CHAPTER 9.—CONTROL OF METHANE DURING COAL MINE SHAFT EXCAVATION AND FILLING

By Fred N. Kissell, Ph.D.[1]

In This Chapter

- ✓ Ventilation and methane sampling guidelines for conventional shafts
- ✓ Dealing with restricted spaces where methane can accumulate
- ✓ Ventilation and methane sampling at raise bore drills

and

- ✓ Filling shafts at closed coal mines

It is not unusual to encounter methane gas during shaft excavation or shaft-filling operations. Shafts into coalbeds usually produce the most methane, so the information in this chapter applies primarily to shafts at coal mines. Nevertheless, much of the information is relevant for noncoal mines that have methane in the mine or in the overlying strata.

METHANE IN SHAFTS EXCAVATED BY CONVENTIONAL MEANS (DRILL, BLAST, MUCK)

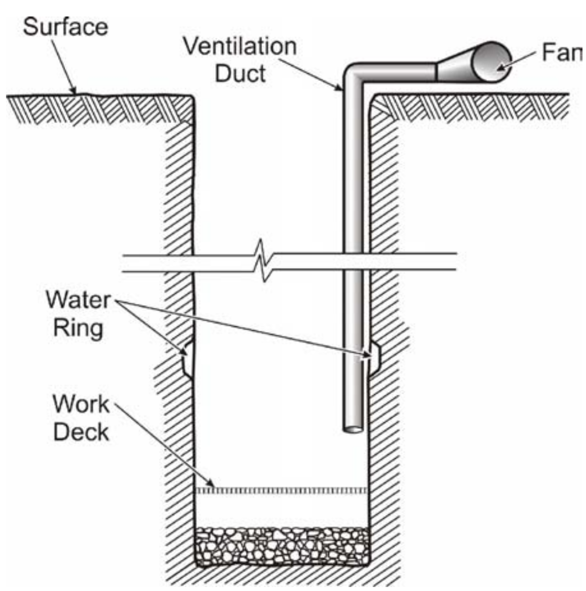

Figure 9–1.—Mine shaft under construction.

Ventilation. Shafts excavated by conventional means are ventilated with a fan on the surface connected to ductwork that extends down into the shaft (Figure 9–1). Shafts into coalbeds should have ventilation systems designed to handle the higher gas flows to be expected as the shaft excavation passes through any overlying gas-containing strata and nears the coalbed to be mined. Following are some simple ventilation guidelines for the minimum amount of air required and the selection of the ventilation duct:

- Provide enough air to meet the minimum OSHA tunnel requirement of 30 ft/min air velocity in the open shaft, as specified in 29 CFR[2] 1926.800(k)(3). For example, a 20-ft-diam shaft having

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

an area of 314 ft^2 would require 9,420 cfm at the inby, or bottom, end of the ventilation duct.

- Assume at least 35% leakage between the fan and the inby end of the ventilation duct. Using the 9,420-cfm figure above, the fan would have to deliver at least 14,500 cfm.

- Size the ventilation duct diameter to achieve a duct velocity of 3,000 ft/min or less. Using the 14,500-cfm fan quantity above, the duct would have an area of 4.8 ft^2 or more and a diameter of at least 2.5 ft.

- Locate the inby end of a duct exhausting air from the shaft within 10 ft of the point of deepest penetration. If exhaust ventilation is used, auxiliary ventilation of the space below the work deck may be necessary.

- Locate the inby end of a duct blowing air into the shaft within 15 duct diameters of the point of deepest penetration. For example, using the 2.5-ft duct diameter figure above, the maximum distance between the end of the duct and the point of deepest penetration would be 37.5 ft.

- Limit fan shutdown times when workers are in the shaft to a maximum of 15 min. Monitor the methane level in the air during fan shutdowns.

Gas sampling. Preshift and on-shift examinations for methane are governed by federal coal mine regulations at 30 CFR 77.1901. This regulation requires that methane be measured by a certified person within 90 min before each shift, at least once during the shift, and both before and after blasting. Other examinations for methane must be made immediately before and periodically during any welding or cutting in the shaft, per 30 CFR 77.1916(c). In all instances, work must not continue when the air contains 1.0 vol % or more of methane.

Particular attention should be paid to sampling the gas level in restricted spaces (as described in the later section on water rings) and in any portion of the shaft where the free movement of air is restricted. Figure 9–2 illustrates how the free movement of ventilation air is inhibited by the presence of a work deck, even if the deck is fabricated from metal grating. In such circum-stances, methane measurements must be made with an extensible probe positioned to draw air samples immediately below the work deck and at regular intervals all the way down to the muck pile. Measurements are necessary at regular intervals because assumptions cannot be made as to where the methane is likely to accumulate.[3]

[3]Cook [1998] describes a shaft explosion in a South African mine where the workers assumed that any methane would layer just below the work deck, making any measurements further down unnecessary. They failed to recognize that methane released from the muck at the bottom is very unlikely to layer and that once the methane is mixed into the air, it cannot unmix to form a layer. Because of this, measurements must be made at regular intervals over the entire distance between the work deck and the muck pile. For more information on layering, see Chapters 1 and 11.

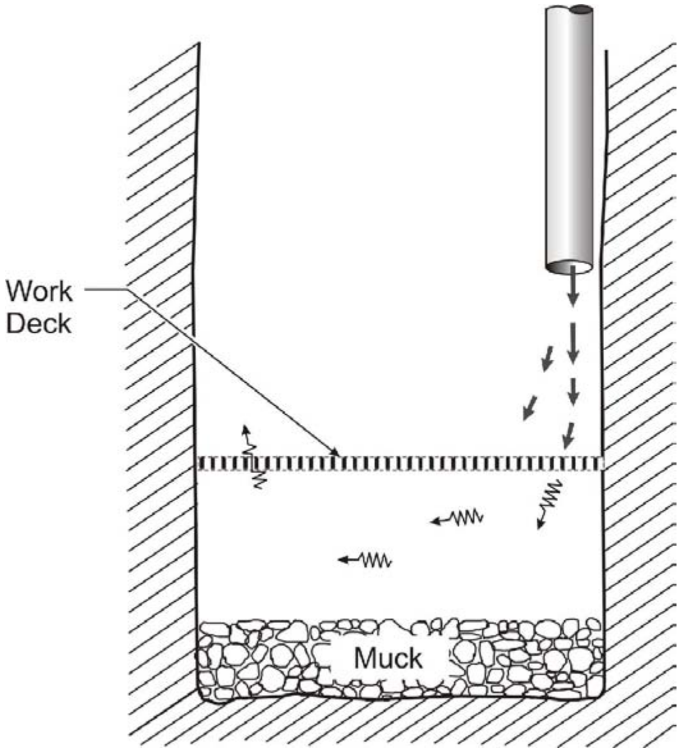

Figure 9–2.—Ventilation airflow is restricted by work deck. Therefore, methane must be monitored at regular distances between the work deck and the muck pile.

Welding and cutting. To the extent possible, welding and cutting should be done on the surface. When welding and cutting in the shaft cannot be avoided, gas check procedures must be carefully followed, and the number of people in the shaft must be held to the minimum required to conduct the work and check for gas—usually two individuals.

Water rings. A water ring cross-section is shown in Figure 9–3. Water rings are circular spaces excavated from the rock in a shaft wall. They are used to provide water drainage from the exterior side of the concrete shaft lining and are often located to drain water from an adjacent aquifer. Methane gas may be drained along with the water, resulting in additional hazard.

Water ring spaces in shaft walls are an example of a so-called restricted space, where the ventilation and methane sampling require extra effort.[4]

Failure to monitor restricted spaces such as water rings can have disastrous consequences. For example, in January 2003, three miners were killed by a methane explosion during a shaft-sinking operation in West Virginia [Mills 2003]. A water ring space had been excavated back into the strata from the shaft wall. Before pouring the concrete shaft lining, the water ring space was sealed off with corrugated sheets of steel to prevent it from being filled with concrete. After the concrete had set, the three workers were killed while in the process of opening an access door with an acetylene torch. The torch ignited methane that had accumulated in the water ring space after it was sealed off.

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[4]Sampling for methane in restricted spaces is described in more detail in the sampling chapter (Chapter 2).

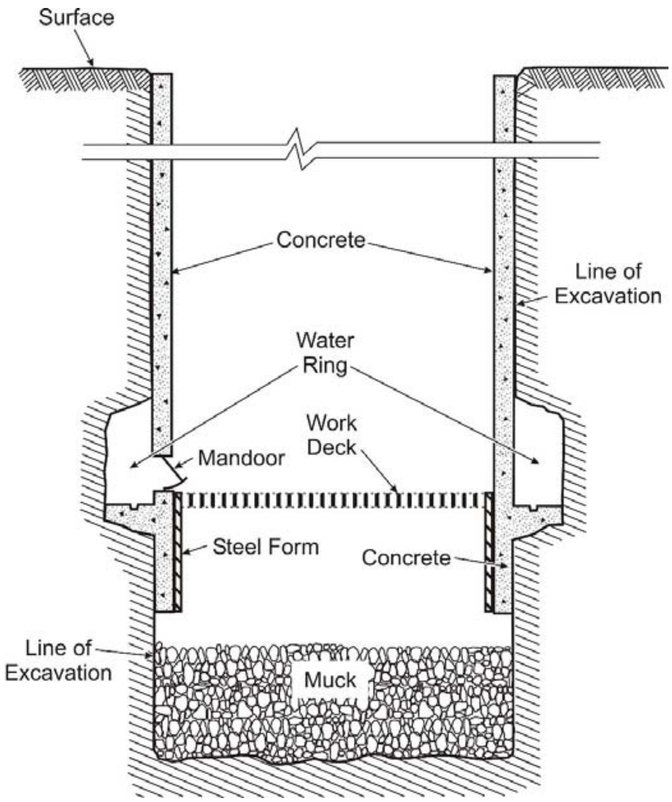

Figure 9–3.—Water ring in shaft wall (adapted from Oakes et al. [2003].

In the case of the abovementioned West Virginia mine, any one of the following measures would have reduced the chance of an explosion:

- Thoroughly ventilating the water ring space with compressed air.
- Carefully checking for methane using a methane detector with a probe inserted into the water ring space.
- Opening the access door without using an acetylene torch.

To avoid methane problems when dealing with water rings, the appropriate action is to incorporate all three measures into standard operating practice.

METHANE IN SHAFTS EXCAVATED WITH RAISE BORE DRILLS

Like conventional shafts, raise bore shafts at coal mines must be well-ventilated and the methane level must be monitored frequently. Maksimovic [1981] reported on some methods to ventilate raise bore shafts. These involve moving air through the drill stem or the annular space between the drill stem and the wall of the pilot hole. A more recent approach is to drill a second hole for ventilation and methane sampling (Figure 9–4).

The methods reported by Maksimovic involve the use of air compressors to inject air into the shaft in quantities ranging from 600 to 3,000 cfm, and vacuum pumps to withdraw air from the shaft in quantities ranging from 600 to 1,000 cfm. These are used separately or in combination as follows:

- *Alternating the use of the air compressor and vacuum pump*. Compressed air is injected down the drill stem[5] for a period of 2–4 hr, and then a vacuum pump is used for a short interval to bring an air sample through the drill stem to the surface for a methane measurement.

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[5]At the same time, air can also be forced down through the annulus.

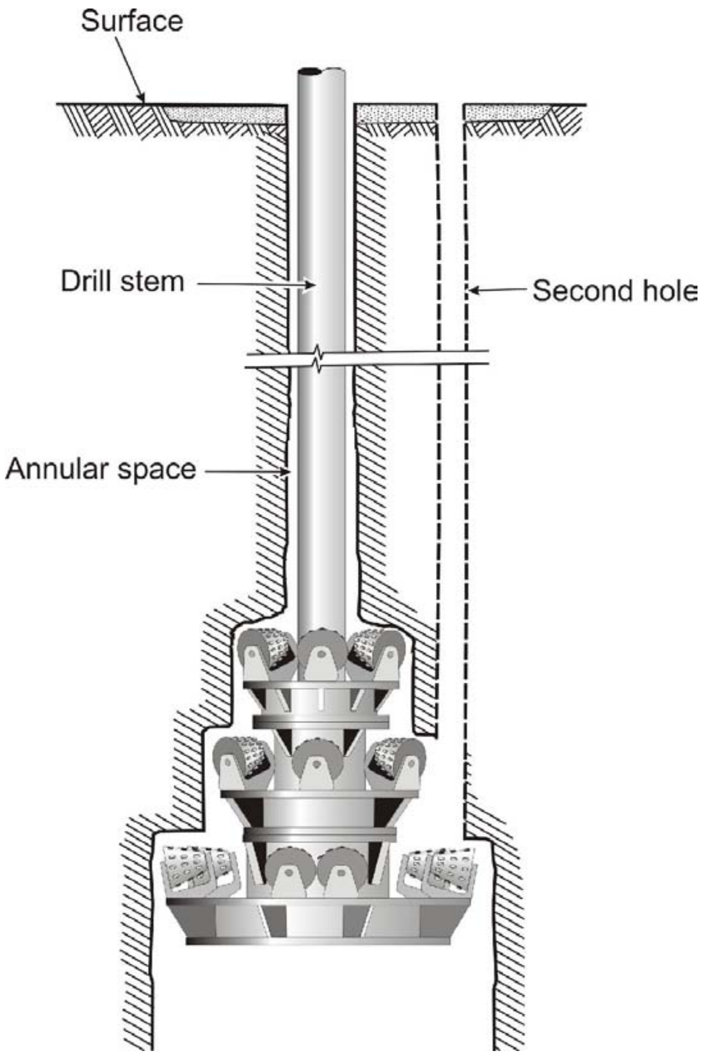

Figure 9–4.—Raise bore shaft with second hole for ventilation.

- *Simultaneous use of the air compressor and vacuum pump*. Compressed air is continuously injected down the drill stem. At the same time, for methane sampling, a vacuum pump is used to draw air up through the annulus between the drill stem and pilot hole wall. This method allows for continuous sampling of methane, but requires the installation of a seal (a stuffing box) around the drill stem at the surface to prevent surface air from entering the annulus and contaminating the sample. Any leaks in this seal will cause the indicated methane concentration to be lower than it actually is.

- *Use of the vacuum pump only*. A vacuum pump is used to draw air up through the drill stem. This approach may be suitable when the methane level is very low, and it allows for continuous sampling. However, dust builds up inside the drill stem and accumulates on the joints when sections are removed.

In recent years, an alternative technique to ventilate raise bore shafts has been to drill a second hole for ventilation and methane sampling. This second hole is drilled close to the pilot hole and within the perimeter of the hole to be reamed by the raise drill (Figure 9–4). For gassier mines or those that are likely to have gas in the overburden, this is a better method than using the drill stem or the annulus. Larger quantities of air can be drawn to the surface using a vacuum pump, and the methane concentration can be monitored continuously. Surface leaks are also less of a problem. Finally, the diameter of the hole can be matched to the air quantity requirements.

A disadvantage of using a second hole for ventilation and sampling is that it can only be used for reamed hole diameters of about 8 ft or more. It also requires careful drilling to ensure that the holes do not wander too far apart.

FILLING SHAFTS AT CLOSED MINES

Filling a shaft at a closed coal mine can be hazardous because of methane accumulations in the shaft or at the surface. This gas may be ignited by rock dumped into the shaft or by cutting torches used to dismantle surface structures such as fan housings. The key to maintaining safe conditions is adequate methane and barometric pressure monitoring.

Shaft filling at U.S. coal mines. Under 30 CFR 75.1711–1, the Mine Safety and Health Administration (MSHA) requires that shafts be filled with incombustible material or covered with a 6-in-thick concrete cap that is equipped with a 2-in vent pipe extending upward 15 ft or more.[6] In addition, precautions to deal with methane are necessary during the shaft-filling operation.

Denk et al. [1987] discussed the methods used to monitor methane and the precautions taken to ensure worker safety during a shaft filling operation at a U.S. coal mine. At this mine, an explosion occurred as rock was being initially dumped into the 16-ft-diam, 953-ft-deep shaft. Following the explosion, MSHA measured the shaft methane concentration by extending a sampling tube down the shaft to the bottom and pumping air samples through the tube to the surface.[7] The methane concentration ranged from 2.2% to over 12%.[8]

At this mine, the most cost-effective way of dealing with this gas was to pump compressed air into the shaft to dilute it. Air from a compressor rated at 750 scfm and 100 psi was delivered to the shaft bottom through a 2-in PVC[9] natural gas line secured with a hemp rope. A copper ground wire was attached along the entire length of the gas line to guard against explosion due to static electricity. The gas line was to be pulled up as the shaft was filled. After 4 hr of operation with this system, methane at the 835-ft level in the 16-ft-diam shaft was reduced from 9.5% to 1.4%.

Subsequently, MSHA specified that while work was being conducted in the shaft area, the methane concentration at the bottom of the shaft was to be maintained at 2.0% or less and elsewhere in the shaft at 3.0% or less. Alternating 1-hr periods with the air compressor turned on and off was enough to keep the methane concentration within these limits as the shaft was being filled.

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[6]Under MSHA regulations, shafts must be either filled or capped. Other federal or state agencies may require that shafts be filled.

[7]An alternative method, using newer technology, is to lower a data-logging methane detector into the shaft.

[8]MSHA used an infrared analyzer to measure the methane concentration. Infrared analyzers are accurate at high methane concentrations and/or low oxygen levels. Bear in mind that methane detection instruments that use heat of combustion sensors are not accurate at methane concentrations above 8% or oxygen concentrations below 10%. See the sampling chapter (Chapter 2) for more information on the distinction between infrared analyzers and heat of combustion sensors.

[9]Polyvinyl chloride.

After the shaft was filled, mine gases continued to leak to the surface. Explosive concentrations of methane were measured at the surface, so air-powered tools were used to dismantle the fans. In addition, elevated carbon dioxide levels and oxygen deficiencies persisted in the fan housing and the structures surrounding the shaft collar. Nevertheless, the project was completed without further incident.

Shaft filling in Germany. Hinderfeld [1995] reported on the methane safety precautions taken during shaft filling in Germany, where more than 100 shafts had been filled in the previous 10 years. When shafts are not under the influence of a fan, the flow of methane is controlled by the barometric pressure. High flows of methane have been observed when the barometric pressure falls and the gas-laden mine air expands and fills the shaft from below. In this situation, it is important to monitor the barometric pressure.

The preferred approach to shaft filling at each mine is to ensure that the shaft being filled is downcast and ventilated with a fan in another shaft. The last two shafts at the mine are then closed off simultaneously and filled as quickly as possible.

During filling, the methane concentration is continuously measured at a point 50 m (164 ft) below the surface. If a threshold value—established for that particular shaft—is reached, then filling work stops and the shaft is probed to the bottom.

When high methane concentrations are recorded, and if these are not diluted during a subsequent barometric pressure increase, the shaft atmosphere is inerted by adding enough carbon dioxide or nitrogen to reduce the oxygen content below 10%.[10]

REFERENCES

CFR. Code of federal regulations. Washington DC: U.S. Government Printing Office, Office of the Federal Register.

Cook AP [1998]. The occurrence, emission, and ignition of combustible strata gases in Witwatersrand gold mines and Bushveld platinum mines, and means of ameliorating related ignition and explosion hazards. Final project report, project GAP 504. Braamfontein, Republic of South Africa, Safety in Mines Research Advisory Committee (SIMRAC) (www.simrac.co.za).

Denk JM, Francart WJ, Baran JN [1987]. Monitoring mine gases during shaft filling operations. In: Proceedings of the Third Mine Ventilation Symposium (University Park, PA, October 12–14, 1987).

[10]When a shaft is under the influence of barometric pressure, adding carbon dioxide or nitrogen can be a better approach than diluting methane with compressed air. When compressed air is used, a spike in the methane flow due to a falling barometer may move the shaft atmosphere into the explosive range. When the shaft is inerted, a spike in the methane flow may drive the shaft atmosphere at the bottom further into the inert range.

Hinderfeld G [1995]. Ventilation-technical and gas management measures within closing down of coal mines. In: Proceedings of the 26th International Conference of Safety in Mines Research Institutes (Katowice, Poland, September 4–8, 1995). Vol. 2. Katowice, Poland: Central Mining Institute, pp. 201–217.

Maksimovic SD [1981]. Control of methane by ventilation of shafts during raise drilling. Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, IC 8847. NTIS No. PB81234502.

Mills B [2003]. Fatal shaft explosion report investigation, McElroy Coal Co., McElroy mine, Permit No. U–83–33, Central Cambria Drilling Co., contractor No. C–618, January 22, 2003. Fairmont, WV: West Virginia Office of Miner's Health, Safety and Training.

Oakes JK, Tortorea JS, Stoltz RT, Stephan CR, Brown VF, Penigar RA, et al. [2003]. Report of investigation, fatal shaft sinking explosion, January 22, 2003. McElroy mine, McElroy Coal Company (subsidiary of CONSOL Energy Incorporated), Cameron, Marshall County, West Virginia, ID No. 46–01437. Arlington, VA: U.S. Department of Labor, Mine Safety and Health Administration.

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