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An Investigation of Longwall Gob Gas Behavior and Control Methods

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ABSTRACT

The National Institute for Occupational Safety and Health (NIOSH) has initiated the use of a tracer gas in field studies to characterize geologic and mining factors influencing the migration of longwall gob gas. Three studies have been conducted using sulfur hexafluoride (SF_6) at a coal mine in the Northern Appalachian Basin operating in the Pittsburgh Coalbed. Eight underground tracer gas releases and one gob gas venthole release are summarized. The results indicate that the gas flow in the bleeder network and in the interior regions of longwall panel gobs do not strongly interact and that the negative pressure provided by gob gas venthole exhausters is very significant in maintaining this behavior. The data also show that ventilation practices employed in a large multi-panel gob area are functioning in accordance with the intent of the engineering design, a fact which would be difficult to evaluate using conventional mine ventilation measurement methods.

KEYWORDS

Methane Control, Gob Gas Migration, Longwall Mining, Sf_6, and Tracer Gas.

INTRODUCTION

Prior research has demonstrated that the majority of methane emissions in coal mines utilizing longwalls are generated in gob areas (Curl, 1978; McCall, *et al.*, 1993; Schatzel, *et al.*, 1993; Diamond, *et al.*, 1997). In order to advance the existing state of knowledge on the behavior of methane in gobs, to investigate methane loading in adjacent airways and to optimize gob gas methane control systems, tracer gas research studies are being conducted by the National Institute for Occupational Safety and Health (NIOSH). Ultimately, the goal of this project is to protect underground workers through decreasing methane concentrations in entries which receive methane loading from the gob and thereby diminish the likelihood of combustible gas mixtures and the subsequent explosion potential.

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Study Area

The mine in which the study was conducted operates a single longwall section and three continuous miner sections in the Pittsburgh Coalbed. The mine is located in Greene County, PA. and produced approximately 4,900,000 t (5.4 million st) of coal in 1998. The mine design is primarily a three-entry gate road system, except near the start-up (back) end of the panels near the bleeders and near the submains at the completion (front) end of the panels where four entries are commonly used. Entries are nominally 4.9 m (16 ft) wide and 5.2 (7 ft) high. Longwall panels in the study area (Figure 1) were generally about 240 m (780 ft) wide initially (panels A+ through E) and were increased to 305 m (1,000 ft) starting with F panel. Panel lengths generally increased with each successive panel. G panel was the most recently mined out panel included in this study. It is located in the southernmost portion of the study area and was approximately 3,656 m (12,000 ft) in length.

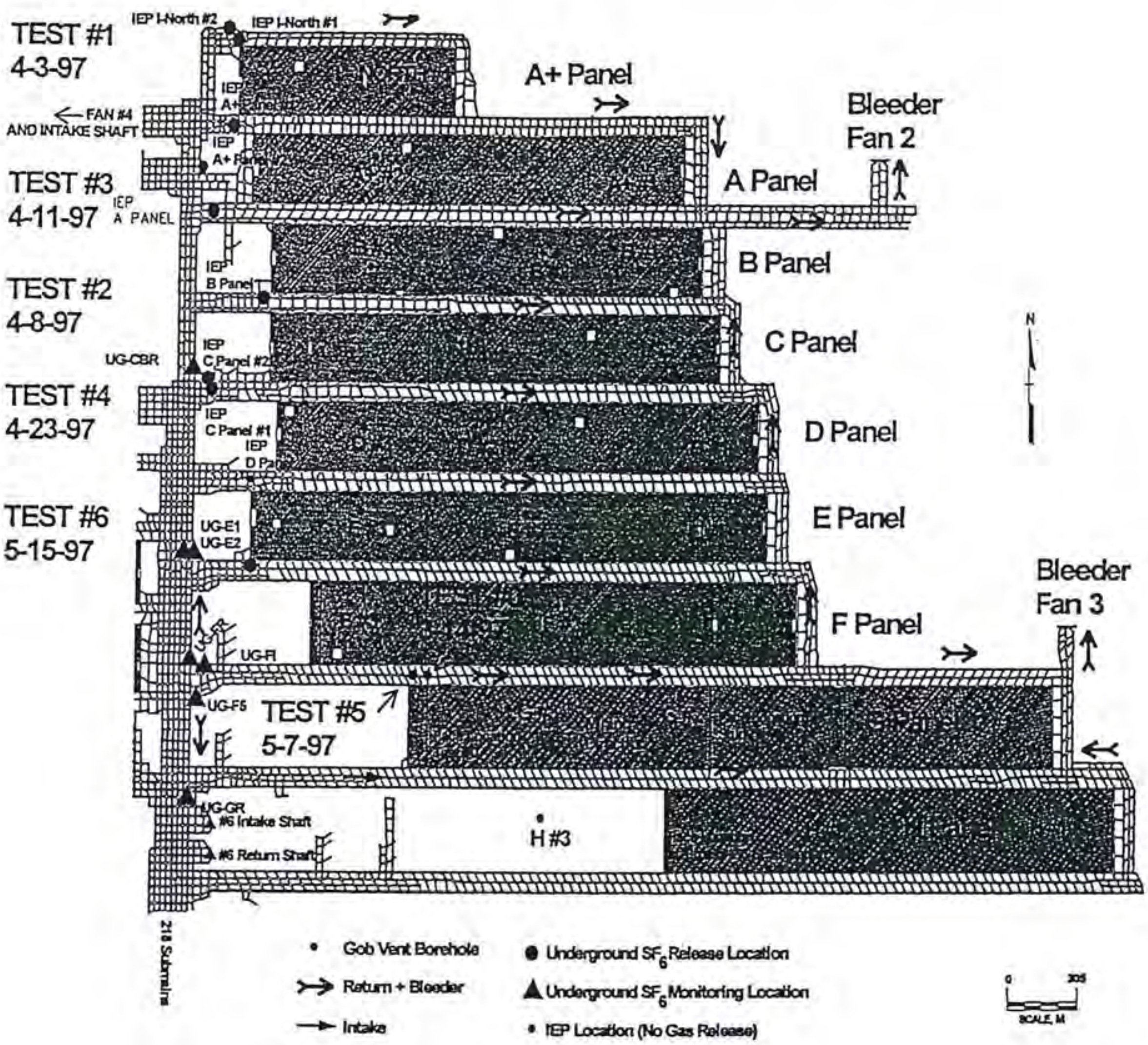

Figure 1. Mine map of study area.

Ventilation System Design

The mine's primary ventilation is supplied by an exhausting ventilating system incorporating a number of intake air shafts and return air shafts. At the time of the study, the area shown on Figure 1 was ventilated by intake air supplied primarily by the No. 4 intake shaft for panels A+ through F and the associated submains. The return air for this same area reported to the No. 4 fan return shaft. The remainder of the panels and the associated 218 submains were ventilated by intake and return air from and to the No. 6 intake and the No. 6 return shafts located off the mains at H panel (Figure 1). Joy[1] 3.0 m (10 ft) axial vane fans were installed on the return shafts and normally operated at pressures of approximately 0.15 to 0.17 kPa (6 to 7 in water gauge) during the time of the study. The 218 Mains were configured with intake and belt air courses in the center entries. Return entries were located on each side. In active sections, belt air normally traveled outby toward the submains, at which point, it was coursed to the return while the section was being developed or after it had retreated to about one-half of its length. During the first half of a longwall panel retreat or

[1]Reference to specific products does not imply endorsement by the National Institute for Occupational Safety and Health.

the second half of a gate road section development, the belt entry normally served as an additional intake entry for face ventilation.

The ventilation configuration on active longwall panels has intake air on the headgate side of the panel. In the longwall face area, some of the intake air continues through the remaining gate road entries to the back of the panel where it is regulated into the bleeder system. This configuration is used to maintain a positive ventilating pressure on the active longwall gob area. Longwall intake air traversing the face then splits in the tailgate with a fraction of the air going towards the bleeders at the back of the panel due to the influence of the bleeder fan and the remainder moving as return air through the tailgate entry towards the submains at the front of the panel and on to the main ventilating fan(s). Bleeder fans BF2 and BF3 are designed to remove a substantial portion of the gas produced by the large gob area formed by the mined-out panels as well as gas from the active panel (Figure 1). The bleeder fan installations consist of a 1.8 m (6 ft) diameter shaft with a primary and secondary (back-up) fan unit. These fan units are high pressure Robinson[2] centrifugal fans. Overburden depths to the top of the Pittsburgh Coalbed are 184 and 232 m (604 and 762 ft) for BF2 and BF3, respectively. Intake air is permitted to enter the middle entry(s) of each gate road of the worked out panels at designated intake evaluation points (IEP's) to provide an air source for the bleeder system. Regulators are installed at each IEP to control these volumes and provide a positive ventilating pressure from the front of the panels to the bleeder system at the back of the panels.

Additional Methane Control Measures

Gob gas ventholes are used to control gas in the gobs with three holes per longwall panel commonly drilled on the tailgate side. Generally, the surface installation for a gob gas venthole includes a gate valve for shutting-in the hole when necessary, an exhauster (powered by the produced gas) to withdraw gob gas, a one way check valve, a flame arrestor and a flare stack.

EXPERIMENTAL METHOD

Approach

The general concept of the gas flow characterization experiments is to release a defined volume of the tracer gas into the ventilation airflow or longwall gob and then monitor all potential exit points for the gas (Thimons, *et al.*, 1974; Thimons and Kissell, 1974; Vinson and Kissell, 1976; Timko and Thimons, 1982; Timko, *et al.*, 1986). By determining the tracer gas concentration (if any) at the various monitoring locations and measuring the associated tracer gas flow rate, the volume of tracer gas passing through each monitoring site can be calculated. Thus, the relative distribution of gas flow to the various outlet points can determined. Arrivals, peaks and tails were determined based on the SF_6 data from glass sampling bottles. The tracer gas arrival time is defined as the time corresponding to the first show of the tracer gas above detection limits. The peak is the maximum concentration of the tracer gas. The tail is the final indication of tracer gas above detection limits prior to gas concentrations dropping below the detectable concentration range.

Gas Sampling Methodology

Gas samples were retrieved to measure tracer gas concentrations at the monitoring stations. They were collected in 20 ml glass sample bottles. These evacuated sample bottles draw in a sample of the gas when a resealable stopper is punctured with a syringe needle. An automated gas sampling (AGS) device was used in this study (Figure 2). Each AGS device consists of a battery-powered chart drive attached to a protective cylindrical metal housing containing twelve 20 ml sample bottles (Figure 2). A complete AGS system consisted of an AGS device sealed inside an instrument housing and a permissible programmable air-sampling pump mounted outside an air-tight instrument housing (Figure 2). All retrieved gas samples were analyzed by gas chromatography.

Tracer Gas Release Specifications

The SF_6 tracer gas used in the releases was 99.99 % pure and was contained in lecture bottles containing 0.03 to 0.04 m^3 (1.1 to 1.3 ft^3) at 760 mm Hg, 0° C. Two methods of tracer gas release (fast or slow) were used for the underground airflow studies. A fast release would empty a standard 0.04 m^3 (1.3 ft^3) lecture bottle in 30 to 90 s, producing a relatively high peak concentration in the air stream at the release point and subsequently, a relatively short duration high concentration peak at the monitoring locations. It commonly took about 3 min to release two 0.04 m^3 (1.3 ft^3) lecture bottles for the underground releases conducted in this study. Previous research has suggested a maximum allowable limit of 100 ppm of SF_6 in air for this tracer gas to simulate the movement of the host air stream. To maintain

SF_6 concentrations above 100 ppm, a minimum velocity of 10 m/s (2,000 ft/min) was established for a successful fast release of tracer gas from two lecture bottles. The slow-release method empties a standard 0.04 m^3 (1.3 ft^3) lecture bottle in about 20 minutes.

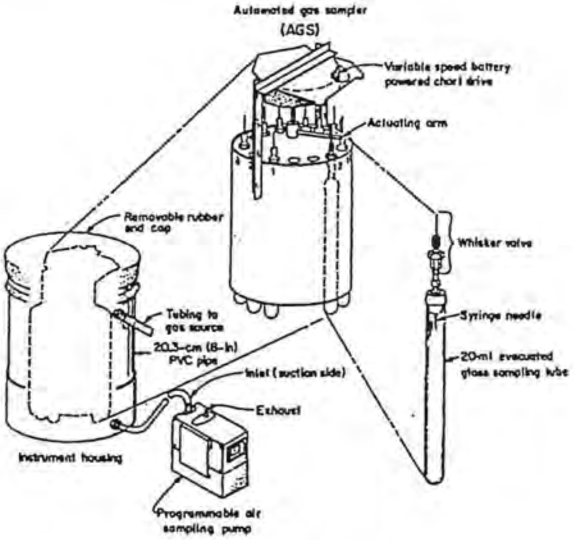

Figure 2. Schematic drawing of AGS system.

DISCUSSION AND RESULTS

Study 1

This study investigated the distribution of air moving through the active G Panel tailgate to BF2 and BF3. The release point for the tracer gas was just inby the longwall face in the number 2 tailgate entry (Figure 1). At the time of the study, the face on G Panel was about 76 m (250 ft) inby gob gas venthole G2, and 1,830 m (6,000 ft) inby the longwall take-out room. This study showed that approximately 79 % of the ventilation airflow associated with the release point went to BF2, 19 % went to BF3, and about 2 % was not recovered. The amount of tracer gas recovered from the monitoring stations was between about 97 and 98 % of the released gas volume. The high recovery rates achieved in this experiment demonstrated that tracer gas evaluation methods have a high degree of sensitivity in characterizing airflow movements in areas of underground mines, such as longwall gob areas, where access is limited or impossible.

Study 2

Selected Individual Tests. Seven underground SF_6 tracer gas releases were conducted as part of Study 2. The majority of the underground releases were conducted at IEP's located at the completion ends of the subject panels as indicated on Figure 1. The locations for the underground SF_6 releases were chosen to assess a complete geographic distribution of gas flows from the study area. Prior to the underground tracer gas releases, ventilation surveys were conducted throughout the underground study area by conventional techniques using anemometers and smoke tubes to measure quantities and altimeters and Magnahelics[2] to measure pressure and pressure drops. These data were used to design each individual release (Table 1).

Test 2-0. This test was designed and performed by mine personnel with technical assistance provided by the NIOSH research staff. The SF_6 release was located in the F Panel bleeder and former headgate, just inby the G Panel face (Table 1). At the time of the tracer gas release, G Panel was active, and the face location is given in Figure 1. Tracer gas monitoring sites included BF2, BF3 and gob gas ventholes G1, G2, and G3 (Figure 1). All three gob gas ventholes were equipped with surface exhausters. However, the exhauster on G1 was not operating due to mechanical problems, and the exhauster on G3 was operating with a tank of propane gas as a fuel source. The exhauster at G3 was started just before the test began and ran out of fuel less than 1 hour after the cessation of tracer gas monitoring. The AGS system was not used for tracer gas monitoring during Test 2-0. Tracer gas monitoring for this test consisted of manual sampling at the surface sites. No tracer gas was present in any of the samples from any of the monitored locations on the day of the release. Samples collected the following day at the same locations by mine personnel showed evidence of tracer gas above detectable limits at all of the monitoring locations except for G1 (Figure 1, Table 1). At the time of gas sample collection, the exhauster on gob gas venthole G2 was running, and the exhausters on G1 and G3 were idle, but the holes appeared to be free flowing gas. Test 2-0 consisted of essentially only a single data point in time that was above the SF_6 detection limit at each monitoring location which recovered SF_6. Consequently, no determination of recovered tracer gas volumes could be made for Test 2-0. The rate of tracer gas migration was much slower than in Study 1 (due to different airflow rates) and required about 24 hours for the tracer gas to reach BF2, BF3, G2, and G3 (Figure 1, Table 1). The arrival of the tracer at the gob gas ventholes, including the G3 venthole where the exhauster was not operating was perhaps the most significant result of the test.

Table 1. Tracer gas release specifications and cumulative recovery percentages.

A

Description of SF_6 Release

Study/ test	Date-Time yy/mm/dd+hh:mm:ss	Vol m^3 STP	Vol ft^3 STP	Release Method	Location
2-0	97/03/14 Fri 08:00:00	0.123	4.34	2 bottles, slow (24 min), 08:00-08:24	No. 29 cross-cut in the No. 2 entry of F Panel entries, inby G face
2-1	97/04/03 Thu 09:00:00	0.124	4.38	1 bottle, fast, 0.059 m^3, 09:00 1 bottle, fast, 0.066 m^3, 10:45	Release 1: IEP 1North No. 1 Release 2: IEP 1North No. 2
2-2	97/04/08 Tue 09:17:00	0.125	4.40	2 bottles, fast	IEP B-Panel
2-3	97/04/11 Fri 09:05:00	0.116	4.10	2 bottles, fast, 0.064 m^3, 09:05-09:08 1 bottle, fast, 0.053 m^3, 10:35	Release 1: IEP A Panel Release 2: IEP A+ Panel No. 1
2-4	97/04/23 Wed 09:13:00	0.148	5.23	2 bottles, fast, 0.074 m^3, 09:13-09:16 2 bottles, fast, 0.074 m^3, 09:17-09:20	Release 1: IEP C Panel No. 1 Release 2: IEP C Panel No. 2
2-5	97/05/07 Wed 08:15:00	0.146	5.14	4 bottles, fast	No. 26 cross-cut in the No. 2 entry of F Panel entries, inby G face
2-6	97/05/15 Thu 07:50:00	0.148	5.22	4 bottles, fast	IEP E Panel
3-1	97/07/21 Mon 08:15:00	0.272	9.62	Slow (25 min), 08:15-08:40	GVB-G3

B

Recovered Percentage of SF_6 at Monitoring Locations, %

Study\ Test	Underground							Bleeder Fan		Gob Ventilation Borehole							Total
	CBR	E1	E2	F1	F5	FR	GR	BF2	BF3	A+1	D1	E1	F1	G1	G2	G3	
2-0								***Det***[1]	***Det***					ND[1]	***Det***	***Det***	
2-1								***65.99***	0.00	0.00							65.99
2-2								***89.09***	0.00	0.00							89.09
2-3								***57.40***	0.00	***Trace***							57.40
2-4	***0.72***							***85.16***	0.00		0.00	0.00	0.00				85.88
2-5				0.00	***1.11***			***56.17***	***1.14***				0.00	0.00	***0.74***	0.00	59.15
2-6		0.00	0.00					***68.75***	0.00		0.00	0.00	0.00				68.75
3-1						0.00	0.00	***4.48***	***0.00***				0.00	***3.19***	***75.34***	***Injected***	83.01

Note: Bolded-italicized values indicate monitoring sites where SF_6 was detected.
[1] Det = Detected, ND = Not Detected.

Test 2-3. Test 2-3 was performed on A Panel. The test plan specified two release locations, IEP-A Panel and IEP-A+ Panel No. 1 (Figure 1, Table 1). Tracer gas monitoring was conducted at A+1 gob gas venthole and bleeder fans BF2 and BF3. The exhauster on gob gas venthole A+1 was not operational during the test, but the hole was free flowing gas. SF_6 was recovered from the A+1 borehole and BF2 (Figure 3, 4). The recovery from BF2 was about 55% of the released tracer gas volume (Table 1).

Test 2-3 is one of four tracer gas tests performed in this case study which demonstrated some interaction between the ventilation system/bleeder network and the gob gas ventholes (the other tests which displayed similar interactions are Tests 2-0, 2-5 and 3-1). Only two gas samples retrieved from gob gas venthole A+1 contained concentrations of SF_6 over the minimum detection limit (Figure 3). The recovered volume of SF_6 from the A+1 gob gas venthole is estimated to be only a few ten-thousandths of a percent of the released tracer gas volume. The low magnitude of the peak concentration and the steepness of the rise and fall of the gas concentration over time suggests this was a very short duration, low-volume tracer gas recovery site and that the low recovery rate was not due to experimental problems. The graph of SF_6 concentration against time for BF2 during Test 2-3 (Figure 4) displays a somewhat twin peak configuration indicative of the time delay between lecture bottle releases.

Test 2-5. Test 2-5 was conducted in the bleeder which comprised the former F Panel headgate. The release was made in the center entry and the release point was just outby the final position of the F Panel face (Figure 1). Due to the low airflow velocity in the entry designated for the release, manual underground tracer gas monitoring was included in the test procedure at locations UG-F1 and UG-F5 (Figure 1, Table 1). Surface tracer gas monitoring locations are given in Table 1. Of the gob gas ventholes, G2 and F1 were producing gas with operating exhausters; the exhausters at G1 and G3 were not operating, but the boreholes had the potential to free flow gob gas. Tracer gas was detected at multiple sites. Slightly more than 1% of the released SF_6 was recovered at both BF3 and UG-F5 (Figure 5, Table 1). The BF2 site recovered just over 56 % of the released gas (Figure 5, Table 1).

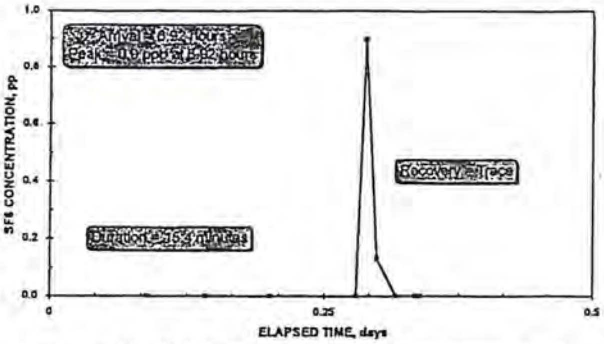

Figure 3. Graph of changing SF_6 concentrations over time at the A+1 monitoring site during Test 2-3.

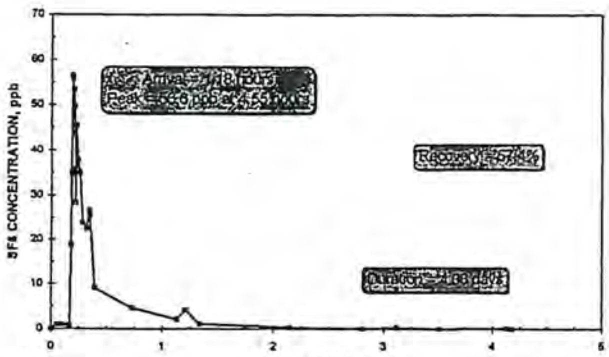

Figure 4. Graph of changing SF_6 concentration over time at the BF2 monitoring site during Test 2-3.

Analysis of the underground sampling indicates that sample collection was terminated before the SF_6 tail reached the UG-F5 monitoring site. Therefore, the SF_6 recovery data underestimates the true volume of tracer gas that flowed through this monitoring site (Table 1). A review of the ventilation practices in use on G Panel during Tests 2-0 and 2-5 suggests a potential cause for the tracer gas recovery from the UG-F5 site during Test 2-5. Changes were made to the ventilation system configuration during the time interval between Test 2-0 and Test 2-5. As previously described, the G Panel intake air flowed from the submains down the headgate and was split at the headgate corner with the majority of the air crossing the face (Figure 1). The air crossing the face is split at the tailgate corner with part of the air flowing in an outby direction in the tailgate, and the remainder flowing inby between the mined-out F and G panel blocks.

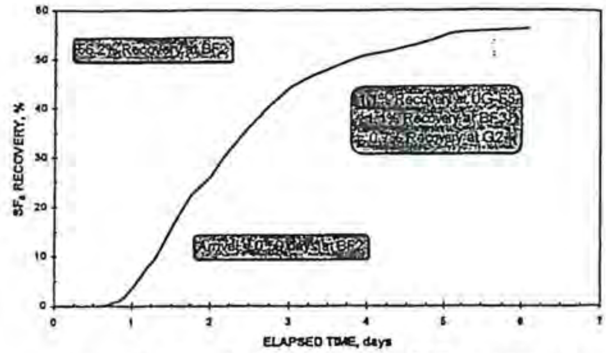

Figure 5. Graph of the amount of SF_6 recovered over time at the underground UG-F5, G2, BF2 and BF3 monitoring sites during Test 2-5 shown as a percentage of the released tracer gas.

However, during Test 2-5, G panel was mined out. The ventilation system had also been modified which produced more negative differential pressures at the regulators in the former G Panel tailgate gate road (Figure 1). The completion of G Panel, and the removal of all longwall shield supports left a highly rubblized zone (gob) between the G Panel headgate and tailgate whereas in Test 2-0, an open airway had existed between the shields and the longwall shearer. The tracer gas release in Test 2-0 allowed the gas to migrate in an inby direction and initially between the two mined out F Panel and G Panel longwall blocks (Figure 1). Tracer gas release Test 2-5 began in the same way. However, the airflow from the G Panel headgate to tailgate was now greatly reduced due to the of formation of the G Panel gob and the resulting increased resistance to airflow. The enhanced negative pressure during Test 2-5 (compared to Test 2-0) outby the release location in the G panel headgate and the limited airflow across the former G Panel face and tended to pull the tracer gas back out of the gob and towards the submains. The migration of tracer gas to the underground monitoring site during Test 2-5 is probably not the result of procedural problems during the Test 2-5 release.

Table 2. Calculated velocities for Study 2 underground tracer gas releases

Test No.	Location	Average Tracer Gas Velocities (first arrival), m/s (ft/min)			
		BF2	BF3	A+1	G2
2-0	F Panel entries	Unknown			
2-1	1 North IEP's	1.32 (259)			
2-2	B Panel IEP	0.16 (31)			
2-3	A&A+ Panel IEP's	0.76, 0.78 (147, 153)		0.08, 0.08 (15,16)	
2-4	C Panel IEP's	0.15, 0.15 (29, 30)			
2-5	F Panel entries	0.09 (17)	0.09 (18)		0.02 (5)
2-6	E Panel IEP	0.16 (31)			

Airflow Velocity Determinations for Underground Releases. Migration velocities (path length/elapsed time) for the movement of SF_6 slugs associated with the underground tracer gas tests are shown in Table 2. This table shows the migration velocity of the SF_6 arrivals from the release location to each monitoring location where detectable levels of the tracer gas were measured. No velocity determinations could be made using the data from Test 2-0. Velocity determinations can also be made relative to either the occurrence of the tracer gas peak or the tail. These values are not included in Table 2 but are proportional to the arrival times; although slower.

Table 2 shows that the highest migration velocity based on the arrival time data is on the order of 1.32 m/s (260 ft/min) to the BF2 monitoring site during Test 2-1. The slowest moving slug of SF_6 which migrated to the BF2 monitoring site, was 0.09 m/s (17 ft/min) during Test 2-5. The monitoring sites at BF3, A+1 and G2 each yielded only one tracer gas show during the various underground tracer gas release tests. The migration of tracer gas to G2 during Test 2-5 produced a velocity of 0.03 m/s (5 ft/min), the slowest measured for this suite of tests.

Study 3

Test 3-1. The final tracer gas release experiment conducted at the mine study area was an injection into gob gas venthole G3. The hole is located on the completion (west) end of G panel, approximately 46 m (150 ft) off the centerline (tailgate side of the 305 m (1,000 ft) wide panel), 396 m (1,300 ft) from the longwall take-out room, and 2,600 m (8,500 ft) from the start-up end (Figure 1). At the time of the release, approximately 5 months had passed since hole G3 had been mined through and 3.6 months since G panel had been completed. The adjacent H panel longwall face was approximately 700 m (2,300 ft) east of hole G3 and 55 m (180 ft) west of hole G2 at the time of the injection (Figure 1). Hole G3 was inactive at the time of the injection and had not produced gob gas for 2.3 months. The hole was shut-in but when opened would intake into the gob. Hole G3 (Figure 1) was originally drilled to a depth of 179 m (587 ft), and 17.8 cm (7-in) casing with 61 m (200 ft) of slotted pipe on the bottom was installed.

Release Specifications. Two 3.2 mm (1/8-in) ID polyethylene lines were installed in the hole; one to a depth of 36.6 m (120 ft) to release the tracer gas, and the other to a depth of 33.5 m (110 ft) for periodic monitoring of the SF_6 concentration after the release. Due to the limited free space available in the injection borehole and large volume of tracer gas injected, it was not possible to keep the tracer gas concentration below the recommended 100 ppm concentration in air. Gob gas venthole G3 was open and intaking for a short time before and after the SF_6 release to aid in dispersing the tracer gas into the gob. The hole was intaking for approximately 35 min at 0.03 m^3/s (66 cfm) during the release. In addition, the release tubing line was flushed with approximately 1.4 m^3 (50 ft^3) of nitrogen, a volume sufficient to displace the tubing volume 30 times. The monitoring sites for Study 3 included two underground monitoring locations and are given in Table 1.

Results. The presence of tracer gas was not detected at either of the underground monitoring locations or at gob gas venthole F1 (Table 1). The first arrival of tracer gas after the release into gob gas venthole G3 was at gob gas venthole G2, the closest inby producing hole on the same panel (Figure 1). Tracer gas was first detected in gas samples 1.1 days (27 h) after the release. The peak concentration was the highest recovered at any site, 1,309 ppb, attesting to the very high degree of communication between the two holes.

At the time hole G2 was taken off production, 75.3% of the injected gas had been recovered at this location (Figure 6, Table 1) and the SF_6 concentration was still at 111 ppb.

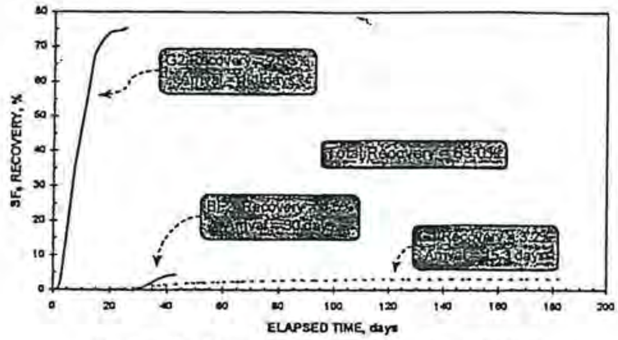

Figure 6. Graph of tracer gas cumulative recoveries for borehole injection experiments.

The second monitored location where SF_6 tracer gas was detected was gob gas venthole G1. Tracer gas was first detected in gas samples 15.3 days after the release (Figure 6). The peak SF_6 concentration of 43.65 ppb was significantly lower than the peak concentration measured at hole G2, presumably due to wider dispersal in the gob atmosphere as it migrated inby past hole G2.

During this study, the pressure of venthole G3 was recorded as was the gas production from G1 and G2 (Figure 7). Breaks in the gas production flow lines on Figure 7 indicate periods when the surface exhausters were not operating. Barometric pressure was also recorded at G3 but appeared to have only minor influence on the pressures recorded at G3 and does not seem to account for the fluctuations and, therefore, is not shown. During the first day of Study 3, both G1 and G2 were operating and the negative pressure measured at the top of gob gas venthole G3 approximated 0.22 kPa (9 inches of water). The following day however, G1 went off production and remained off for approximately 1 week until about day 9 of the study. During this period, the pressure at G3 was approximately 0.17 kPa (7 inches of water). When G1 was returned to operation, the pressure at G3 returned to approximately 0.22 kPa (9 in of water). On days 13 and 14 of the study the same off/on cycle of G1 was repeated with approximately the same 0.05 kPa (2 in of water gauge) pressure attributable to the G1 exhauster influence (Figure 7). On days 18 through 21 of the study, the G2 exhauster went off production. During this period the pressure at G3 fell to about 0.1 kPa (4 in of water) indicating that about 0.12 kPa (5 in) of the 0.22 kPa (9 in water gage) at G3 was due to the operation of the relatively nearby G2 exhauster with the remaining 0.1 kPa (4 in) due to G1 exhauster and the bleeder fan(s) or about 0.05 kPa (2 in) each (Figure 7). The venthole exhausters at this mine typically operate at between 0.37 and 1.0 kPa (15 and 40 in of water) when measured at the top of the venthole before the exhauster. This range is generally a function of the availability of methane for fuel and the resulting engine RPM. During this period, BF2 and BF3 were operating at approximately 0.42 and 0.32 kPa (17 and 13 in of water), respectively. The magnitude and relative influence of the venthole exhausters and bleeder fans demonstrated by the pressure data at G3 provides insights and understanding to the behavior observed from the tracer gas studies. Especially notable was the interaction of the venthole gob drainage system and the mine bleeder system, i.e,.that the gob interior remains a deeper pressure sink than the bleeder system when at least one or more of the exhausters are operating. Also noted was the communication between the holes and the far reaching influence of the G1 gob gas venthole at the G3 venthole, even though separated by a rather large distance along a gob communication line.

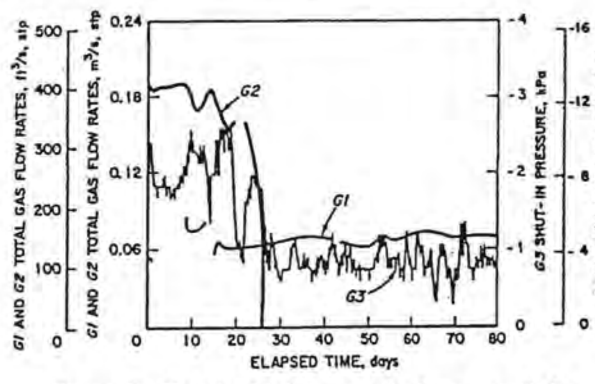

Figure 7. Graph of influence of gob gas venthole production on GS shut-in pressure.

The only other confirmed location to which tracer gas migrated from the G3 borehole injection experiment was BF2 (Figure 1, Figure 6). Tracer gas arrived at this location on day 30 after the release. Tracer gas was detected at BF2 only four days after gob gas venthole G2 went off production on day 26 of the test. Although tracer gas was remained at detectable levels at BF2 for over 9 days and 4.5% of the released gas recovered from the site, the peak concentration at was only 0.25 ppb or about 2x the analytical lab's SF_6 detection limit (Figure 6, Table 1). SF_6 concentrations at G3 did not fall below the detection limit of the laboratory based GC until July 13, 1998 (day 357 of the study).

SUMMARY AND CONCLUSIONS

In four of the seven underground tracer gas releases, it was demonstrated that SF_6 migrated from the bleeder network to a gob gas ventholes, in some cases when free-flow condition existed on the boreholes (e.g., no operating exhauster). However, the largest amount of tracer gas recovered was from any gob gas venthole location was only 0.7% of the released gas volume. Consequently, the underground releases have demonstrated that 1) the outer regions of the gob near the panel margins are directly influenced by airflow in the bleeders, and 2) the interior gob regions function highly (but not completely) independent of the bleeder network. Air movement within inaccessible bleeder locations was depicted by the migration of the tracer gas which demonstrated that the ventilation network was effective in moving air through the bleeders in the gob in an inby direction, towards the start-up ends of the panels throughout the study area. A high degree of sensitivity was also demonstrated in Study 1 which suggests that many more ventilation applications may be possible for tracer gas technology to accurately depict gas movement in underground areas with limited accessability.

In Study 3, it was clearly demonstrated that three gob gas ventholes on a single longwall panel were in communication with each other despite being separated by lateral distances of up to 2,300 m (7,500 ft). The level of communication between adjacent gob gas ventholes can be extremely high as was shown in the relatively rapid movement of the tracer from G3 to G2 (1.1 days), the magnitude of the peak concentration at G2 (over 1,300 ppb), and the high rate of tracer gas recovery by gob gas venthole G2 (75.3%). A small percentage of the released gas migrated into the bleeder network and was recovered at BF2 (4.5%). The experimental results suggest that if the gob gas venthole exhausters on G panel had not experienced any production interruptions, tracer gas from Study 3 may have migrated only to the gob gas ventholes and may have never reached the bleeder network. The lack of interaction between the interior of the gob regions and exterior portions of the gob adjacent to the bleeder network appears to be strongly influenced by the negative differential pressures produced by the operating gob gas venthole exhausters. These findings may be applicable to other mines operating in the Pittsburgh Coalbed in the Northern Appalachian Basin but may not be highly relevant to mines operating in other coal basins.

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