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Control of Methane by Ventilation of Shafts During Raise Drilling

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At some coal mines, methane gas is released during raise drilling. At the request of the Mine Safety and Health Administration (MSHA), U.S. Department of Labor, the Bureau of Mines conducted ventilation surveys at different raise drill sites to assess various methods of reducing methane concentration. The resulting data indicate that raise drill shaft cavities are ventilated by air compressors, vacuum pumps, auxiliary blower fans, and free intake air from the surface. The compressors, pumps, and fans operate simultaneously or separately. At the bottom of the shaft cavities, ventilation is controlled by regulators and airlocks. Methane is monitored, measured, and periodically sampled on the surface, at the bottom and at different levels in the shaft cavities. Maximum concentration of 3.5 percent was measured in one shaft in West Virginia. Air velocity down the raise drill shafts is always very low. Maximum recorded air down the drill stem was 3,000 cfm, which can be increased by adding air compressors. The best way to ventilate shaft cavities is through the simultaneous use of air compressors and vacuum pumps. If the methane concentration cannot be reduced with additional compressors, then the inside diameter of the drill rod should be increased, or larger pilot hole drill bits should be used.

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IC 8847

Bureau of Mines Information Circular/1981

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By Slavoljub D. Maksimovic

UNITED STATES DEPARTMENT OF THE INTERIOR

Information Circular 8847

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UNITED STATES DEPARTMENT OF THE INTERIOR
James G. Watt, Secretary
BUREAU OF MINES

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CONTROL OF METHANE BY VENTILATION OF SHAFTS DURING RAISE DRILLING

by

Slavoljub D. Maksimovic [1]

ABSTRACT

At some coal mines, methane gas is released during raise drilling. At the request of the Mine Safety and Health Administration (MSHA), U.S. Department of Labor, the Bureau of Mines conducted ventilation surveys at different raise drill sites to assess various methods of reducing methane concentration. The resulting data indicate that raise drill shaft cavities are ventilated by air compressors, vacuum pumps, auxiliary blower fans, and free intake air from the surface. The compressors, pumps, and fans operate simultaneously or separately. At the bottom of the shaft cavities, ventilation is controlled by regulators and airlocks. Methane is monitored, measured, and periodically sampled on the surface, at the bottom, and at different levels in the shaft cavities. Maximum concentration of 3.5 percent was measured in one shaft in West Virginia. Air velocity down the raise drill shafts is always very low. Maximum recorded air down the drill stem was 3,000 cfm, which can be increased by adding air compressors. The best way to ventilate shaft cavities is through the simultaneous use of air compressors and vacuum pumps. If the methane concentration cannot be reduced with additional compressors, then the inside diameter of the drill rod should be increased, or larger pilot hole drill bits should be used.

INTRODUCTION

In raise drilling, a small-diameter pilot hole is drilled from a higher (surface or underground) elevation to a lower accessible underground elevation. A large cutter assembly is attached to the bottom of the drill rod and enlarges the hole while reaming upward. [2]

Raise drilling in mining has grown rapidly since its introduction in 1957. The mining industry has taken full advantage of the method only recently when the raise drill shaft diameters exceeded 20 feet. Raise drill shafts are used to improve ventilation systems and provide better access to

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[1]Mining engineer, Pittsburgh Research Center, Bureau of Mines, Pittsburgh, Pa.

[2]Christensen, R. Raise Boring Experience at Sunnyside Coal Mines. Pres. at 1971 Coal Conv., Am. Min. Cong., Pittsburgh, Pa., May 16-18, 1971, 9 pp. American Mining Congress, Washington, D.C.

working areas by locating air shafts and miner portals at strategic points.[3] This technique offers the possibility of a cheaper, faster, and safer way to build ventilation shafts, and was first applied for this purpose in the coal mining industry about 10 years ago. However, it was found that at some coal mines methane gas is released during raise drilling. This has generated some concern over proper ventilation at raise drill cavities. At the request of the Mine Safety and Health Administration (MSHA), U.S. Department of Labor, in 1977, the Bureau of Mines collected ventilation data at different drill sites, from equipment manufacturers, and from drilling contractors. The results of this survey are presented in this report.

PILOT HOLE DRILLING

Pilot holes are drilled from the surface or underground down to lower elevations in advance of raise-drilling operations, employing the same drilling machine as for reaming up the shafts. Cuttings are removed from the bottom of the holes by compressed air or water. One or more air compressors hooked to a single manifold can be used to supply compressed air. However, if water is encountered during drilling, air cannot lift the cuttings from the bottom of the hole, and water must be used for this purpose.

The holes range in depth from 50 feet in Indiana to 2,298 feet[4] in New York, and the pilot hole diameters range from 7-7/8 to 13-7/8 inches.

RAISE DRILL SHAFTS

For reaming up the raise drill shafts, drilling manufacturers have introduced specially designed drilling machines that are ruggedly built to suit the tough restrictive conditions, with large torque and variable speed to suit specific rock conditions. Cutter assemblies used for upreaming can be single or multistage, and can be assembled in stages of increased diameter from the top to the bottom. Drill stems are regularly in 4- and 5-foot sections; larger diameter sections are 11-1/2 feet long. Drill stem outside diameters range from 5-3/4 to 15 inches and minimum inside diameters from 2-11/16 to 5-7/16 inches. The shaft diameters range from 3 to 20.25 feet and the depths from 50 to 2,298 feet.

VENTILATION OF RAISE DRILL SHAFTS

Raise drill shafts are ventilated by air compressors, vacuum pumps, and auxiliary blower fans operating simultaneously or separately. In some cases, for coal seams wtih little gas, the free intake air from the surface is used. One or more compressors are used depending on the amount of air required. Rated compressor capacities were 600 cfm. Rated capacities at vacuum pumps ranged from 620 to 1,000 cfm.

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[3]Wright, W. L. Kaiser's Sunnyside Mines Go All Out for Raise Boring. Coal Age, v. 76, No. 1, January 1971, pp. 61-65.

[4]Davis, H. Raising High Volume Airshafts. Ch. in Coal Age Operating Handbook of Underground Mining. McGraw-Hill, Inc., New York, v. 1, 1977, pp. 122-125.

Ventilation at the bottom of the raise shafts is controlled by regulators used in normal mine ventilation systems. A general location plan with ventilation systems during the drilling of two raise shafts is shown in figure 1. Figure 2 shows a typical plan view at the bottom of the raise shaft with ventilation systems. Airlocks at the bottom of the raise shafts insure that normal mine ventilation is not interrupted during the breakthrough.

The survey showed that raise drill cavities can be ventilated in several ways, some of which are not standard practice.

Alternate Use of Air Compressors and a Vacuum Pump (fig. 3).--This method is generally used in gassy coal seams and gassy overburden. The air compressor and vacuum pump are located on the surface near the drilling machine. During hole upreaming, compressed air is forced down the drill stem to the cutterhead area. Air sweeps the cutting surface and moves down the completed portion of the shaft to the mine return entries. The amount of air through the drill stem ranges from 600 to 3,000 cfm, depending on the number of compressors used. Air compressors operate during the upreaming and during all idle periods of more than 15 minutes.

Every 2 to 4 hours, air compressors are shut down, and a vacuum pump operates to prevent downward movement of methane-air mixtures and to bring these mixtures to the surface to make methane concentration measurements. The pump operates for 5 to 30 minutes drawing methane-air mixtures from the cutterhead area up through the drill stem. A methane-monitoring system installed on the vacuum pump discharge monitors and records methane concentrations while reaming continues. Rated vacuum pump capacity is 1,000 cfm.

Simultaneous Use of Air Compressors and a Vacuum Pump (fig. 4).--This method is used in mines with an unusual amount of methane. Compressed air is forced down the drill stem to the cutterhead area during the cutting. Some of the air is moved down through the completed portion of the shaft to the mine return entries. Simultaneously, a vacuum pump draws air from the cutterhead area up through the annulus between the drill stem and pilot hole wall. Compressed air is also forced down during idle periods of more than 15 minutes to prevent methane accumulations in the shaft cavities.

A methane-monitoring system located on the pump discharge monitors and records methane concentrations during the raise drilling. The amount of compressed air ranges from 600 to 3,000 cfm. Rated vacuum pump capacity is 620 cfm. The amount of air at the bottom of the shaft ranges from 9,000 to 13,000 cfm.

The simultaneous use of air compressors and a vacuum pump allows a continuous downward movement of the methane-air mixture in the shaft, and the methane concentration is monitored continuously at the vacuum pump discharge while cutting advances continuously upward. The disadvantage of this method is the leakage of surface air into the vacuum pump, which requires the installation of a blooie seal (stuffing box) around the drill stem on the surface.

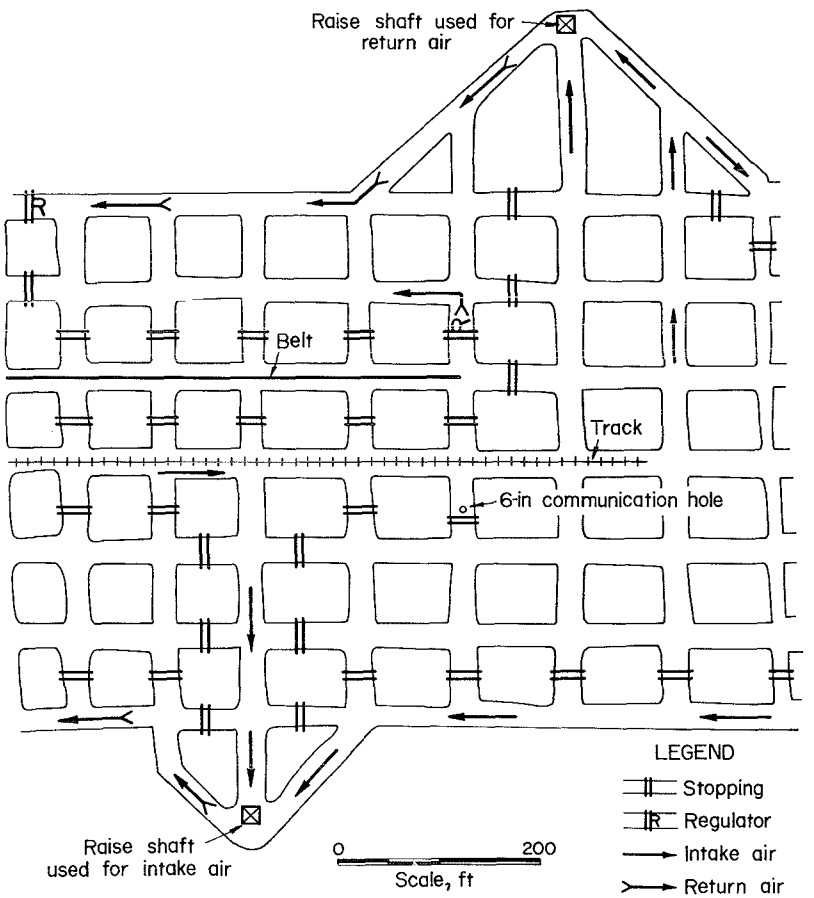

FIGURE 1. - General location plan during drilling of two raise shafts.

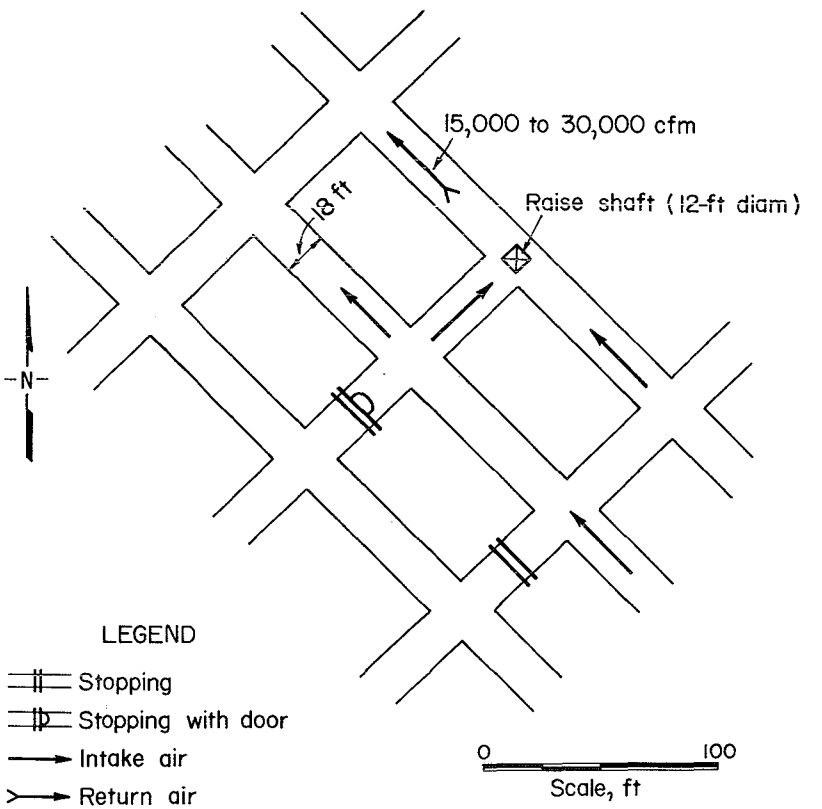

FIGURE 2. - Ventilation system at bottom of raise shaft.

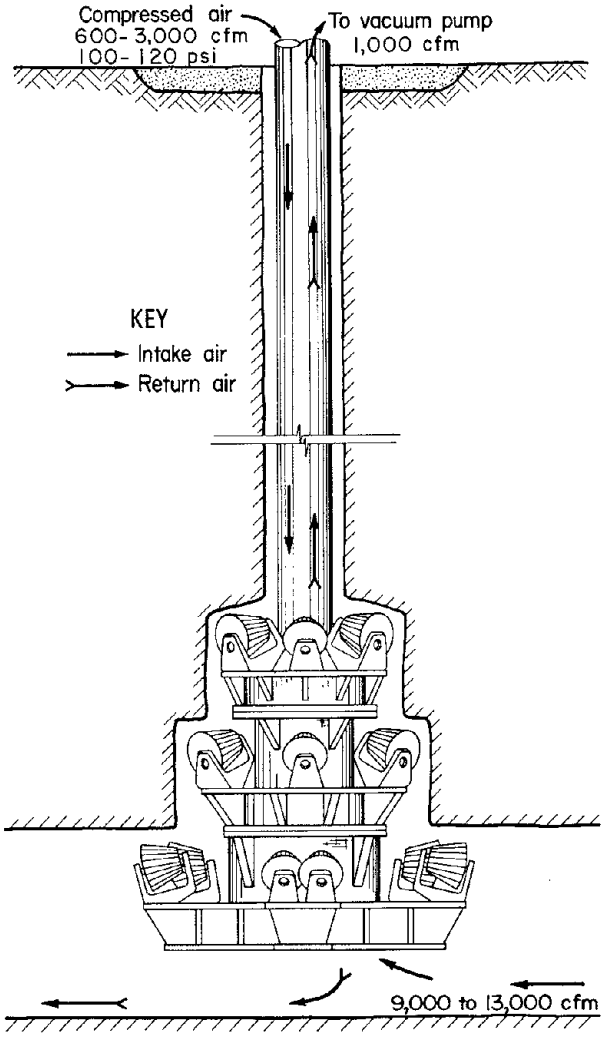

FIGURE 3. - Alternate use of air compressors and vacuum pump for shaft ventilation.

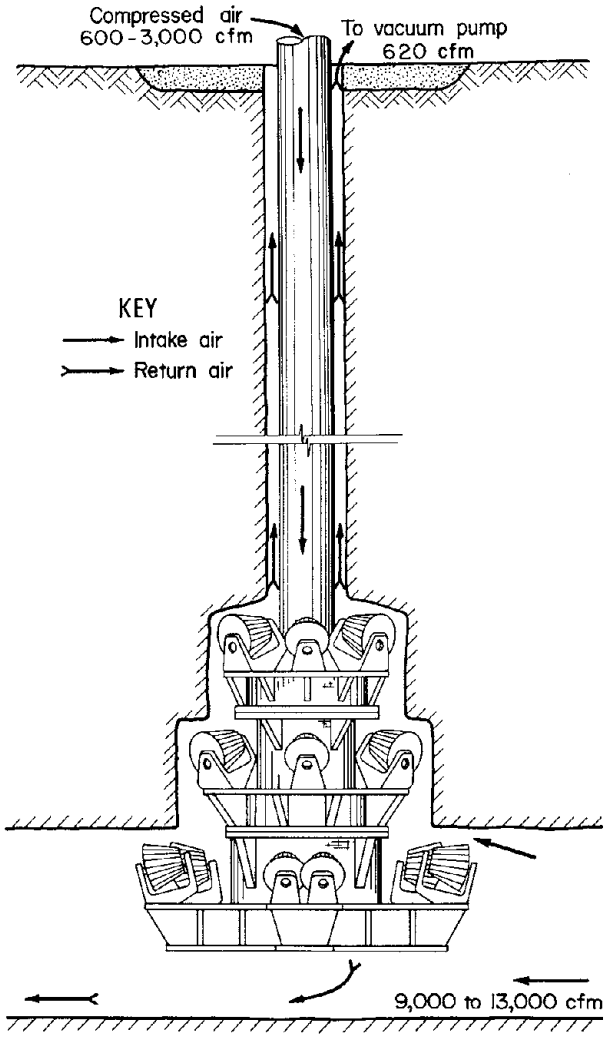

FIGURE 4. - Simultaneous use of air compressor and vacuum pump.

Simultaneous Use of Air Compressors and Auxiliary Blower Fans (fig. 5).--This method is used in some gassy mines in Utah. Compressed air is forced down the drill stem during upward reaming. The air flushes the cutterhead area and moves down the completed portion of the shaft cavity to the mine return entries. One or more compressors are used. If more air is required and the compressors cannot supply it, an auxiliary blower fan on the surface is used to force air down the pilot hole between the outside of the 10-inch-diameter drill stem and the 11-inch-diamter pilot hole.[5] Other auxiliary fans provide additional air which, together with the compressed air, successfully dilutes methane to a safe level.

[5]Work cited in footnote 2.

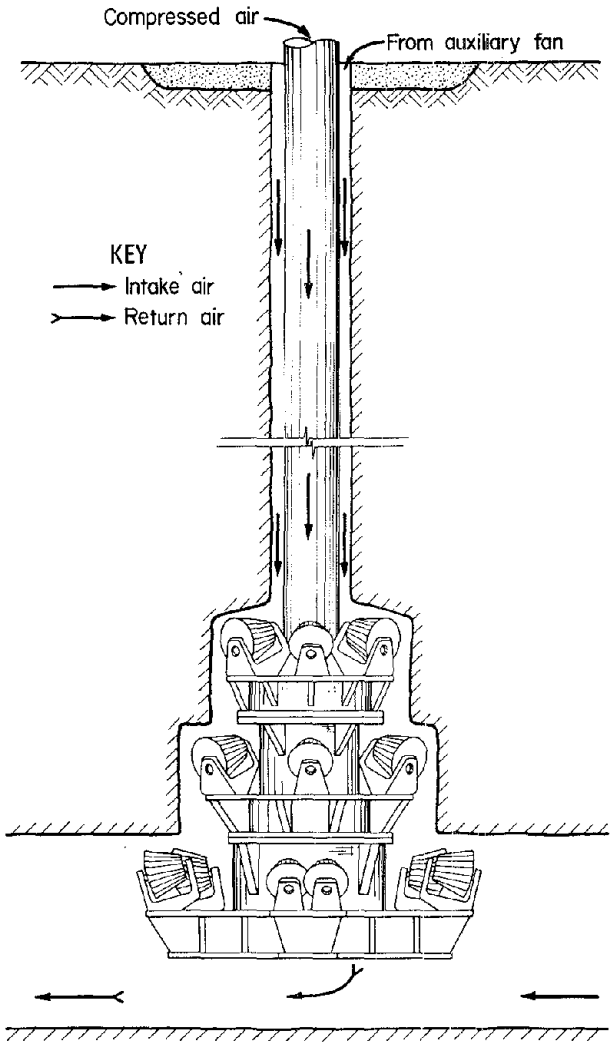

FIGURE 5. - Simultaneous use of air compressor and auxiliary blower fan.

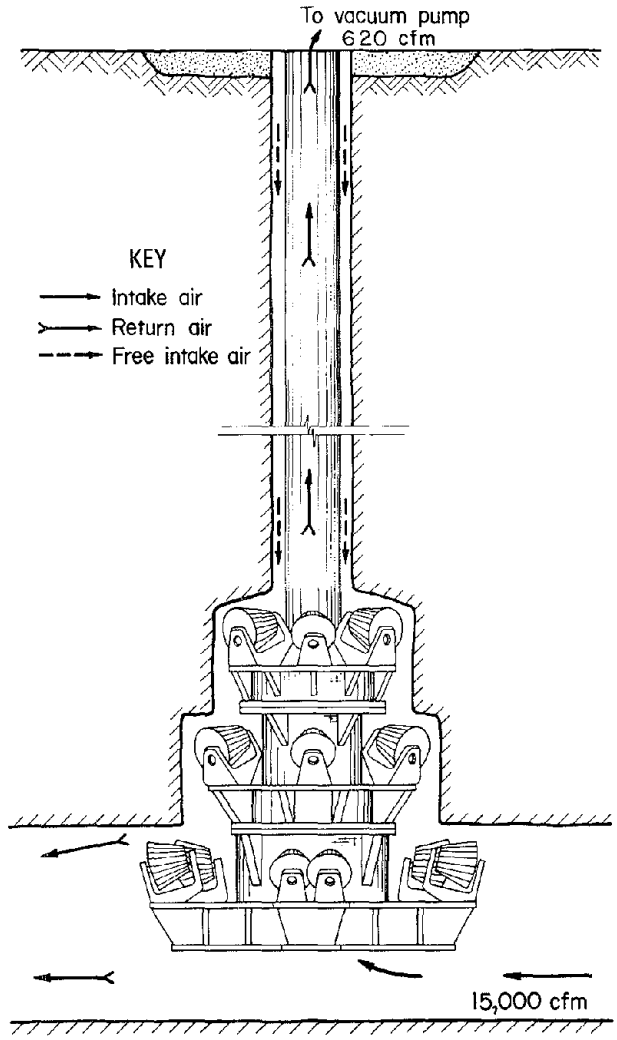

FIGURE 6. - Use of vacuum pump for shaft ventilation.

Disadvantages of the simultaneous use of air compressors and auxiliary blower fans are additional expense and the fact that methane concentrations cannot be monitored on the surface as in the previous case.

Use of a Vacuum Pump (fig. 6).--This method is used in coal seams with low gas. A vacuum pump located on the surface operates continuously during upward reaming, drawing up the methane-air mixture from the cutterhead area through the drill stem. A methane-monitoring system, installed at the pump outlet, is set to flash a light when methane in the pump effluent exceeds some preset value. Rated pump capacity is 620 cfm. Free intake air from the surface moves down the annulus and amounts to a few hundred cubic feet per minute. The amount of air in the underground mine return entries at the bottom of the shaft cavity is about 15,000 cfm.

The advantage of using a vacuum pump for shaft ventilation is that air compressors are not required. The disadvantages are (1) the methane concentration cannot be measured at the bottom of the shaft because of the low rate of free intake air from the surface, (2) considerable dust buildup inside the drill pipe gets on the tool joints when the drill pipe sections are removed, and (3) air samples are not pulled from the face area since inlets may be 8 to 10 feet below the upper cutters.

Use of Free Intake Air (fig. 7).--This method is used in western Kentucky, Indiana, and New Mexico where the coal mines are not deep (50 to 750 feet) and/or the coal is not very gassy. Free intake air from the surface is moved down the annulus and the completed portion of the shaft. At the shaft bottom, this air is mixed with 15,000 to 30,000 cfm of air from the mine

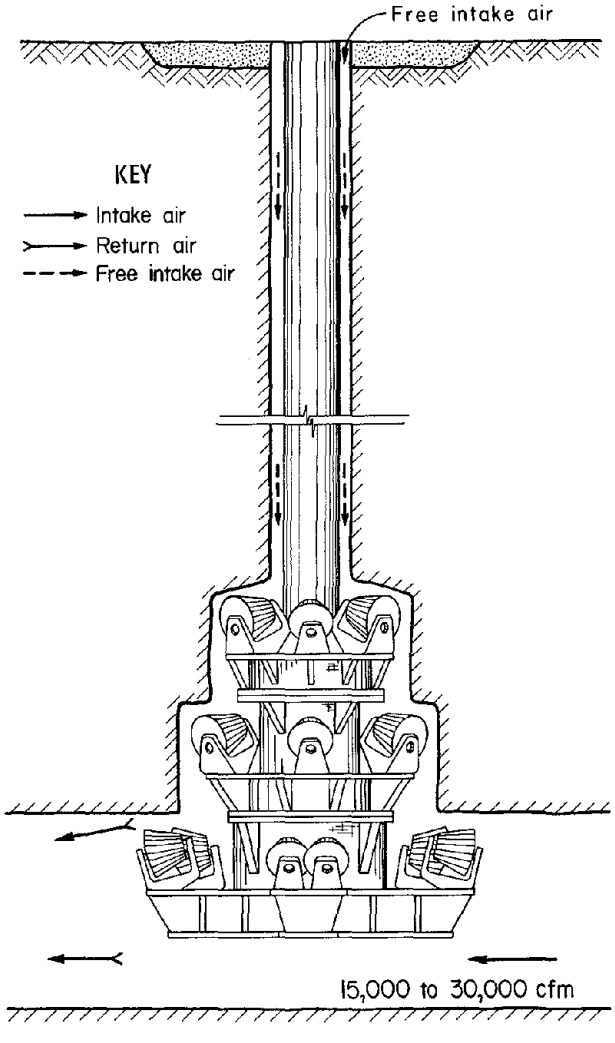

FIGURE 7. - Use of free intake air for shaft ventilation.

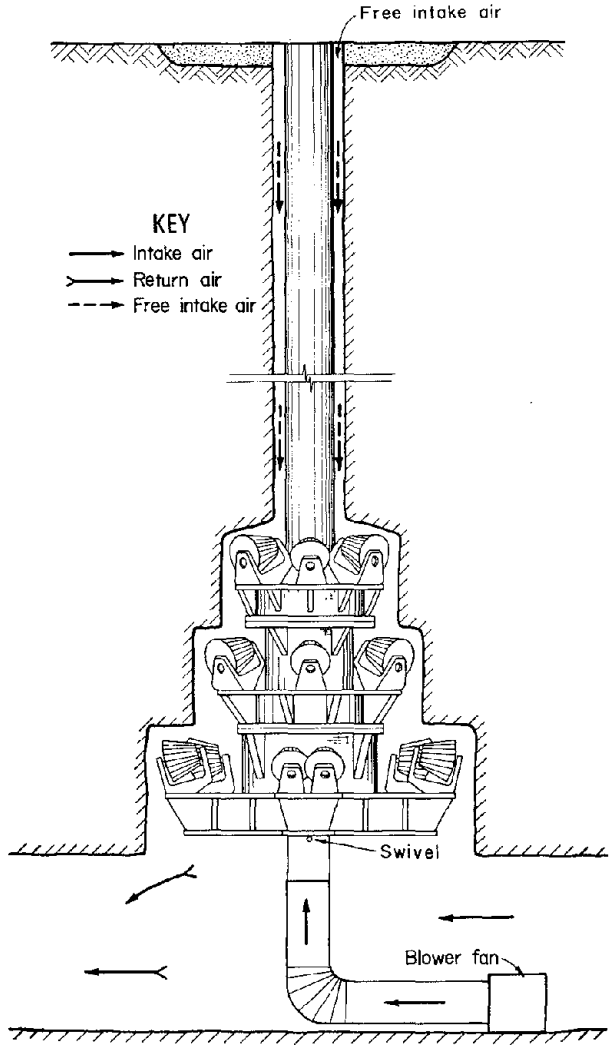

FIGURE 8. - Temporary use of auxiliary blower fan at shaft bottom.

ventilation system (which is under negative pressure). The amount of intake air from the surface does not exceed a few hundred cubic feet per minute.

Normally, methane concentrations in the coal seams where free intake air is used for ventilation are low and are not measured during raise drilling. On the surface, a compressor is on standby in case the concentrations exceed the safe level. In some coal seams where this method is used, methane is found only in small pockets in a coal seam or overburden.

Temporary Use of the Auxiliary Blower Fan at the Bottom of the Shaft (fig. 8).--This method is applied in Utah during reaming of the first 35 feet of the raise shaft when methane concentrations exceed permissible levels. To dilute methane to a safe level, Neoprene[6] tubing 36 inches in diameter and auxiliary blower fans are used. Tubing is attached to a swivel on the bottom of the cutterhead and air is blown up the tube.[7] This is more than adequate to dilute methane at the cutterhead. Later, when the cutter is changed, holes are drilled into the stinger intersecting the hollow center portion. This allows free air movement from the air compressor and auxiliary blower fan down the completed portion of the shaft to the mine return entries, as described earlier in the discussion of air compressors and auxiliary blower fans used simultaneously (fig. 5).

METHANE CONTROL DURING RAISE DRILLING

Methane concentration during drilling of raise shafts varied from site to site. A maximum concentration of 3.5 percent was measured in one raise drill shaft in West Virginia. Concentration during the idle periods at some raise drill sites decreased from 0.50 to 0.25 percent; at others, it increased from 0.50 to 1.10 percent. In coal seams with little or no gas, methane concentrations were measured only periodically during raise drilling because they did not constitute any hazard. Concentrations were not measured during the drilling of pilot holes.

Methane from the raise drill shaft at gassy mines was monitored, measured and sampled periodically on the surface, at the bottom of the shaft, and at different levels in the shaft. On the surface at gassy mines, a methane-monitoring system was installed at the vacuum pump discharge. It monitored and recorded methane-air mixtures drawn up from the cutterhead area. The system is normally set at 1.0 percent to sound an alarm, and drilling is shut off if the concentration reaches 1.50 percent. Normally, if the concentration is too high, the cutter continues to rotate after reaming is stopped and the cutter has been lowered at least 1 foot. This continues until the methane concentration is reduced to less than 1.0 percent.

If still higher concentrations are measured, rotation is stopped, and methane is diluted with compressed air and removed through the mine return entries. Simultaneously or separately, a vacuum pump operated on the surface

[6]Reference to specific trade names does not imply endorsement by the Bureau of Mines.

[7]Work cited in footnote 2.

draws up methane-air mixtures for sampling; methanometer readings are made every 2 to 4 hours. The pump operates 5 to 30 minutes before methane readings are taken, and while it operates, air compressors are shut off. The results are checked periodically with bottle samples.

Underground, at the bottom of the shaft cavity and in the mine return entries, methane is monitored and measured regularly at some drill sites. At one location in Alabama, a monitoring system with readout tape was installed at the bottom of the shaft to record the concentration during upward reaming.[8] Readings were made every 15 to 20 minutes, or every 2 to 4 hours, depending on the methane concentration at the shaft bottom. Bottle samples were taken periodically to check the methane concentration.

In West Virginia, MSHA has attempted to measure methane concentration in the shaft below the cutterhead as drilling advanced upward. Telescoping probes and inflatable balloons are used for this purpose. A telescoping probe, 8 to 25 feet long, is used at the bottom of the shaft cavities. A methanometer is clamped to the probe by a support bracket, and readings are made periodically. Inflatable balloons 5.5 feet in diameter, filled with helium, are used to take gas samples from different levels in the shaft. Flexible surgical tubing, attached to the balloon, is used to draw the methane-air mixture down to the bottom of the shaft. The balloon can be used only to about 160 feet above the floor level because the weight of the tubing prevents it from rising higher.

Prior to the beginning of raise drilling, after an idle period of 15 minutes or more, a methane reading is made at the bottom of the shaft and on the surface. If the methane concentration is 1.0 percent or more, methane is diluted to a safe operating level. A preshift examination is normally made and the concentration recorded on the surface and underground at the shaft bottom.

DISCUSSION

Air velocity down raise drill shafts is always very low. If the raise shaft has a 15-1/4-foot diameter, the cross-sectional area is 183 ft^2. If 3,000 cfm of air is blown down the drill stem, the air velocity in the shaft cavity is only 16.4 fpm.

The raise drill stem can carry more than 3,000 cfm of air, the highest amount recorded during this study. From charts in the Chemical Engineer's Handbook,[9] it was calculated that airflow through a 5-inch-ID clean pipe,

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[8]Carroll, W. Going Down Deep for Coal in Dixie. MESA, The Magazine of Mining, Health and Safety, v. 2, No. 5, October-November 1977, pp. 2-5. Available for consultation at the Bureau of Mines library, Pittsburgh, Pa.

[9]Drew, T. B., H. H. Dunkle, and R. P. Genereaux. Flow of Fluid. Sec. in Chemical Engineer's Handbook, ed. by J. H. Perry. McGraw-Hill, Inc., New York, 3d ed., 1950, pp. 360-460.

1,000 feet long with 150 psi at one end, is 14,800 cfm, which indicates that 3,000 cfm could easily be boosted to 6,000 cfm or more by adding more air compressors.

The annular space between the raise drill stem and the borehole wall cannot be used to move much air. For a typical case of a 10-inch-OD drill stem and 12-1/4-inch-diameter pilot hole, the cross-sectional area of the annulus is 39.30 in^2. However, because of the shape, the friction to airflow is much greater than in a round pipe of the same area.

Mine ventilation air passing under the shaft cavities creates an air swirl at the bottom of the shaft, making precise methane concentration measurements difficult. Since the raise shaft air from the compressor is moving downward at a velocity of 3 to 16 fpm, and since the mine ventilation air is moving at a much higher velocity (200 fpm or higher), the swirl of mine ventilation air could easily extend upward 30 feet. If a telescoping probe is used at the floor level of the shaft cavity, the measured concentration will be that of a mixture of shaft air and mine ventilation air in varying proportion. This was verified by methanometer readings and bottle samples. The results showed higher methane concentrations at the vacuum pump discharge than at the bottom of the shaft cavity.

Using inflatable balloons for gas sampling in the shaft at different levels is not always practical because of the limited lifting capacity and other operational difficulties.

The air velocity down the completed portion of the shaft is very low. Any increase in methane at the cutterhead level will be registered at the bottom of the shaft only after a long delay.

CONCLUSION AND RECOMMENDATIONS

The recommended way to ventilate raise drill shaft cavities is through the use of air compressors and vacuum pumps operating simultaneously, blowing air down the drill stem and drawing methane-air mixtures up the annulus for surface measurements. If the methane concentration is too high, more air compressors can be added; however, adding more compressors to increase the airflow can reach the point of diminishing returns because of the shock losses inside the drill pipe and fittings and especially at the rotary swivel on top of the machine. These losses and others occurring at the discharge holes in the cutterhead may result in back pressure sufficient to explode the air tube seals in the machine.

When a compressor and a vacuum pump are used simultaneously, the compressor air volume should be much greater to maintain a downward movement of air in the raise shaft cavities.

Simultaneous use of air compressors and a vacuum pump requires the use of a blooie seal installation around the drill stem on the surface to prevent air leakage into the pump.

If the methane concentration is not diluted with additional compressors, some other solutions should be found. Possible solutions are a larger minimum inside diameter for the drill rod, or the use of larger pilot hole drill bits. Increasing ventilation through the drill string by increasing the inside diameter of the drill pipe will result in increasing the outside diameter, which will require drilling a larger pilot hole. These changes require more expensive machines and drill pipes. Increasing the pilot hole diameter may not increase the airflow appreciably in the annulus because there must be several full gage stabilizers immediately above the cutterhead to provide stability for the head.

More research is needed on raise-drilling ventilation to establish the most practical methods for implementation when it is required. It has yet to be shown that the methods discussed here are practical and effective under a wide variety of circumstances.

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