CHAPTER 3.–METHANE CONTROL AT CONTINUOUS MINER SECTIONS

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In This Chapter

- ✓ Methane emission peaks
- ✓ Exhaust line curtain or duct
- ✓ The spray fan system
- ✓ Dust scrubbers with blowing ventilation
- ✓ Dust scrubbers with exhaust ventilation
- ✓ The ventilation of abnormally gassy faces
- ✓ Methane detection at continuous miner faces
- ✓ Ventilation and methane detection at bolter faces

and

- ✓ Reducing frictional ignitions

This chapter gives guidelines for preventing methane gas explosions at continuous miner sections in coal mines, both at continuous miners and at roof bolters. The need to control peak methane emissions is particularly stressed. Emphasis is also placed on ventilation principles, monitoring for gas, and reducing frictional ignitions.

METHANE EMISSION PEAKS

Methane emission from the coal at continuous miner faces varies considerably. Plotted on a chart, methane emissions consist of a series of peaks and valleys corresponding to the cutting cycle of the mining machine, with the methane concentration spiking as the machine cuts into the coal (Figure 3–1) [Kissell et al. 1974]. These methane peaks can be substantial. For this reason, efforts to safely dilute the methane must focus on the level of the

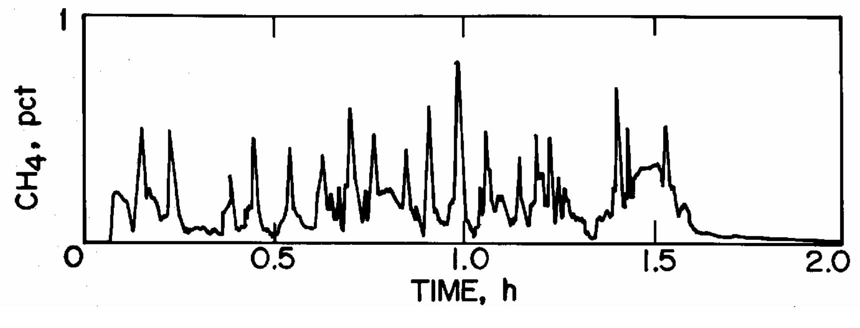

Figure 3–1.—Recorder chart from a machine-mounted methane monitor.

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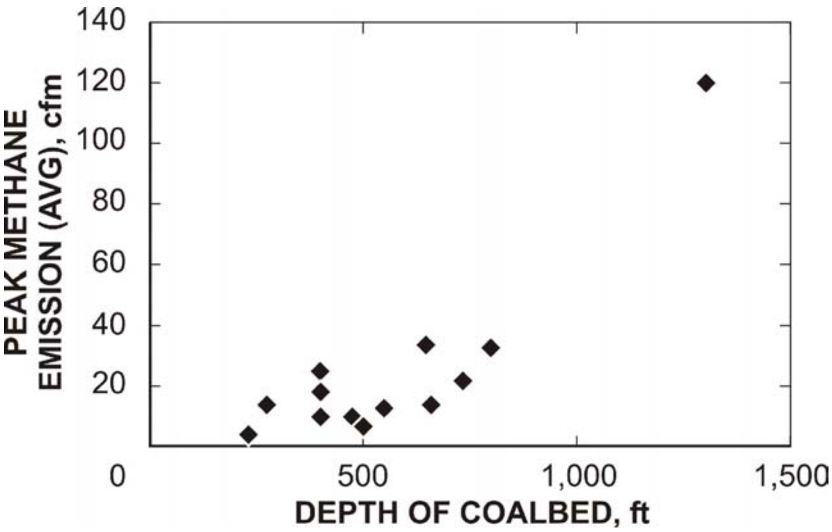

Figure 3–2.—Peak average methane emissions for several U.S. coalbeds.

peaks, not the overall methane level. Figure 3–2 shows peak average[4] methane emissions in several U.S. coalbeds [Haney et al. 1983]. Except for one coalbed at 1,300 ft depth, peak average coalbed emissions range from 4 to 33 cfm, with an overall U.S. average of 17 cfm. Any face ventilation system must be able to safely handle gas flows of this magnitude.

Although the values cited here are peak averages, the value for individual peaks can vary widely. For example, a study by Smith and Stoltz [1991] has shown a variation[5] of 46% in emission peak values. Similarly, there was a variation[5] of 50% in methane dilution capacity.

VENTILATION WITH EXHAUST LINE CURTAIN OR DUCT

Prior to the development of improved face ventilation systems, most coal mine faces were ventilated with exhaust line curtain or ventilation duct. For this reason, exhaust line curtain or ventilation duct can serve as a baseline against which newer systems can be measured. Federal coal mine regulations [30 CFR[6] 75.330] mandate that exhaust systems have a maximum setback distance of 10 ft, i.e., the distance from the face being mined to the inlet of the line curtain or duct is 10 ft or less (Figure 3–3). However, if a mining machine starts a cutting cycle when the setback is 10 ft and subsequently advances another 10 ft, then the curtain or duct ends up at 20 ft if it has not been moved forward during the cutting cycle.

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[4] This is the average of the emission peak values.

[5] Strictly speaking, the coefficient of variation, which is the standard deviation divided by the mean.

[6] *Code of Federal Regulations.* See CFR in references.

Figure 3–3 [Ruggieri et al. 1985b] shows why the methane dilution capacity of exhaust line curtain is not high. Air flowing up the entry shortcuts to the mouth of the line curtain, leaving the off-curtain side of the face poorly ventilated and subject to a buildup of methane. To further demonstrate, Figure 3–4 shows the methane dilution capacity[7] for exhaust line curtain[8] at setbacks of 10 ft and 20 ft [Kissell and Wallhagen 1976; Haney et al. 1982; Schultz et al. 1993]. A notable feature of Figure 3–4 is the reduced dilution capacity at the 20-ft setback. This is why Mine Safety and Health Administration (MSHA) regulations specify a maximum setback of 10 ft.

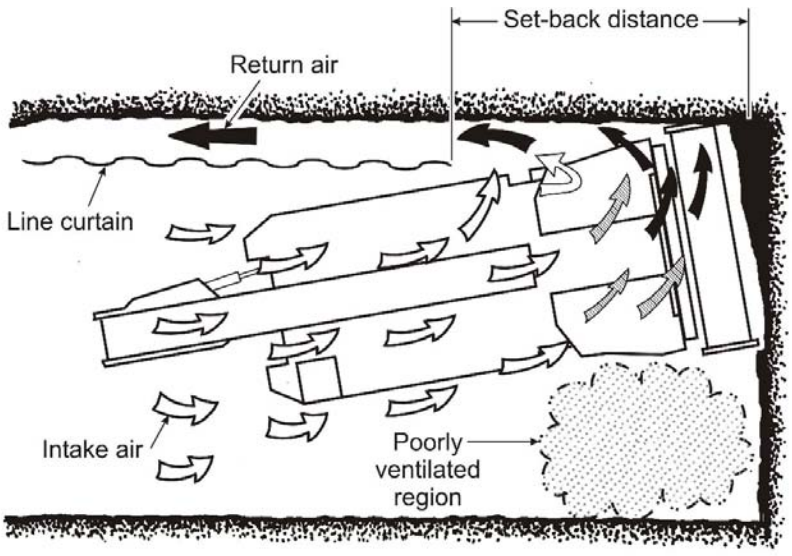

Figure 3–3.—Ventilation setback distance. With exhaust line curtain, the off-curtain side can be poorly ventilated.

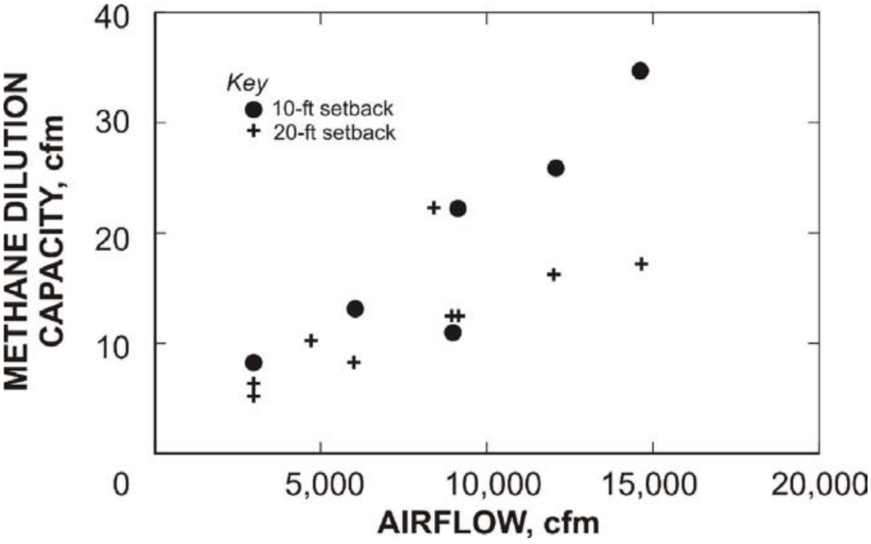

Figure 3–4.—Methane dilution capacity for exhaust line curtain at setbacks of 10 ft and 20 ft.

For those mines using exhaust curtain and/or duct, an extensible system can be used to reduce the setback and possibly permit a deeper cut before place-changing.

Extensible duct systems are fabricated using a duct section a few inches in diameter smaller than the main duct. This smaller section is inserted into the main duct at the inlet end and is slid forward as the miner advances. A typical extensible curtain system is fabricated by attaching a 20-ft section of brattice cloth to 20 ft of ½-in-diam pipe. The pipe is

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[7] Methane dilution capacity is the highest methane flow that the ventilation system can handle without exceeding a 1% methane concentration value anywhere in the face area. It is the best measure of how well a ventilation system is working. See Haney et al. [1983].

[8] The performance for exhaust duct is similar.

hung on J-hook assemblies, which are installed on the last two roof bolt plates next to the rib [Muldoon et al. 1982], and the pipe is slid forward as the miner advances. Urosek et al. [1988] described 11 extensible line curtain systems used in coal mines.

Despite the development of extensible curtain systems, the continuing need for better methane control has led to improved face ventilation systems using spray fan and scrubber systems.

VENTILATION WITH THE SPRAY FAN SYSTEM

The spray fan system is an auxiliary ventilation system that makes use of the air-moving ability of water sprays. Moving droplets in the spray drag the surrounding air forward to create a considerable airflow, particularly when several sprays are arranged in a series as fans in a row. To install the spray fan system on a continuous miner (Figure 3–5), spray manifolds 1 and 2 are placed on the off-curtain side of the miner. These sprays move air forward to ventilate the off-curtain corner of the face (in Figure 3–5, the right corner). Spray manifold 3 moves air from right to left underneath the boom. Spray manifold 4 has 11 sprays angled 30° left to sweep air from right to left across the face and 1 spray on the right edge angled right to wet dust and clear gas from the right end of the cutter head. These manifolds are arranged for a working face that has the exhaust curtain on the left side.

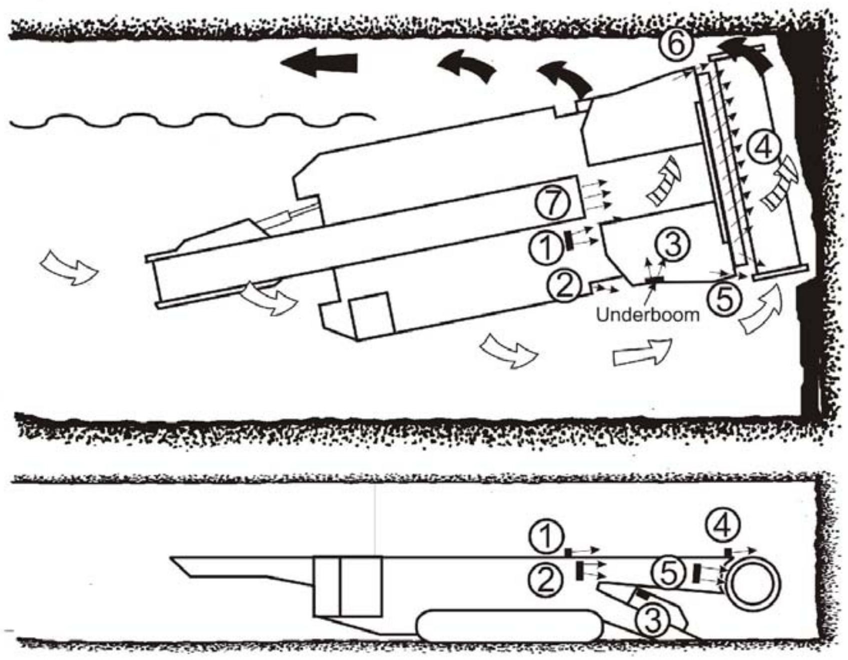

Figure 3–5.—Spray fan system on a continuous miner. The numbers correspond to the spray manifolds.

When the exhaust curtain is on the right side, another spray system, a mirror image of the one described, must be provided.

In addition to the spray manifolds already described, additional dust suppression spray manifolds 5, 6, and 7 are directed at the ends of the cutting head and into the throat. These also help to keep the cutter head ends and the throat clear of gas, and they operate whether the left- or right-side curtain is in use.

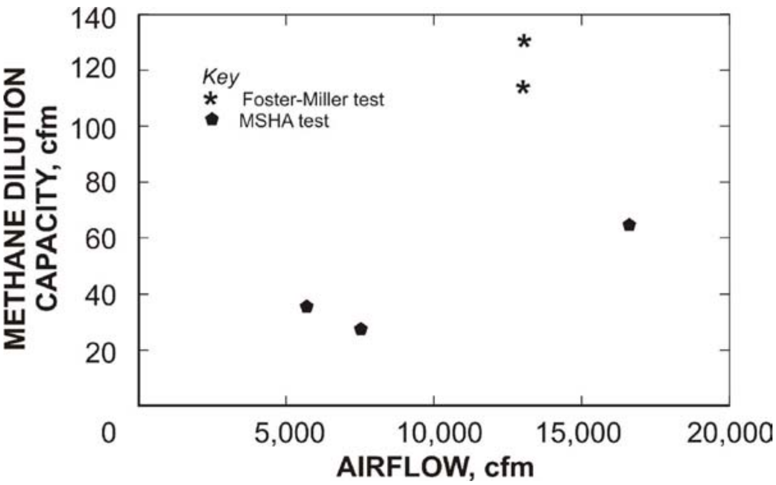

Figure 3–6.—Methane dilution capacity of the spray fan system.

The methane dilution performance of the spray fan is shown in Figure 3–6. Testing in the laboratory and underground by Foster-Miller Associates [Ruggieri et al. 1985b] at 13,000 cfm and at a water pressure of 100 and 150 psi yielded impressive methane dilution capacities of 115 and 135, respectively. Later testing by MSHA gave lower values, in part because of different design and lower water pressures.[9] Still, the improvement with spray fans over the baseline 10-ft setback can be substantial.

An installation guide for the spray fan is available [Ruggieri et al. 1985a]. Close control of the water pressure is particularly important. If the water pressure is too low, little air will be moved. High water pressure will move more air, but if the pressure is too high, the spray fan can move more air than the line curtain, producing an airflow imbalance that raises the dust level at the operator cab.

Good performance from spray fan systems requires that they be used according to established spray location and water pressure guidelines [Ruggieri et al. 1985a]. Following these guidelines ensures that the amount of air moved is adequate.

DUST SCRUBBERS WITH BLOWING VENTILATION

Dust scrubbers were first installed on continuous miners in the 1970s. Today, almost all new machines come equipped with them. Their popularity is due to improved methane dilution at large curtain setbacks, enabling the coal industry to achieve efficiency gains through extended cutting. Figure 3–7 shows a dust scrubber used in conjunction with blowing ventilation, the most common ventilation configuration. The scrubber collects dusty air at the boom, removes the dust, and discharges the clean air at the rear corner of the miner. This section covers the methane dilution effectiveness of scrubbers with blowing ventilation and the operating factors that impact the methane dilution.

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[9] The effectiveness of spray fan systems depends on the water pressure. See Figure 3–11.

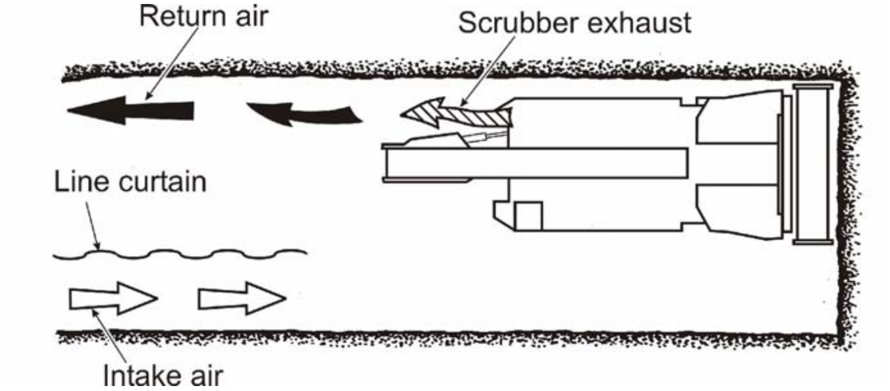

Figure 3–7.—Dust scrubber used in conjunction with blowing ventilation.

Methane dilution effectiveness. The first comprehensive underground study to measure the methane dilution effectiveness of a high-volume scrubber used in an extended cut with blowing ventilation was conducted by Haney et al. [1983]. With a 6,700-cfm dust scrubber, they obtained a methane dilution capacity of 24.5 cfm using blowing line curtain located on the side of the entry opposite the scrubber exhaust. There was no deterioration in performance up to the largest line curtain set-back tested (35 ft).

A subsequent test by Halfinger [1984] gave similar results. The 7,000-cfm scrubber provided a methane dilution capacity averaging 26 cfm (see footnote 12). The scrubber system performed equally well at all line curtain setbacks tested (25, 35, and 50 ft). Halfinger also noted that the methane dilution effectiveness was independent of line curtain airflow between 3,500 and 6,000 cfm, the lowest and highest line curtain airflows tested.

Subsequent to the Halfinger study, MSHA conducted an extensive series of scrubber tests in mines across the United States [Zuchelli et al. 1993; Schultz et al. 1993; Stoltz and Snyder 1991; Snyder et al. 1993; Smith and Stoltz 1990; Denk et al. 1988; Snyder et al. 1991; Dupree et al. 1993; Mott and Chuhta 1991; Denk et al. 1989]. Methane dilution results (Figure 3–8) indicated that methane dilution capacity was roughly related to scrubber quantity. For scrubbers over 4,000 cfm in coal heights 60 in or more, the average methane dilution capacity ranged from 28 to 44 cfm; for scrubbers over 4,000 cfm in coal under 60 in, the

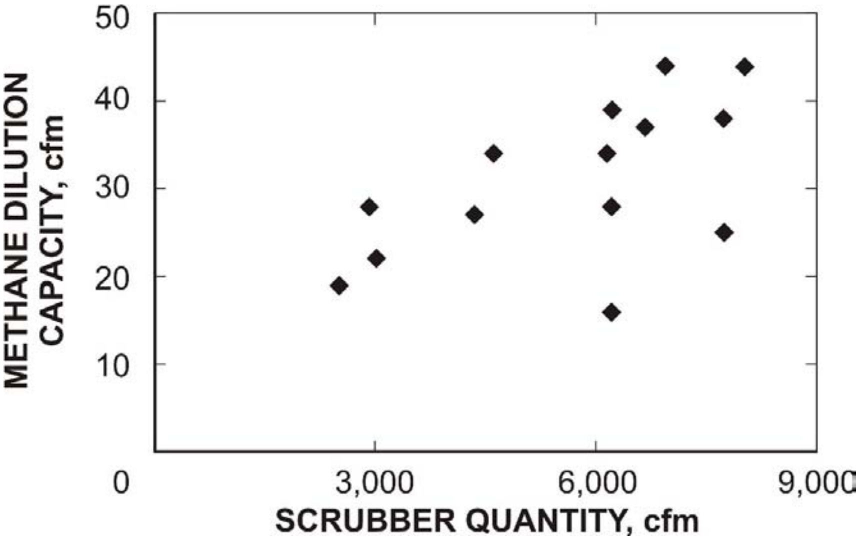

Figure 3–8.—Methane dilution capacity from MSHA scrubber tests.

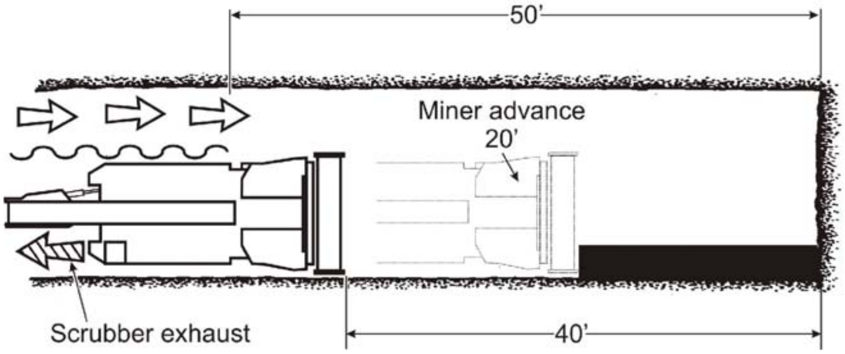

Figure 3–9.—Test configuration used by Thimons et al. [1999].

average methane dilution capacity ranged from 16 to 27 cfm.[10] With regard to the effect of line curtain setback, the results mirrored those of Haney and those of Halfinger. The methane dilution capacity did not decline at the largest line curtain setbacks measured, typically up to 40 ft.

An important aspect of scrubber system effectiveness is how well the box is being ventilated while the slab cut is being made. An investigation by Thimons et al. [1999] (Figure 3–9) indicated that with the blowing line curtain at 50 ft and the continuous miner at the start of a 40-ft slab, the amount of fresh air reaching the face of the box was 400–600 cfm. However, as the miner advanced, more air reached the face of the box. When half of the slab was cut—a 20-ft advance—the amount of air reaching the face of the box was 2.5 times higher. Bringing the curtain forward also helped. For example, moving the curtain from 50 ft to 40 ft increased the airflow by a factor of 1.6 to 2.0 depending on test conditions.

Operating factors that impact methane dilution. Many factors impact the ability of scrubbers to dilute methane safely. Some are related to the original design, others to the quality of maintenance.

It is important to have an understanding of the operating factors that impact scrubber methane dilution: air quantity, water sprays, exhaust direction, clogging, and turning crosscuts.

- *Scrubber air quantity*. Taylor et al. [1997] conducted studies in a full-scale surface test gallery to assess the impact of changing the scrubber air quantity and intake air quantity. On average, raising the scrubber air volume from 6,000 to 14,000 cfm produced a modest 23% decrease in methane concentration. The greatest decrease in methane concentration was at an intake airflow of 6,000 cfm, where raising the scrubber volume from 6,000 to 14,000 reduced methane levels by 38%. These results generally mirror those of MSHA's scrubber tests shown in Figure 3–8, indicating improved methane dilution at higher scrubber airflows.

- *Water sprays*. The impact of water sprays on scrubber ventilation effectiveness has been studied by Volkwein and Wellman [1989] and Taylor and Zimmer [2001]. Volkwein and Wellman

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[10] Bear in mind that these figures are only averages. On a cut-to-cut basis, peak methane values vary widely. For example, Haney et al. [1983] found that the methane dilution capacity had a coefficient of variation of 55%. Similar variability has been found by Smith and Stoltz [1991].

found that effective scrubber operation depends on the air movement generated by the dust-suppression water sprays. Turning off the spray system doubled the methane level.[11]

Volkwein and Wellman also tested a directional spray system (similar in concept to the spray fan system described above) to help direct the air into the single inlet scrubber they were testing. Switching from a conventional spray system to a directional spray system yielded a 23% reduction in the methane level. Taylor and Zimmer saw no benefit from directional sprays because they were testing a dual-inlet scrubber system.

- *Exhaust direction*. Taylor and Zimmer [2001] conducted tests to assess the impact of changing the scrubber exhaust toward or away from the blowing line curtain. As might be expected, directing the exhaust toward the blowing curtain interfered with the air stream from the curtain and gave the highest methane levels. By comparison, directing the exhaust straight back lowered methane levels at the face by 30%. Directing the exhaust toward the return-side rib lowered methane an additional 25%, for a total decrease of 55%.

When a scrubber is used in conjunction with blowing ventilation, it is important that the blowing curtain (or duct) be on the side of the entry opposite the scrubber exhaust and that the exhaust be directed at the return-side rib.

- *Clogging*. Clogging of the flooded-bed filter panel or the scrubber ductwork will seriously inhibit the methane dilution capacity of scrubbers. Denk et al. [1988] conducted a study in an Alabama mine that measured the methane dilution impact of a clogged scrubber inlet. The scrubber being tested had a metal plate that restricted the airflow at one of the two inlets, and the methane dilution capacity of the system was 28.5 cfm. When the metal plate was removed, subsequent testing showed that the methane dilution capacity had risen to 39.3 cfm, a 38% improvement.

Clogging from coal particulate can be very rapid. For example, Campbell and Dupree [1991] noted a scrubber air decrease of 23% after just one 30-ft cut of coal. Schultz and Fields [1999] noted that some scrubbers lose as much as one-third of their airflow after just one cut.

Schultz and Fields [1999] reported on a method used by one mine operator to block large pieces of coal from entering the scrubber inlets under the boom. The mine had installed a flap of conveyor belt about 8 in inby each inlet, and the flaps extended downward about 8 in. The flaps forced the air to make an extra turn before entering the inlet, blocking the larger particles flying from the cutting drum. These flaps worked so well that the scrubber lost only 10% of its airflow capacity after an entire shift of operation.

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[11] This result is not surprising. Wallhagen [1977] found the same effect with a conventional exhaust ventilation system with conventional sprays and no scrubber.

When a dust scrubber clogs, its air quantity declines. Taylor et al. [1995] investigated ways to alert the miner operator to a clogging problem. The most effective was to monitor the fan motor current, since an air quantity decline resulting from clogging will lower the fan motor current.

- *Turning crosscuts*. Using a small-scale model, Tien [1989] assessed the ventilation provided by scrubbers whenever crosscuts were being mined. Results showed that keeping the line curtain as close as practical to the rear of the miner is essential for controlling both respirable dust and methane.

- *Less critical operating factors*. Other operating factors, once thought to be important, have turned out to be less critical. For example, Taylor et al. [1997] found that changing the line curtain airflow in the range between 6,000 and 14,000 cfm does not change the average face methane concentration. Also, methane levels do not increase when the line curtain airflow is less than the scrubber airflow (6,000-cfm line curtain versus 14,000-cfm scrubber), a situation that leads to a high amount of recirculation. Many years earlier, a study by Kissell and Bielicki [1975] led to a conclusion that recirculation per se was not harmful, as long as a sufficient quantity of fresh air was provided by the line curtain.

DUST SCRUBBERS WITH EXHAUST VENTILATION

Dust scrubbers have also been used with exhaust ventilation. However, the major drawback to using scrubbers with exhaust ventilation is the need to ventilate the empty headings that have been mined out, but not yet bolted. The jet from a blowing curtain can provide some minimal ventilation level, but an exhaust curtain may not [Luxner 1969].

Haney et al. [1983] conducted the first tests with scrubbers and exhaust curtain, obtaining a methane dilution capacity of 33.4 cfm using a 6,700-cfm dust scrubber. A subsequent study using a full-scale model [Taylor et al. 1996] gave methane dilution capacities ranging from 22 to 58 cfm, depending on airflow.[12] Both of these studies employed an exhaust line curtain located on the *same* side of the entry, so the air jet from the scrubber fed directly into the line curtain as shown in Figure 3–10.

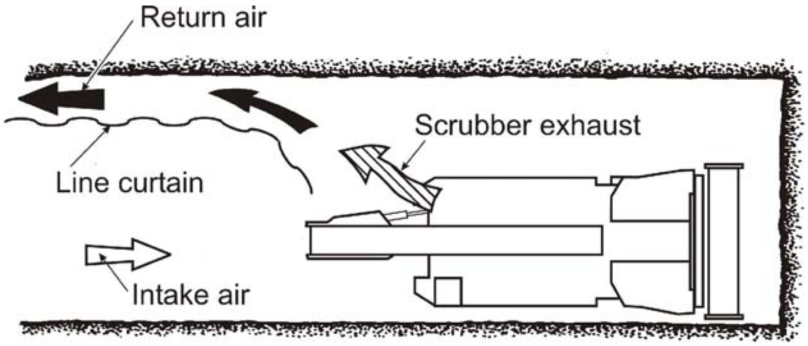

Figure 3–10.—Dust scrubber used with exhaust ventilation.

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[12] This study gave average methane concentrations, whereas the methane dilution capacity is normally calculated based on the highest measured concentration (see footnote 7). To obtain the methane dilution capacity values stated, we assumed that the highest measured concentration would be 30% greater than the average concentration.

When the scrubber exhaust is *not* on the *same* side of the entry as the exhaust curtain, methane dilution suffers. For example, Stoltz et al. [1991] conducted a scrubber ventilation study at a mine that had an exhaust curtain on the opposite side of the entry from the scrubber exhaust. The measured methane dilution capacity was only 13 cfm.

Another exhaust line curtain requirement is that the mouth of the curtain be *outby* the scrubber exhaust (Figure 3–10). Jayaraman et al. [1990] conducted a series of tests that included a line curtain setback of 10 ft, which was about 10 ft *inby* the scrubber exhaust. The methane dilution was one-half to one-fourth of that obtained with a curtain setback of 30 ft.

When using a scrubber in conjunction with exhaust ventilation, keep the curtain on the same side of the entry as the scrubber exhaust and keep the mouth of the curtain outby the scrubber exhaust (as shown in Figure 3–10).

THE VENTILATION OF ABNORMALLY GASSY FACES

Some continuous miner faces have abnormally high methane emissions, and it is helpful to explore the various alternatives a mine operator might have to safely ventilate such faces. Although mine tests have not been conducted, a high-pressure spray fan and a high-volume scrubber have each achieved a methane dilution capacity on the order of 100 cfm in laboratory tests, provided that line curtain air quantities were large[13] and curtain setback distances were modest.

Abnormally gassy faces may be ventilated with diffuser fans, high-pressure spray fans, or high-volume scrubbers.

However, degasification with horizontal or vertical boreholes is necessary if the section emits over 300 cfm of methane. For more on degasification, see Chapter 6.

Diffuser fan. The diffuser fan is a small fan mounted on the continuous miner that directs an air jet at the working face. Used in conjunction with exhaust line curtain, it was the primary means of ventilating gassy faces before the development of the spray fan. Wallhagen [1977] developed an optimized two-nozzle, 1,750-cfm fan that essentially induced all 9,000 cfm of the line curtain

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[13] Methods to increase airflow by decreasing line curtain and check curtain leakage have been described by Muldoon et al. [1982]. A high-capacity duct system designed to deliver 45,000–50,000 cfm has been described by Hagood [1980].

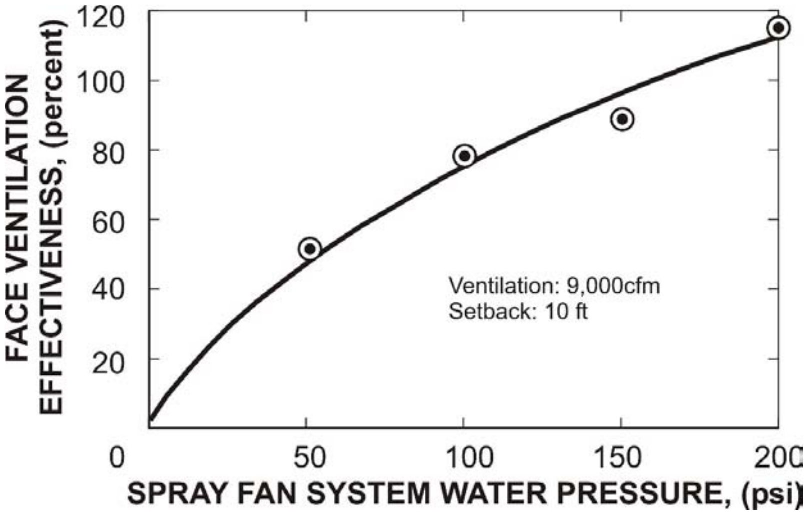

Figure 3–11.—Graph showing that performance of a spray fan depends on water pressure.

air to the face, yielding a methane dilution capacity of roughly 65 cfm (see footnote 12). The ventilation setback (duct was used) was 10 ft. Some years later, Haney et al. [1982] tested a high-volume 5,000-cfm diffuser fan. With line curtain airflows of 9,000 cfm and higher, the minimum methane dilution was 74 cfm for a 10-ft curtain setback and 67 cfm for a 20-ft curtain setback.

Although effective for diluting methane, diffuser fans were not popular in the past because they were noisy and kicked up dust. They might be more acceptable on today’s remote-control machines. Wallhagen [1977] gives tips on how to design a diffuser fan system that is matched to a line curtain airflow of 15,000–20,000 cfm.

High-pressure spray fan. It was mentioned earlier that a spray fan tested by Ruggieri et al. [1985b] gave methane dilution capacities of 115 and 135 at pressures of 100 and 150 psi, respectively, but that subsequent MSHA tests gave much lower values. To get full performance from a spray fan system, the system must be installed and operated according to established guidelines [Ruggieri et al. 1985a] and with line curtain airflows of 15,000 cfm or more. High performance from spray fan systems also requires that they be operated at high water pressure, as shown in Figure 3–11 [Wallhagen 1977].

High-volume scrubber. In a full-scale laboratory test facility, Taylor et al. [1996] tested a 14,000-cfm scrubber in conjunction with a 14,000-cfm blowing line curtain. At a 25-ft curtain setback, the methane dilution capacity was 111 cfm (see footnote 12). At a 35-ft setback, the methane dilution capacity decreased to 68 cfm.

When the 14,000-cfm scrubber was used in conjunction with a 14,000-cfm *exhausting* line curtain, the methane dilution capacity was 58 and 53 cfm at 25- and 35-ft setbacks, respectively.

METHANE DETECTION AT CONTINUOUS MINER FACES

Two methods of methane detection are used at continuous miner faces: intermittent sampling with portable methane detectors and continuous monitoring with machine-mounted methane monitors. These are both required by MSHA regulations [30 CFR 75].

Methane monitors are usually mounted on the side of the cutting boom of the continuous miner. The best practice is to select the side that normally sees the highest concentrations.[14] For exhaust ventilation systems, including spray fan and scrubber systems, this is normally the same side of the entry where the exhaust curtain (or duct) is located. For blowing ventilation used with scrubber systems, it is normally the opposite side of the entry from the blowing curtain (or duct) [Zuchelli et al. 1993; Schultz et al. 1993; Stoltz and Snyder 1991; Snyder et al. 1993; Smith and Stoltz 1990; Denk et al. 1988; Snyder et al. 1991; Dupree et al. 1993; Mott and Chuhta 1991; Denk et al. 1989].

The required intermittent sampling is a gas check every 20 min with a portable methane detector. A common practice is to attach the portable methane detector to the end of an extensible pole, then to extend the pole out over the continuous miner as far forward as possible. However, this is an awkward procedure that requires a long pole, a methane detector with a large readout, and good eyesight. Another approach, used at deep-cut faces, is to tram out the miner and attach the methane detector to the head using a magnet. The miner is then trammed back in and the detector read.

VENTILATION AND METHANE DETECTION AT BOLTER FACES

On faces that are being bolted, the line curtain or ventilation duct must always be extended to the last row of bolts and moved forward when a new row of bolts is installed. For particularly gassy faces, it may be necessary to use an extensible curtain or duct system [Muldoon et al. 1982].

With regard to methane detection, it has always been difficult to make a methane concentration measurement at the face while, at the same time, remaining safely under bolted roof. Extended-cut mining methods have increased this difficulty because the freshly cut face can extend 40 ft or more beyond the last row of bolts. To deal with this problem, MSHA has published a new rule [68 Fed. Reg.[15] 40132 (2003)]. This new rule, based on the work of Taylor et al. [1999], allows methane tests to be made at intervals not exceeding 20 min by sweeping a 16-ft probe inby the last permanently supported roof, provided that a methane monitor is also mounted on the roof-bolting machine.[16] The methane monitor must be capable of giving a warning signal at 1.0% methane and capable of automatically deenergizing the machine at 2.0% methane, or if the monitor is not working properly.

Typical ignitions at roof bolter faces have been discussed by Urosek and Francart [1999].

REDUCING FRICTIONAL IGNITIONS

Up to this point, the emphasis of this chapter has been solely on ventilation methods and monitoring for gas. However, the chance of a methane ignition may be further reduced by

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[14] For additional information on methane monitor placement, see Chapter 2 on sampling.

[15] See Fed. Reg. in references.

[16] See 68 Fed. Reg. 40132 [2003] for requirements on methane testing.

dealing directly with the ignition source. When a continuous miner cutter bit strikes rock, abrasion from the rock grinds down the rubbing surface of the bit, producing a glowing hot metal streak on the rock surface behind the bit. The metal streak is often hot enough to ignite methane, causing a so-called frictional ignition.

At continuous miner faces, there are two approaches to lower the incidence of frictional ignitions. The first approach concerns the bit itself—providing a regular change-out schedule to replace worn bits, providing bits with a larger carbide tip to reduce wear, and possibly changing the bit attack angle or the type of bit.

The second approach is to mount a water spray behind each bit, aiming the spray toward the location on the rock where the hot metal streak is expected. This anti-ignition back spray quenches the hot streak, reducing its temperature and the chance of a frictional ignition.

Bit changes to reduce frictional ignitions. The most important action one can take to reduce frictional ignitions is to replace bits regularly, thus avoiding the formation of wear flats on the bits. Frictional ignition with a mining bit always involves a worn bit having a wear flat on the tip of the bit [Courtney 1990]. A small wear flat forms a small hot spot, which does not lead to an ignition, whereas a large wear flat forms a large hot spot that is more likely to cause an ignition. Also, mining bits consist of a steel shank with a tungsten carbide tip. The steel is more incendiary than the tungsten carbide tip, so if the tip is worn off and the steel shank exposed, the chance of an ignition is much greater. As an example, Figure 3–12 shows the results of a test in which a cutter bit was used to cut a sandstone block in the presence of an ignitable methane concentration. With the tungsten carbide tip in place, no ignitions were obtained even after 200 or more cuts. With the steel shank exposed, ignitions quickly began. With as little as 0.3-cm bit wear, fewer than 10 cuts were necessary to produce an ignition.

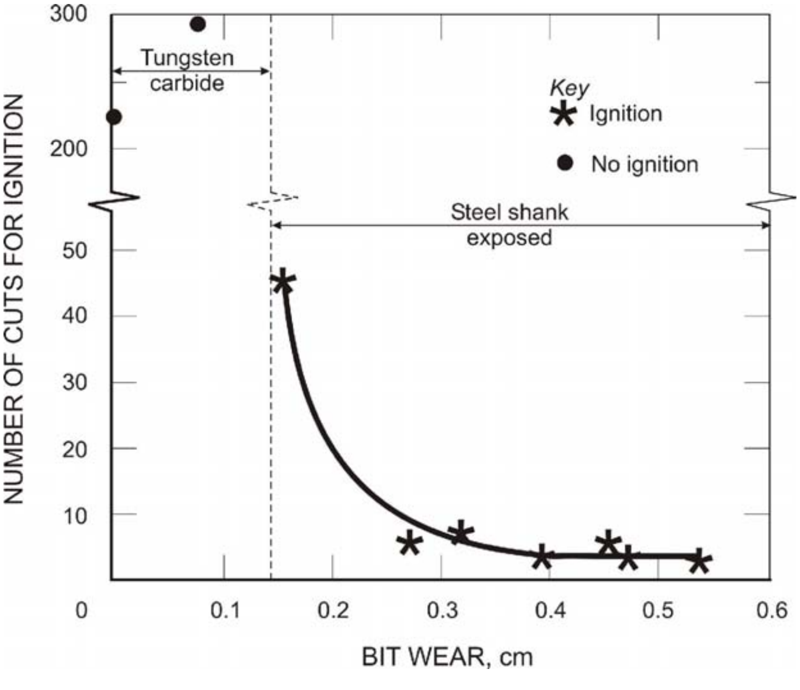

Figure 3–12.—Effect of bit wear on frictional ignition [Courtney 1990].

Bits that wear more slowly can be changed less frequently. Bit wear is reduced by using bits that have larger carbide tips or by using bits that have a highly abrasion-resistant polycrystalline diamond layer on the rake face of the tip.

Other methods to reduce frictional ignitions are to change the attack angle and tip angle of conical bits [Courtney 1990] and to use radial bits instead of conical bits [Phillips 1996]. McNider et al. [1987] reported a decrease in frictional ignitions by using bits with larger carbide tips and by changing the bit attack angle.[17]

Anti-ignition back sprays. Anti-ignition back sprays, an effective method to reduce frictional ignitions, are discussed in the longwall chapter (Chapter 4). Bringing water to the cutter head on continuous miners has been an engineering challenge. However, in recent years, practical (if expensive) water seals for continuous miner heads have been developed. As a result, a few "wet-head" continuous miners equipped with anti-ignition back sprays have been installed in U.S. coal mines with a history of frictional ignition problems. Phillips [1997] has provided a status report on wet-head cutting drums.

A thorough review of frictional ignitions in mines, including metal-to-metal ignitions and those from roof falls, is provided by Phillips [1996].

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