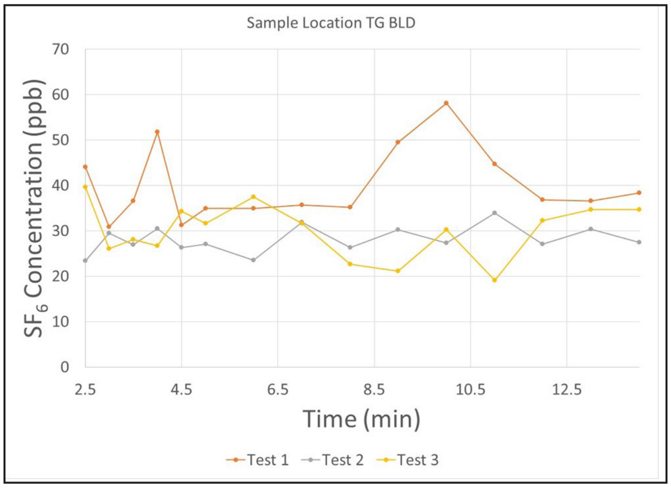

Figure 4. Individual sample SF_6 concentration results for the TG BLD location in Test Series A

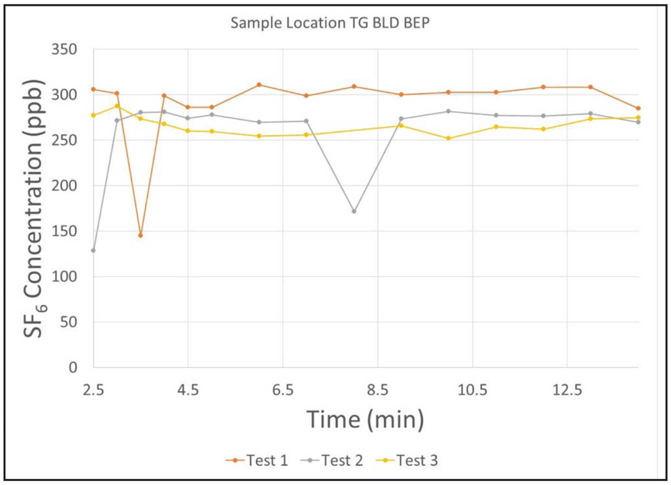

Figure 5. Individual sample results for the TG BLD BEP location in Test Series A

entering the mine ventilation system at the headgate side of the panel, air exiting the active longwall face to the tailgate entry as well as air traveling in the adjacent tailgate entries.

Sample location TG BLD BEP in Figure 5 depicts a concentration range generally from 250 to 325 ppb with three samples during the series of tests from 135 to 155 ppb. The TG BLD BEP sample location is critical as it represents any gas in the ventilation system prior to 'fresh' air mixing and dilution. This sample location receives the face ventilation air coursed down the longwall face as well as any air in the secondary flow path behind the shields and air from the mined panel gob area adjacent to the tailgate entry. These locations are on fan pressure from the bleeder fan at the back end of the bleeder system.

Sample location TGCG (Figure 6) shows that gas concentrations range from 0 to 3 ppb. One sample displays a value of 8.5 ppb. This may be an instance in which the injected inflow of SF_6 was not completely mixed, diluted, and coursed out of the corner of the gob at the same rate as the others. This sample location is directly behind the tailgate shields in the panel gob and is influenced by the secondary flow path of longwall face air created by resistance of the longwall face [7].

Test Series B

For Test Series B, the individual test averages are shown in Table 5. In Test Series B, the sample locations at TG #1–3, GOB MID, TGCG, and FACE showed no SF_6. Test 3 had 1 ppb of SF_6, while Tests 1 and 2 had 0 ppb of SF_6 at the GVB location. The GOB location averaged 3 ppb of SF_6.

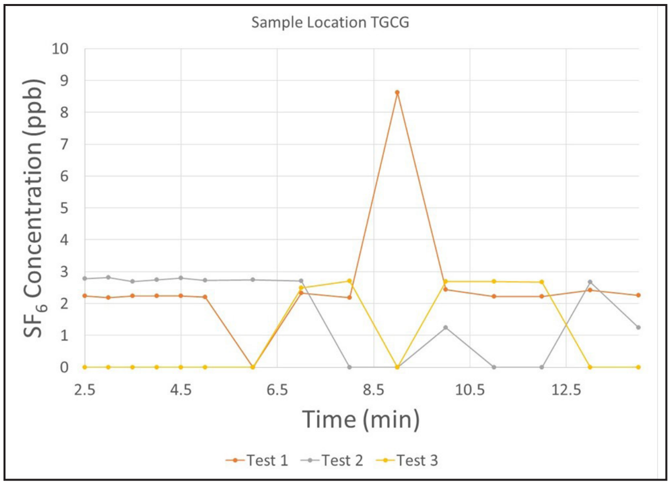

Figure 6. Individual SF$_6$ gas concentration sample results for the TGCG location in Test Series A

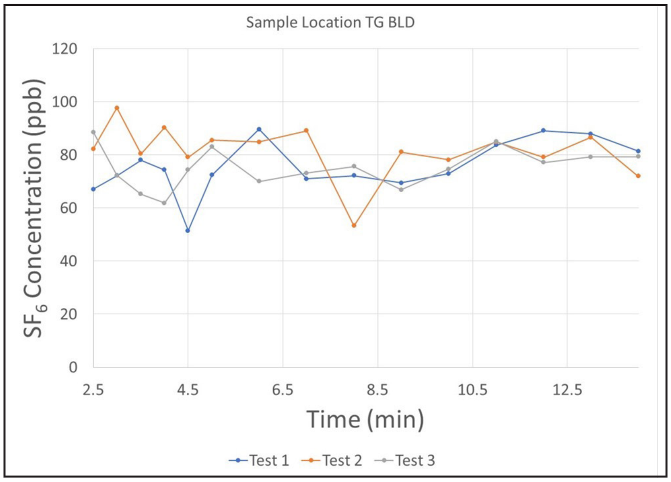

Figure 7. Individual sample SF$_6$ concentration results for the TG BLD location in Test Series B

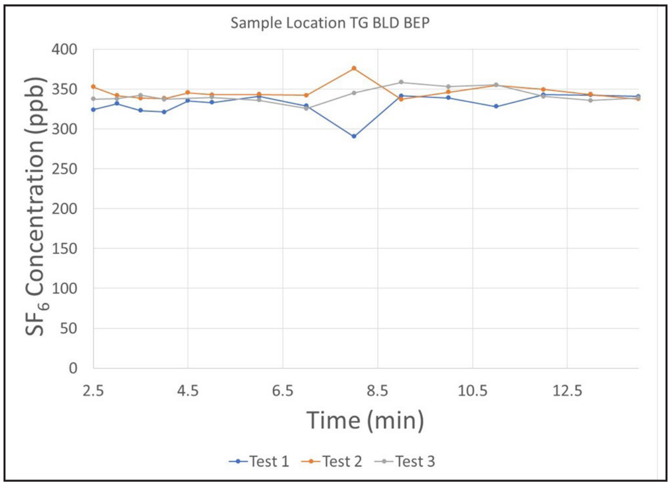

Figure 8. Individual sample SF$_6$ concentration results for the TG BLD BEP location in Test Series B

Sample location TG BLD (Figure 7) depicts SF$_6$ concentrations ranging from 60 to 100 ppb with two samples < 60 ppb. This location is inby the BEP on the tailgate side of the longwall panel and is affected by dilution from bleeder air entering the mine ventilation system at the headgate side of the panel, air exiting the active longwall face to the tailgate entry, and air traveling in the adjacent tailgate entries.

Figure 8 shows the SF$_6$ concentration measurements for sample location TG BLD BEP. The sample concentrations generally ranged from 325 ppb to 375 ppb. This sample location receives the face ventilation air coursed down the longwall face as well as any air in the secondary flow path behind the shields and air from the mined panel gob area adjacent to the tailgate entry. These locations are under pressure from the bleeder fan at the back end of the bleeder system. The TG BLD BEP sample location is critical as it represents any gas in the ventilation system prior to 'fresh' air mixing and dilution.

Test Series C

For Test Series C, the individual average SF$_6$ concentrations for each test are shown in Table 6. Concentration measurements at sample locations TG #1, GVB, GOB, GOB MID, and FACE average 0 ppb SF$_6$. Minimal amounts of SF$_6$ were measured at TG #2, TG #3, and the TGCG sample locations (<2 ppb SF$_6$). Sample location TGCG SF$_6$ concentration measurements are affected by the secondary ventilation flow path directly behind the tailgate shields and proximity to the insertion points in the corner of the tailgate gob shown in Figure 2 [13]. This sample location is located directly behind the tailgate shields in the panel gob and is influenced by the secondary flow path of longwall face air created by resistance of the longwall face. The GVB

Table 5. Test Series B average SF$_6$ concentration measurement at each sample location

	Sample Location Average SF$_6$ (ppb)									
Series B	TG#1	TG#2	TG#3	TG BLD	TGCG	TG BLD BEP	GVB	GOB	GOB MID	FACE
Test 1	0	0	0	76	0	331	0	3	0	0
Test 2	0	0	0	82	0	346	0	3	0	0
Test 3	0	0	0	75	0	319	1	3	0	0
Series Average	0	0	0	77	0	332	1	3	0	0

Table 6. Test Series C average SF_6 concentration measurement at each sample location

	Sample Location Average SF_6 (ppb)									
Series C	TG#1	TG#2	TG#3	TG BLD	TGCG	TG BLD BEP	GVB	GOB	GOB MID	FACE
Test 1	0	0	1	35	0	254	0	0	0	0
Test 2	0	0	2	36	2	259	0	0	0	0
Test 3	0	2	2	35	1	239	0	0	0	0
Series Average	0	1	2	36	1	251	0	0	0	0

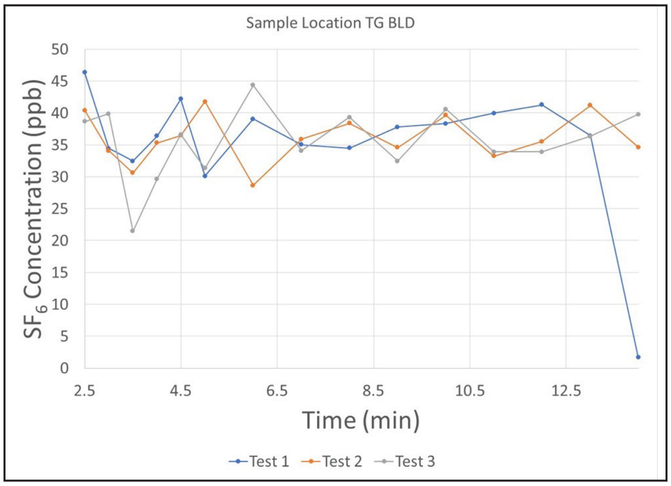

Figure 9. Individual sample SF_6 concentration results for the TG BLD location in Test Series C

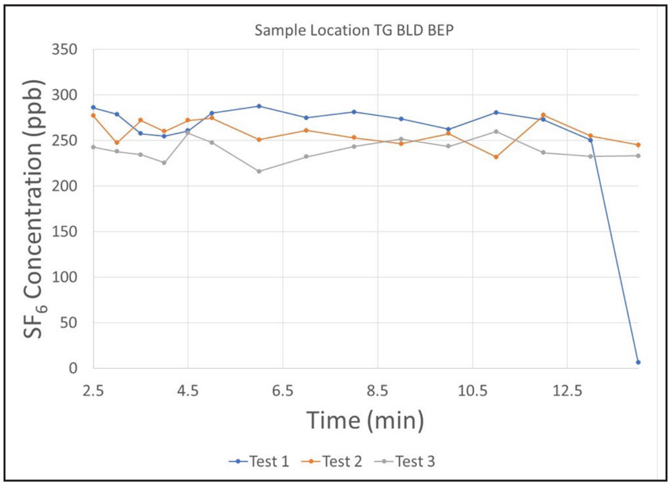

Figure 10. Individual sample SF_6 concentration results for the TG BLD BEP location in Test Series C

sample location is where minimal SF_6 migrates through the panel gob to a gob ventilation borehole located 215 ft from the start of the longwall panel mining, 200 ft into the panel from the tailgate pillar and 185 ft behind the active mining face. Low values are expected considering the resistance in the LIAM for inserted gas to flow to the GVB in the panel gob versus the less restricted and easier flow path from the insertion points to the tailgate bleeder entry influenced by the mine fan. Sample location TG #2 is affected by the tailgate design for the "T Split" in TG #2 entry with air coursed as an intake. Test 3 samples (average 2 ppb) differed from Tests 1 and 2 due to the tailgate design that utilized the TG #2 entry with coursed air flowing outby for the "T Split."

Sample location TG BLD (Figure 9) shows a range of samples from 30 to 45 ppb with one sample at 20 ppb. This location is inby the BEP on the tailgate side of the longwall panel. The TG BLD location is affected by dilution from bleeder air entering the mine ventilation system at the headgate side of the panel, air exiting the active longwall face to the tailgate entry, and air traveling in the adjacent tailgate entries. The displayed variation is due to the turbulent airflow at this location. The low concentration measurement for the Test 1 at 14 min may be due to a premature SF_6 inflow shutdown for the test. This is confirmed in Figure 10 with a very low SF_6 concentration measurement for Test 1 at 14 min.

Figure 10 shows samples for TG BLD BEP ranging from 200 to 300 ppb. This sample location receives the face ventilation air coursed down the longwall face, any air in the secondary flow path behind the shields, and air from the mined panel gob area adjacent to the tailgate entry. These locations are on fan pressure from the bleeder fan at the back of the bleeder system.

Test Series D

Table 7 lists the individual test averages for each sample location monitored in Test Series D with a simulated 500 cfm inflow rate. Sample locations TG#1, TG#2, GVB, GOB, FACE, and BLD #5 all had 0 ppb averages. Zero ppb is expected at TG #1 since it is outby the longwall face. TG#3 measured minimal SF_6, and variations in the ppb are the result of ventilation design for the TG #3 entry (outby and inby flowing scenarios). Low quantities of SF_6 were detected in the GOB MID.

The TG BLD sample location was only sampled in the first test of Test Series D. Figure 11 shows the variability ranging from 65 to 100 ppb (80 ppb average) within this test. This location is inby the BEP on the tailgate side of the longwall panel. It is affected by dilution from bleeder air

Table 7. Test Series D average SF_6 concentration measurement at each sample location

	Sample Location Average SF_6 (ppb)										
Series D	TG#1	TG#2	TG#3	TG BLD	TGCG	TG BLD BEP	GVB	GOB	GOB MID	FACE	BLD #5
Test 1	0	0	2	83	128		0	0	2	0	0
Test 2	0	0	0		1	355	0	0	3	0	0
Series Average	0	0	1	83	65	355	0	0	2	0	0

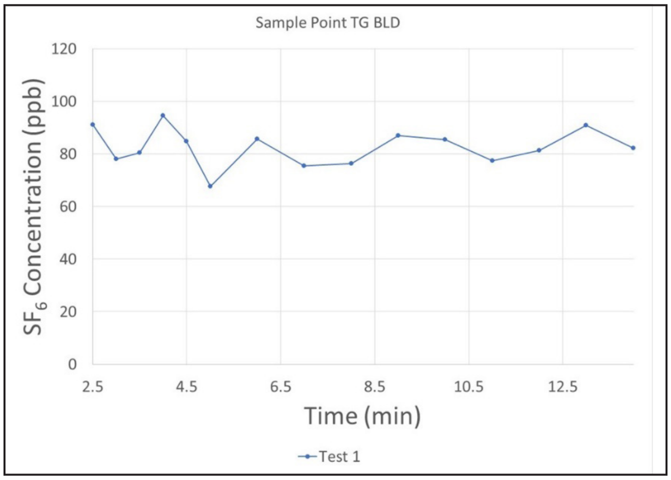

Figure 11. Individual sample SF_6 concentration results for Test 1 at the TG BLD location in Test Series D

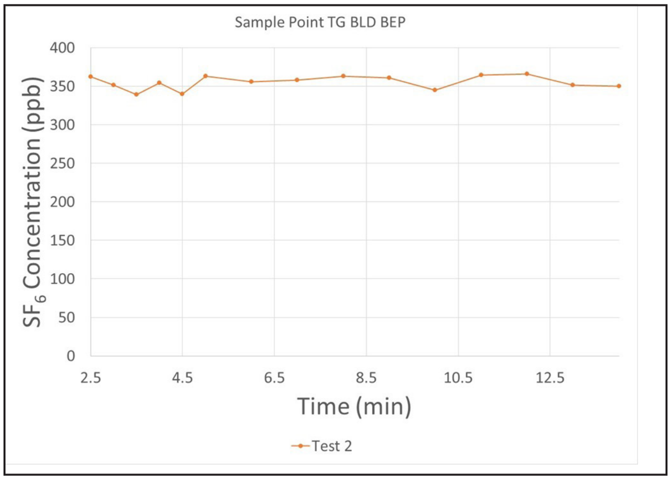

Figure 12. Individual sample SF_6 concentration results for Test 2 at the TG BLD BEP location in Test Series D

entering the mine ventilation system at the headgate side of the panel, air exiting the active longwall face to the tailgate entry, and air traveling in the adjacent tailgate entries. Variations in gas concentrations at this location during the test is a result of resistance in the mine entries and gob areas as well as the variation in gas concentrations from the BEP (GVB).

Sample location TG BLD BEP (Figure 12) measured 340 to 370 ppb SF_6. This sample location receives the face ventilation air coursed down the longwall face, any air in the secondary flow path behind the shields, and air from the mined panel gob area adjacent to the tailgate entry [7, 13]. These locations are on fan pressure from the bleeder fan at the back end of the bleeder system. The TG BLD BEP sample location is critical as it represents any gas in the ventilation system prior to 'fresh' air mixing and dilution.

Figure 13 shows sample location TGCG. The SF_6 at this location ranges from 100 to 160 ppb for Test 1. In Test 1 of the series, the miner was positioned at Shield 115, close to the tailgate entry. However, for Test 2 in this Series, to be more consistent with the other test series, the miner was repositioned to Shield 35 nearer to the headgate entry, and 0 ppb SF_6 was measured. This is because the 22 gas insertion points were located inby the tailgate pillar 1 in inside the gob extending towards the tailgate BEP. Airflow pathways directed the gas directly to the tailgate entry toward the bleeder fan. Therefore, no gas migrated to the sample point TGCG.

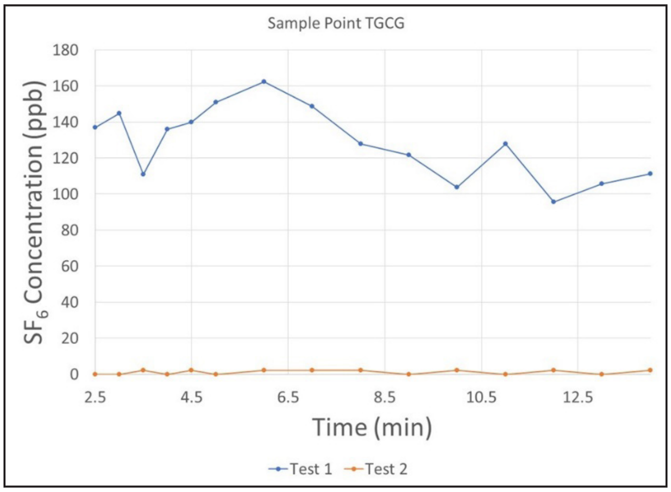

Figure 13. Individual sample SF_6 concentration results for the TGCG location in Test Series D

Mine Methane Percentages

Given the SF_6 concentration measurements and model velocities, what does this effectively mean to the mine engineer? In order to obtain meaningful results for the mine engineer, the SF_6 concentrations were converted to an

Table 8. Average volumetric flowrates for the TG#3, TG BLD, TG BLD BEP, and the FACE sample locations

	No. of	Sample Location Average Volumetric Velocities (cfm) ± standard deviation			
Test Series	tests in	TG#3	TG BLD	TG BLD BEP	FACE
A	3	12568 ± 92	20222 ± 109	23480 ± 434	55085 ± 280
B	3	7405 ± 89	19250 ± 163	25231 ± 248	52538 ± 294
C	3	7363 ± 29	19104 ± 77	25149 ± 68	52198 ± 423
D	2	7107 ± 249	21736 ± 4509	20023 ± 446	52042 ± 952

Table 9. Average methane equivalent percentage is given at TG BLD and TG BLD BEP sample locations for all test series

	Inflow	Methane Equivalent (%)	
Test Series	Rate (cfm)	TG BLD	TG BLD BEP
A	340	0.13	1.09
B	400	0.31	1.33
C	400	0.14	1.00
D	500	0.33	1.42

equivalent mine volumetric flowrate and methane percentage by using the geometrical and aerodynamic scaling factors given by Gangrade et al. [9]. Volumetric flowrates were not able to be defined in certain areas of the model, such as the GOB and GOB MID, due to the unconfined nature of the sample location. However, Table 8 lists the average volumetric flowrates for the TG#3, TG BLD, TG BLD BEP, and FACE locations. The higher standard deviations for Test Series D compared to the other test series may be due to the miner position change from Shield 115, close to the tailgate entry, for the first test to Shield 35 nearer to the headgate entry for the second test. All other test series had the miner located at the miner located at Shield 35 nearer to the headgate entry.

After geometrical and aerodynamic scaling factors were applied to the individual test results [9], the sample locations having more than trace amounts of equivalent methane were determined to be at the tailgate bleeder (TG BLD) and the tailgate bleeder BEP (TG BLD BEP). The average equivalent methane percentages are listed for these sample locations in Table 9. On average, the tailgate bleeder showed less than 0.4% equivalent methane. The tailgate bleeder BEP showed less than 1.5% equivalent methane. Given this information, the tailgate bleeder entry and the tailgate bleeder BEP are locations where a mine may want to focus monitoring efforts. These results also confirm the mine ventilation system's ability to comply with the requirements of 30 CFR Part 75 of the Mandatory Safety Standards for Underground Mines. Given that all the other sample locations had indicated little to no equivalent methane present, this indicates that the likely methane inflow migration paths would not impact workers on the face, energized power sources, or gob areas.

CONCLUSION

The LIAM has been configured with airflow quantities and ventilation controls from cooperating mines to design specific test scenarios. The ventilation controls, airflow coursed pathways, and examination locations are commonly approved by MSHA for operating mines in the Pittsburgh Coal Seam. Each sample location tested during the four-test series was selected based upon critical locations to the mine ventilation system and the possible impact to miners' safety and production. Variations to the intake air quantities coursed from the headgate entries onto the longwall face, and intake air into the mine bleeder system and tailgate entry were utilized during series testing. Gas inflow from a hypothetical gas well breach at 340 cfm, 400, cfm, and 500 cfm air flow quantities were inserted at 30 locations in the tailgate corner gob and tailgate pillar (in the gob).

The gas was introduced to simulate the movement of a breach gas through the mine roof fractures into the mine ventilation system. Migration characteristics in the mine ventilation system and gas concentrations at critical locations were sampled and analyzed. Inflow values and gas insertion locations were provided by NIOSH researchers using DFN, 3DEC software, and Network modelers. At no time was gas detected on the longwall face or tailgate drive area.

The results confirm the mine ventilation systems' ability to successfully course, dilute, and render harmless inserted gas where power would be energized, and miners could be working at locations in the underground mine. Minimal amounts of gas were detected in the mined gob areas with no accumulations detected at sample locations in the gob. Results confirm the mine's ability to comply with the requirements of 30 CFR Part 75 of the Mandatory Safety Standards for Underground Mines [14] and suggest the monitoring of the tailgate bleeder and the tailgate bleeder BEP. The different ventilation system designs did not modify the overall trends in the distribution of gas from the hypothetical breach. The LIAM tracer gas data offers further support for the similitude to in-mine tests, and now includes NAB mines in this comparison.

LIMITATIONS

Selected mine ventilation designs approved by MSHA for use in Pittsburgh Coal Seam longwall operations were utilized for testing. Variations in air quantities, longwall face velocities and tailgate "T Split" designs were included based upon co-operating mines' ventilation data in the testing. Individual test results may not be applied to all mine ventilation design scenarios.

Sample locations in the LIAM mined gob areas have undefined areas due to their location in the mined gob 'rubble' zone behind the active longwall face. A maximum defined area of 25% has been assigned for those locations for calculation purposes. Sulfur Hexafluoride gas is utilized as a surrogate for methane in the LIAM testing. This study inserted tracer gas in the LIAM model only at the (mine) roof level and let it migrate through the model during testing.

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 (NIOSH), Centers for Disease Control and Prevention (CDC). Mention of any company or product does not constitute endorsement by NIOSH.

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24-060

Mineralogy And Geochemistry of Heavy Mineral Beach-Placer Sandstones in New Mexico

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ABSTRACT

Heavy mineral beach-placer sandstones are accumulations of high specific gravity, resistant minerals that form from mechanical concentration by waves, currents, and winds in marginal-marine environments. These sediments are enriched in critical minerals such as titanium, zirconium, and REE. Cretaceous beach-placer sandstones are found in the Colorado Plateau of northwestern New Mexico. Originally discovered by airborne radiometric surveys for uranium in the 1950s, these beach-placer sandstones are being re-examined with modern methods as potential sources for critical minerals. Selected beach-placer sandstones have been sampled, mapped with ground radiometric surveys, and analyzed with whole-rock and trace element geochemical methods. Mineralogy is being determined with optical methods, XRD, and EMPA. Zircon, rutile, ilmenite, and monazite are the primary heavy minerals of interest found in the studied deposits. Initial results show that the sandstones contain up to 1.4% total REE, 29.4% TiO_2, and an estimated 4.9% ZrO_2. Chondrite-normalized REE diagrams show distinct light REE and minor heavy REE enrichment, as well as pronounced negative Eu anomalies for each deposit.

INTRODUCTION

Heavy mineral beach-placer sandstones are accumulations of high specific gravity, resistant minerals that form from mechanical concentration by waves, currents, and winds in marginal-marine environments (Van Gosen et al., 2014). These sandstones contain minerals such as zircon, rutile, ilmenite, and monazite, sources of critical minerals such as zirconium, titanium, and rare earth elements (REE). Critical minerals are mineral commodities that are essential to the economic and national security of the United States (Ellis, 2018). The United States is 100% import reliant on many critical minerals and are currently sourcing them from countries that can easily disrupt supply chains. These commodities are also required for modern electronics, as well as in technology for the green energy transition, such as wind turbines, solar panels, and electric cars (Goodenough, 2018).

Cretaceous heavy mineral sandstones are found in the Colorado Plateau within the San Juan Basin in northwestern New Mexico (Dow and Batty, 1961; McLemore, 2010; 2016; 2017). This Upper Cretaceous-Early Tertiary age structural basin extends into southern Colorado and contains significant coal, uranium, petroleum, and natural