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Water Infusion—An Effective and Economical Longwall Dust Control

By Joseph Cervik, Albert Sainato, and Eugene Baker

UNITED STATES DEPARTMENT OF THE INTERIOR

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

Å	angstrom	mg/m^3	milligram per cubic meter
cm	centimeter	$mg/m^3 \cdot t^{-1}$	milligram per cubic meter per metric ton
ft	foot	$mg/m^3 \cdot ton^{-1}$	milligram per cubic meter per short ton
ft^3	cubic foot	m/s	meter per second
ft/min	foot per minute	min/shift	minute per shift
gal	gallon	mm	millimeter
gal/min	gallon per minute	pct	percent
gal/ton	gallon per ton	psig	pound per square inch gage
in	inch	rpm	revolution per minute
kPa	kilopascal	t	metric ton
L	liter	ton/min	ton per minute
L/m^3	liter per cubic meter	wt pct	weight percent
L/min	liter per minute		
m	meter		
m^3	cubic meter		

WATER INFUSION—AN EFFECTIVE AND ECONOMICAL LONGWALL DUST CONTROL

By Joseph Cervik,[1] Albert Sainato,[2] and Eugene Baker[3]

ABSTRACT

In Europe, water infusion is used widely to reduce generation of respirable dust during mining. Its use in the United States is limited to a few plow operations in the Pocahontas No. 3 Coalbed. This Bureau of Mines report describes the technology for infusing water into a longwall panel and reports the results of a recent demonstration in the Lower Sunnyside Coalbed that achieved dust reductions averaging 58 pct. Because water infusion increases moisture content of the coalbed, face air velocities in excess of 500 ft/min (2.5 m/s) are possible, further diluting dust levels before dust entrainment occurs. An economic analysis shows a 23-pct reduction in operating costs when coal production is increased by changing from unidirectional mining to bidirectional mining with water infusion.

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INTRODUCTION

The most common dust control measures applied during longwall mining in the United States are ventilation, water spray systems, and modified cutting sequences. These measures address the problems of suppressing airborne respirable dust. Procedures such as infusing water (3-4)[4] and optimizing machine cutting parameters (12) (bit size and spacing, vane angle, and drum speed) reduce the generation of respirable dust during mining, but are not in widespread use. In the United States, water infusion of retreating longwalls from panel entries is employed only on a few plow operations in the deeper parts of the Pocahontas No. 3 Coalbed in southwestern Virginia (3, 12).

In Europe water infusion is widely used. German mining regulations require water infusion of all coal faces where possible (2, 10). The German experience indicates that a water content of at least 1.9 gal/ton (10 L/m^3) of coal is required to suppress dust. In the northern coalfields of France, the basic dust prevention technique is water infusion, which covers 89 pct of the coal produced (5). In Belgium, water infusion for dust suppression has been practiced for over 20 years (13). Belgian experience indicates a quantity of water equivalent to 1 pct of net tonnage, or 2.4 gal/ton (13 L/m^3) of coal, reduces the respirable dust particles produced during mining by 65 pct.

In China, the Fushun and Chong Qing Coal Research Institutes conducted water infusion experiments in about 10 coalfields between 1953 and 1974, according to Lide Xu, Fushun Coal Research Institute. Generally, resulting dust reductions during mining ranged from 30 to 50 pct; coalbed moisture content was increased from a preinfusion level of 1.0 wt pct to 2.0 wt pct after infusion.

[4]Underlined numbers in parentheses refer to items in the list of references at the end of this report.

The predominant mining system in Europe is the advancing longwall, whereas in the United States most longwalls are retreating faces. In the Federal Republic of Germany, for example, 75 pct of the longwalls are advancing faces (10). The procedures for infusing an advancing longwall are more complex and difficult than those for infusing a retreating longwall.

Figure 1 shows three European procedures for infusing an advancing longwall (10). In workings where the gate roads are kept on line with the face or are advanced only a short distance, water

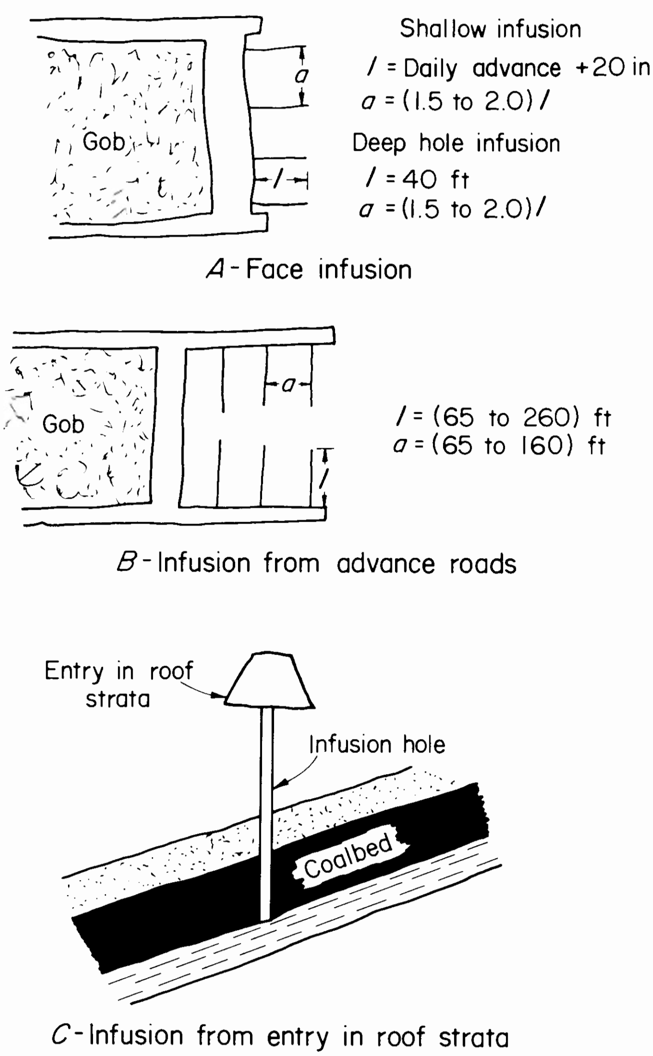

FIGURE 1. - European methods of water infusion.

infusion can only be applied from the coal face (fig. 1*A*). Because hole length is slightly greater than daily advance of the face, a large number of holes must be drilled and infused along the longwall face. Thus, if the daily advance is 10 ft (3.3 m), hole length is about 11 ft (3.4 m) and distance between holes averages 19 ft (5.8 m). If panel width is 550 ft (168 m), about 29 holes are necessary to infuse the face of the panel. This procedure is repeated daily. During the drilling and infusion cycles, no coal can be extracted from the panel. Production delays occur if the drilling and infusion cycles are not completed in one shift. In some cases, holes are drilled to depths of 40 ft (12 m) (deep infusion). The spacing between holes averages 70 ft (21 m); on a 550-ft (168-m) face, about eight holes are required. Although deep infusion requires fewer holes, more time is needed to infuse a larger volume of coal.

If gate roads are driven ahead of the advancing face, holes are drilled and infused from these roads (fig. 1*B*). In this way, water infusion can be carried out without affecting mining operations at the face. In France, advancing longwalls are infused from the advance gate roads and complemented by infusion into the longwall face (5).

In some cases, an entry is driven into the roof strata and water infusion holes are drilled downward from this entry into the mined coalbed (fig. 1*C*). Water infusion is carried out for up to a year before coal extraction and is discontinued when the coal face approaches the infusion hole.

In spite of the operational difficulties of incorporating drilling and infusion cycles on an advancing longwall and not withstanding production delays, water infusion for dust control is a widespread practice in Europe. In the United States, all longwalls are retreating faces, and drilling and infusing the longwall present no operational difficulties or production delays; however, very few U.S. longwalls are infused as a means of dust control. This report briefly describes the technology for infusing a retreating longwall panel, gives results of a recent infusion experiment, and discusses the interaction of water infusion and face ventilation, and cost effectiveness.

ACKNOWLEDGMENT

The cooperation of the management of Kaiser Steel Corp.'s Sunnyside No. 1 Mine, Sunnyside, UT, is greatly appreciated.

WATER INFUSION PROCESS

The water infusion process involves three distinct operations: (1) hole drilling, (2) hole packing, and (3) water infusion. Each must be successfully completed to ensure that the infused panel is saturated with water.

DRILLING

Three-in (7.6-cm) diameter holes are drilled from the rib side of the panel to a depth about 25 ft (8 m) beyond the centerline of the panel. For example, on a 550-ft (168-m) panel, the infusion hole is drilled to a depth of about 300 ft (91 m). The equipment for drilling these short holes is described elsewhere (3, 7).

The hole should be surveyed periodically during drilling to determine bit inclination in the vertical plane and to make necessary changes in drilling parameters to ensure that the hole trajectory remains within the coalbed and reaches beyond the centerline of the panel. Hole surveying can be conducted with an inexpensive instrument such as a Pajari borehole surveying tool[5] (fig. 2). The

[5]Reference to specific equipment does not imply endorsement by the Bureau.

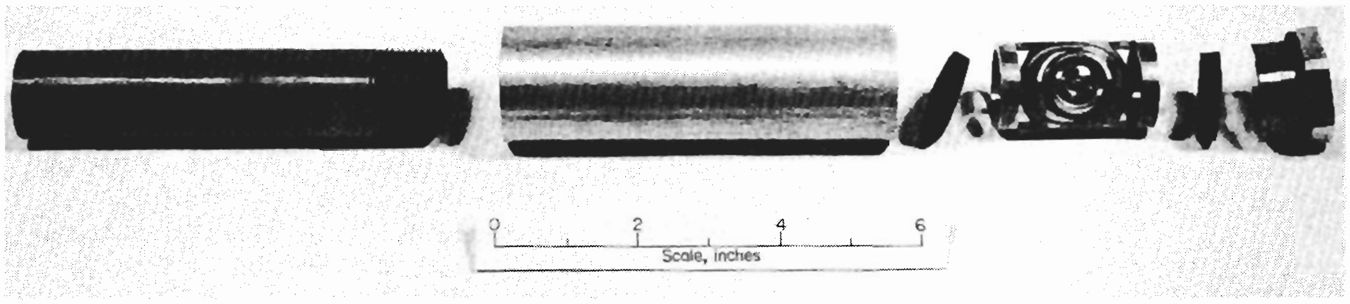

FIGURE 2. - Pajari surveying tool and protective case.

instrument is pushed with plastic pipe, or pumped with water, through the drill pipe to the end of the hole and is retrieved by wireline attached to the protective case. Since Bureau of Mines experience in drilling holes less than 500 ft (152 m) deep indicates insignificant deviations in azimuth with hole depth, the azimuth measurement is not as important as the vertical inclination measurement. If the vertical inclination of the hole is measured frequently during drilling, hole trajectory can be corrected before the bit intercepts roof or floor strata, and the hole can be drilled to the required depth.

HOLE PACKING

To ensure that the longwall panel is saturated with water from rib to rib during the infusion phase, water must enter the coalbed from a small segment of the hole near the centerline of the panel. The segment of hole from the collar to about 25 ft (8 m) away from the centerline of the panel must be sealed. In this way, water is infused into the panel from a 50-ft (15-m) segment of hole across the centerline of the panel (fig. 3).

Holes can be sealed with hydraulic packers, but the cost to effectively seal 250 ft (76 m) of hole is about $50,000. The packers are retrievable and reusable, but installation is time consuming and laborious. If the hole deforms during the infusion cycle, the packers are locked in place and lost.

The Bureau has developed an alternate hole sealing method which is less costly and labor intensive and more reliable (15). It uses expendable packers that can be assembled in any mine machine shop from commercially available materials. Figure 4 shows an assembled packer, with component parts and materials used to construct it. A 10-mil (0.025-mm) thick polyurethane sheet is formed into a tube about 0.5 in (1.3 cm) wider than the hole. This tube is banded to the grout header on one end and to the 2-in (5.1-cm) diameter polyvinyl chloride (PVC) block on the other end. The annulus between the 10-mil (0.025-mm) tube and the 1-in (2.5-cm) diameter PVC pipe is filled with cement and pressurized to about 200 psig (1,380 kPa), forcing the 10-mil (0.025-mm) tube against the wall of the hole to form a good seal. The ends of the packer are protected with 1-ft (30.5-cm) lengths of rubber hose. Pressurizing the cement in the packer does not produce any stress in the 10-mil (0.025-mm) polyurethane tube because it is wider than the hole. Stress does exist near the ends of the packer, and the short pieces of rubber hose prevent the 10-mil (0.025-mm) tube from overexpanding and rupturing. The packer can be constructed in lengths of a few feet to over 250 ft (76 m), and the material cost to seal a 250-ft (76-m) hole is about $250.

Sealing a hole for water infusion is a very important step. If the hole is not sealed properly, water will short-circuit along the hole instead of penetrating the coalbed from the back part of the hole. The Bureau packer filled with pressurized cement ensures that the hole is sealed along its entire length and that water enters the coalbed from the back 50 ft (15 m) of the hole.

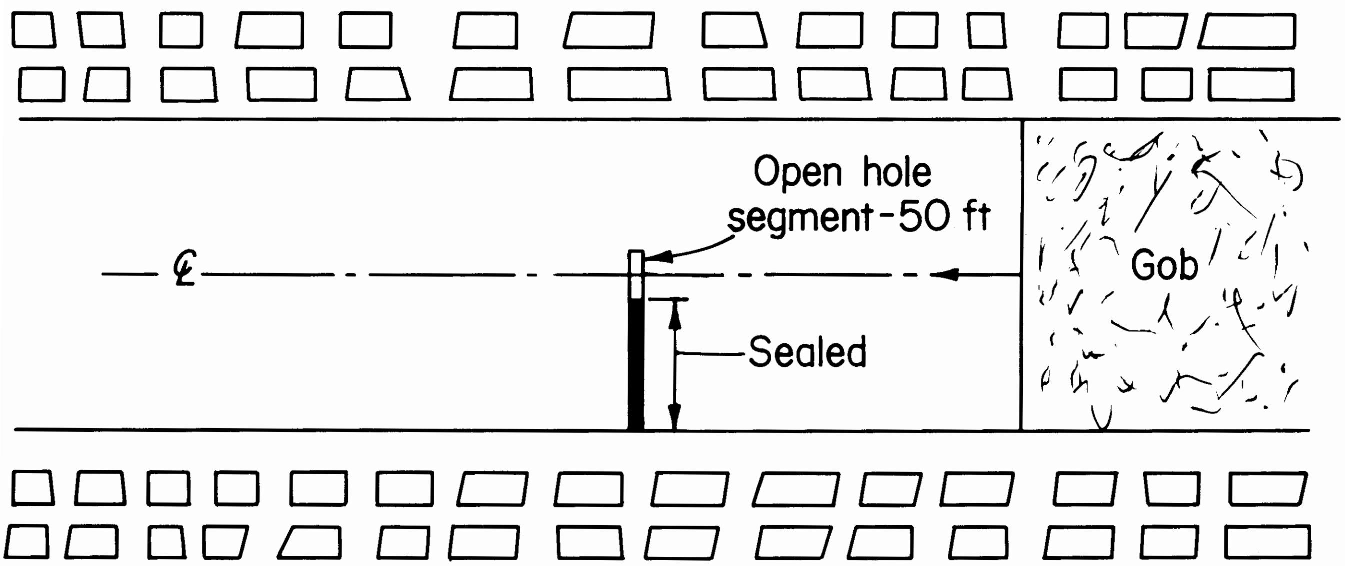

FIGURE 3. - Sealed water infusion hole.

FIGURE 4. - Bureau packer.

WATER INFUSION

Coalbeds are naturally fractured. Generally, there are at least two sets of vertical fractures that intersect at right angles to form an interconnected network thoughout the coalbed (11). These two fracture systems are known as face and butt cleats.

The solid coal between fractures contains an interconnected pore system, but these openings, which are about 5Å (5×10^{-8} cm) in diameter (1), are too small to permit water to pass. Consequently, the infused water is confined to the fracture systems only.

In friable coalbeds such as the Freeport, Kittanning, and Pocahontas No. 3, water tends to run at the same rate in all directions within the coalbed, and the infused zone tends to be circular (fig. 5*A*). In the blocky Pittsburgh and Beckley Coalbeds, water tends to run faster along the more prominent face cleat than along the butt cleat. Consequently, the infused zone tends to be elliptical, which is ideal when the face cleat direction is parallel to the long axis of the longwall (fig. 5*B*). In the latter case, a much larger volume of coal is infused before the water appears along the ribs of the panel, compared with the circular case (fig. 5*A*).

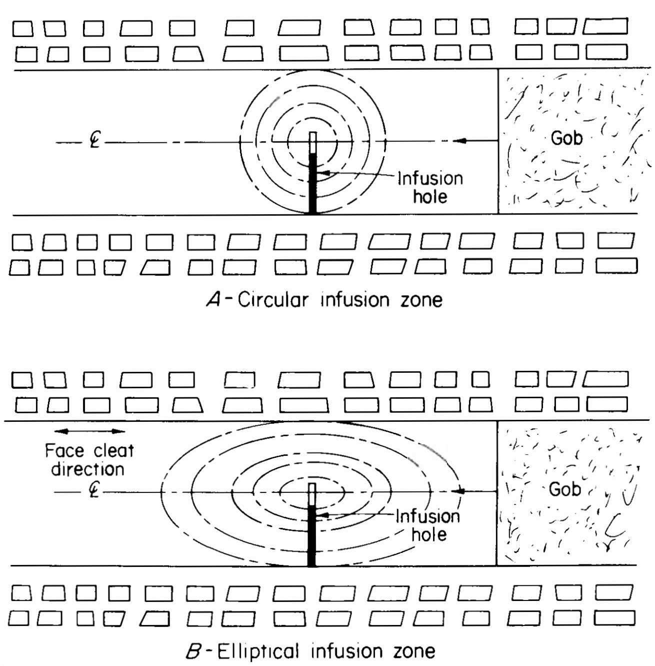

FIGURE 5. - Shapes of infused zones.

Like methane, water is normally associated with coal as inherent moisture in the solid coal and as free water in the fracture systems. During developmental mining, the gas pressure forces some of the free water out of the coalbed. Infusing water into the coalbed refills the fracture systems. Analyses of coal samples obtained on a longwall in the Lower Sunnyside Coalbed (Utah) show that the free water content in the fracture system was 1.4 gal/ton (7.5 L/m^3) of coal. Coal samples obtained in a water-infused zone on the same longwall had a free water content of 3.1 gal/ton (16.6 L/m^3). Thus, water infusion added 1.7 gal/ton (9.1 L/m^3) of coal.

The approximate quantity of water required to infuse a longwall can be calculated by assuming a 1.0-pct fracture porosity for the coalbed and a circular shape for the infused zone (fig. 5*A*). For a 550-ft (168-m) wide panel, the volume of coal infused is

$$V = \pi r^2 h$$

where r = half-width of panel, ft (m)

and h = coalbed thickness, ft (m).

$$V = 237{,}540h \text{ ft}^3 \ (22{,}057h \text{ m}^3)$$

Because fracture porosity is assumed to be 1.0 pct, the fracture volume within the infused zone is 2,375h ft^3 (221h m^3), or 17,760 gal (221,000 L) per unit thickness of coalbed. Thus, for a 7-ft (2.1-m) coalbed, at least 124,300 gal (464,100 L) of water is required. If the infused zone is elliptical, a much larger quantity of water will be required (fig. 5*B*).

During the infusion phase, the ribs on both sides of the panel are inspected periodically for water seeps to determine the extent of water migration through the panel. Seeps may be difficult to find because mining-induced fractures parallel to the ribs of the panel prevent water from migrating to the entry. Consequently, water may not be observed at all places along the ribs, or it may be observed seeping from the panel near the floor.

CASE STUDY

The following example illustrates procedures and gives results of the effects of water infusion on dust generation during retreat longwall mining in the Lower Sunnyside Coalbed.

Panel width was 550 ft (168 m), and coal height was 7 ft (2.1 m). No surfactant was used in the infused water. A 3-in (7.6-cm) diameter hole was drilled to a depth of 300 ft (91 m) and sealed with a Bureau packer (fig. 3) to 235 ft (72 m), leaving 65 ft (20 m) of open hole for infusion of water into the coalbed (fig. 6). During the day shift, water was forced into the coalbed with a pump at a rate of 27 gal/min (102 L/min) at 600 psig (4,130 kPa). On the other two shifts, the mine water supply line was connected to the hole. Water flow rates and pressure were 13 gal/min (49 L/min) and 315 psig (2,170 kPa), respectively.

The calculated quantity of water required to saturate the panel was 124,300 gal (464,100 L), based on a circular infusion zone and 1.0-pct fracture porosity. The actual quantity of water infused over a 10-day period was 208,000 gal (787,300 L). Water seeps were observed along both ribs of the panel up to 550 ft (168 m) on both sides of the water infusion hole. Thus, water migrated faster by a factor of about 2 along the long axis of the longwall (approximate face cleat direction) than towards the ribs of the panel, indicating an elliptical infused zone.

Four dust sampling surveys were conducted to determine the effects of water infusion on dust generation during mining. Each sampling period was 6 to 8 days. The first survey was conducted before water was infused into the panel, to establish a base dust level for comparison with dust levels in the infused zone. The following surveys were conducted in the infused zone: (1) when the panel face was 400 ft (122 m) to the

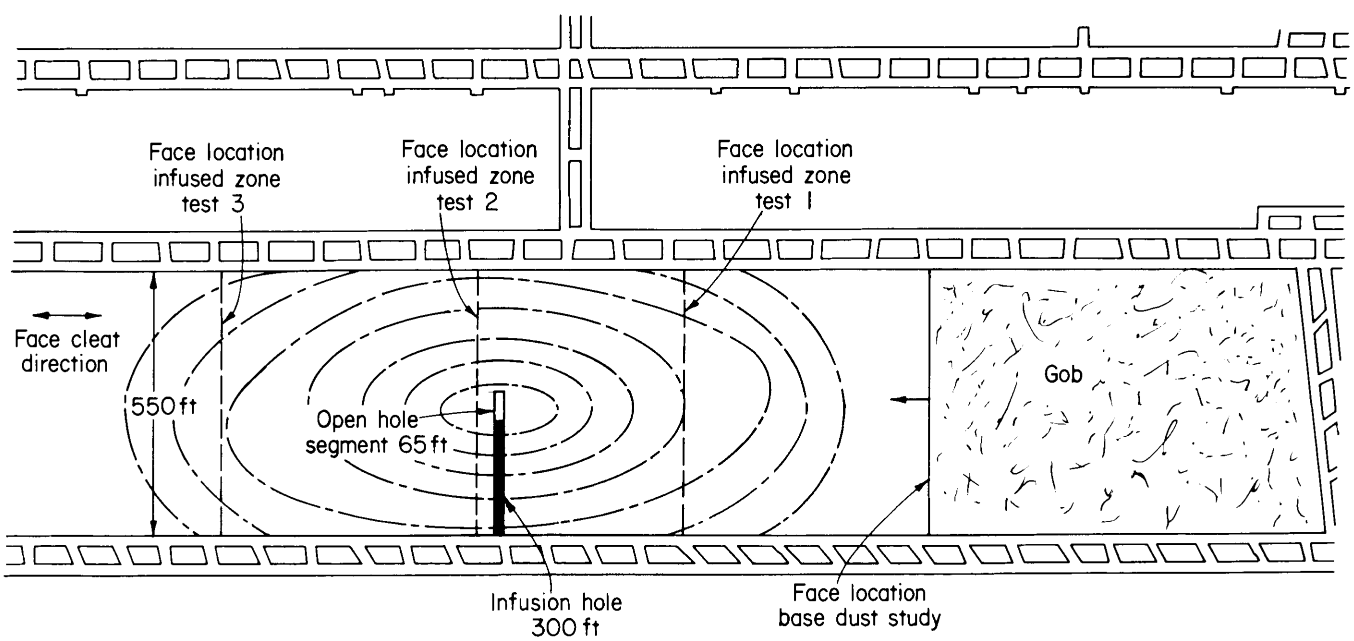

FIGURE 6. - Test longwall panel.

right of the infusion hole (test 1), (2) when the face passed through the vicinity of the infusion hole (test 2), and (3) when the face was about 600 ft (183 m) to the left of the infusion hole (test 3) (fig. 6).

Dust measurements were made with MSA Monitore model G personal dust samplers. A set of four instruments was hung from a shield directly over the chain conveyor and approximately 100 ft (30 m) upstream from the tailgate entry. Intake air was also monitored with a set of four instruments, and those dust levels were subtracted from the dust levels at the tailgate station. Because the velocity of the ventilating air varied from 93 to 400 ft/min (0.5 to 2.0 m/s) and the tonnage of mined coal varied from 630 to 3,940 tons (572 to 3,574 t)[6] between sampling shifts, all dust measurements were divided by tonnage of coal mined during the sampling shift and then corrected to an air velocity of 300 ft/min (1.5 m/s). Data for the air velocity correction were generated by the Mine Safety and Health Administration (MSHA) from a 1978 survey of all longwall sections for compliance with respirable dust standards (14) (fig. 7). This survey showed that dust levels during mining tended to be less on longwalls where air velocities at the tail end of the longwall were higher. However, where air velocities were above 500 ft/min (2.5 m/s), dust levels increased because of dust entrainment.

The effects of water infusion on respirable dust generation during longwall mining are summarized in table 1. Line 1 shows the average Mining Research Establishment (MRE) dust concentration for the noninfused zone and the three surveys in the infused zone. The measured dust levels are affected by variations in air velocity near the tail end of the longwall (line 2) and by coal production (line 3), which increased by a factor of about 3 between the first and last survey. To correct for variations in air velocity and coal production, dust concentrations were normalized to an average air velocity of 300 ft/min (1.5 m/s) and then divided by tonnage mined during the sampling shift. Line 4 shows the corrected dust concentrations. In noninfused coal, dust concentrations averaged 0.0045 $mg/m^3 \cdot ton^{-1}$ (0.0050 $mg/m^3 \cdot t^{-1}$) of mined coal, compared with 0.0016 to 0.0024 $mg/m \cdot ton^{-1}$ (0.0018 to 0.0026 $mg/m^3 \cdot t^{-1}$) in the infused zone. Thus, water infusion reduced the generation of respirable dust during mining by 47 to 64 pct (line 5). Average dust reduction was 58 pct.

Because of day-to-day variations in dust levels and variations between dust sampling periods, the dust data were analyzed statistically using the t test to determine if the differences between the average dust levels in noninfused and infused coal (line 4) are significant (8). The t test involves setting up the hypothesis that no difference exists between average dust levels in infused and noninfused coal. A t value is computed for the experimental data and then compared with a theoretical t value for a given probability level. If the computed t is greater than the theoretical t for a given probability level, the conclusion

[6] 1 t (metric ton) = 2,205 lb.

TABLE 1. - Effects of infusion on dust generation

Effect	Noninfused zone	Infused zone Test 1	Test 2	Test 3
Average MRE conc.............mg/m^3..	5.2	2.3	2.4	4.8
Average air velocity........ft/min..	190	340	350	240
Production.............tons/shift..	830	1,010	1,420	2,680
Corrected MRE conc, per ton...................mg/m^3..	0.0045	0.0024	0.0017	0.0016
Dust reduction................pct..	NAp	47	62	64
Average water use.............gal..	10,200	9,500	10,500	14,700
Average water use..........gal/ton..	12.3	9.4	7.4	5.5

NAp Not applicable.

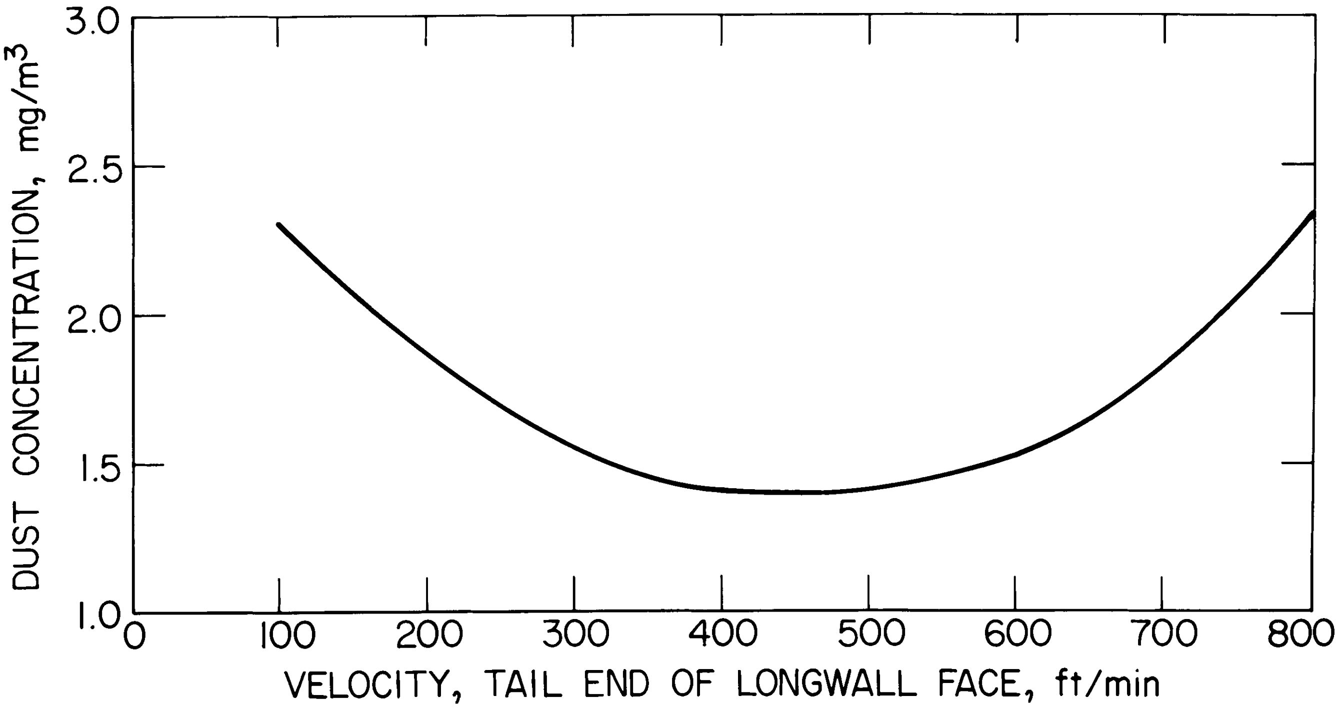

FIGURE 7. - Air velocity correction.

is that differences are significant. A computed *t* less than the theoretical *t* implies that the differences are not significant.

The average dust level of each test in infused coal was compared to the average dust level in noninfused coal. The calculated *t* values were in each case greater than the theoretical *t* value at the 1-pct probability level. Thus, the probability that no differences exist between dust levels in noninfused and infused coal is only 1 pct or less. Stated in another way, the probability is 99 pct or greater that water infusion suppresses dust generation during mining.

The average quantity of water used by the spray system of the shearer each shift during the study is shown in line 6. No changes were made to the shearer's spray system during the study. Line 7 shows that the water consumed by the spray system gradually decreased from 12.3 gal/ton (65.8 L/m^3) of mined coal during the first survey to 5.5 gal/ton (29.4 L/m^3) during the last survey. One would expect dust concentrations to increase, but the three surveys in the infused zone (line 4) show that dust concentrations generally decreased. These data suggest that increasing the water consumption of the spray system above 5.5 gal/ton (29.4 L/m^3) of mined coal in the Lower Sunnyside Coalbed would not be effective in suppressing respirable dust during mining.

COST EFFECTIVENESS

According to a 1978 MSHA survey (12) 70 pct of longwall mining operations employing a double-drum shearer were not in compliance with the 2.0-mg/m^3 dust standard, and the average high-risk occupational exposure (shearer operator) was 2.6 mg/m^3. Water infusion, which reduces the generation of respirable dust during mining by as much as 64 pct, should reduce the high-risk occupational exposure well below the 2.0-mg/m^3 standard. Thus, production could be increased without exceeding the 2.0-mg/m^3 standard.

Time and motion studies on double-drum shearers employing unidirectional mining show that the actual working time of the shearer averages 180 min/shift. This can be divided further into cutting, cleaning, and turnaround times (table 2) (6). Coal cutting is primarily in one direction, with the return pass used to clean up. Thus, if bidirectional mining is introduced, an additional 35 min/shift is available for coal cutting and increasing production.

TABLE 2. - Working time distribution of shearer

Operation	Time, min/shift
Cutting.............	117
Cleaning............	35
Turnaround..........	28

Table 3 shows that 273 working days are required to mine a 5,000-ft (1,524-m) panel where 1,500 tons of coal are produced per shift by unidirectional mining. With bidirectional mining, cutting time increases from 117 to 152 min/shift, and consequently coal production increases to 1,950 tons per shift. The same 5,000-ft (1,524-m) panel can then be mined in 210 days, or 63 days less than with unidirectional mining.

An economic analysis of costs associated with mining of one longwall panel is shown in table 4 (9). Capital costs are higher for bidirectional shearing because the costs of drilling and infusion equipment are included. A water infusion test on a retreating longwall in the Lower Sunnyside Coalbed indicated that one infusion hole will saturate over 800 ft (244 m) of the panel. Consequently, six holes spaced 800 ft (244 m) apart are required to saturate a 5,000-ft (1,524-m) panel. The labor requirement for drilling and infusing a 5,000-ft (1,524-m) longwall is 120 man-days, which increases

TABLE 3. - Unidirectional versus bidirectional mining of longwall

	Unidirectional mining	Bidirectional mining
Longwall dimensions......ft..	5,000 × 550 × 7	5,000 × 550 × 7
Tons per panel...............	818,100	818,100
Cutting time......min/shift..	117	152
Cleaning time.....min/shift..	35	0
Production.......tons/shift..	1,500	1,950
Production.........tons/min..	12.8	12.8
Shifts per day...............	2	2
Run of mine........tons/day..	3,000	3,900
Reject..................pct..	15	15
Clean coal.........tons/day..	2,550	3,310
Clean coal.......tons/panel..	696,000	696,000
Mining time......days/panel..	273	210

TABLE 4. - Economic summary (mining of one longwall)

	Unidirectional mining (273 days)	Bidirectional mining with water infusion (210 days)
Capital cost[1].........................	$6,370,000	$6,407,000
Production...........tons clean coal..	696,000	696,000
Operating cost[1].....................	$3,157,000	$2,428,000
Operating cost per ton of clean coal..	$4.54	$3.49
Capital cost per ton of clean coal....	$9.15	$9.21

[1]Costs updated to 1981.

operating costs. However, this increase is counterbalanced by the decrease in operating costs, because 63 fewer days (1,386 fewer man-days) are required to mine the panel with bidirectional mining (table 3) and operating costs per ton of clean coal decrease from $4.54 to $3.49, a reduction of 23 pct (table 4). The preceding analysis was conducted for a longwall production of 1,500 tons per shift. A similar analysis for a longwall production of 800 tons per shift also shows a 23-pct reduction in operating costs when bidirectional mining with water infusion is employed.

INTERACTION OF FACE AIR VELOCITY AND WATER INFUSION

The principal means for diluting and removing respirable dust on longwall mining operations in the United States is face ventilating air. The average face air velocity measured at the midpoint of the face on double-drum shearers in the United States is 285 ft/min (1.4 m/s). Experience indicates a higher face air velocity of approximately 450 to 500 ft/min (2.3 to 2.5 m/s) (fig. 8) (12) is required to minimize the shearer operator's respirable dust exposure. In addition to the dilution effect, higher air velocities tend to keep airborne dust nearer the face, again reducing the operator's respirable dust exposure.

Studies in the Federal Republic of Germany indicate similar results (fig. 9). The optimum face air velocity is about 450 to 500 ft/min (2.3 to 2.5 m/s) when the moisture content of the coal is 3 to 4 wt pct (12). Air velocities exceeding 500 ft/min (2.5 m/s) result in increased dust concentrations, because the dust entrainment effect is greater than the dilution effect. However, when the moisture content of the coal is 5 to 8 wt pct, velocities up to about 900 ft/min (4.5 m/s) are possible before dust entrainment occurs.

Infusion of water into a longwall panel is the only known method of increasing the moisture content of coal before mining. Analyses of coal samples taken from a longwall face in the Lower Sunnyside Coalbed showed that the average in situ moisture content of the coal is 3.7 wt pct. After infusion of water into the

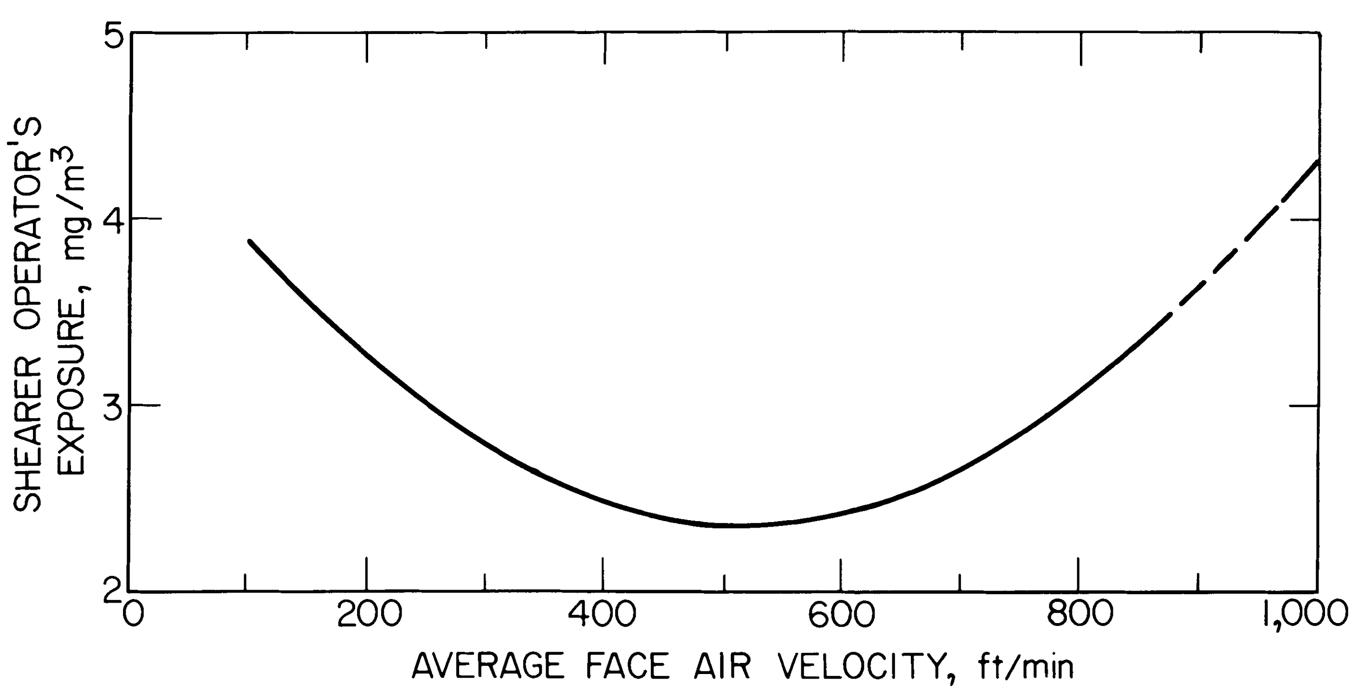

FIGURE 8. - Effect of ventilation on shearer operator's dust exposure.

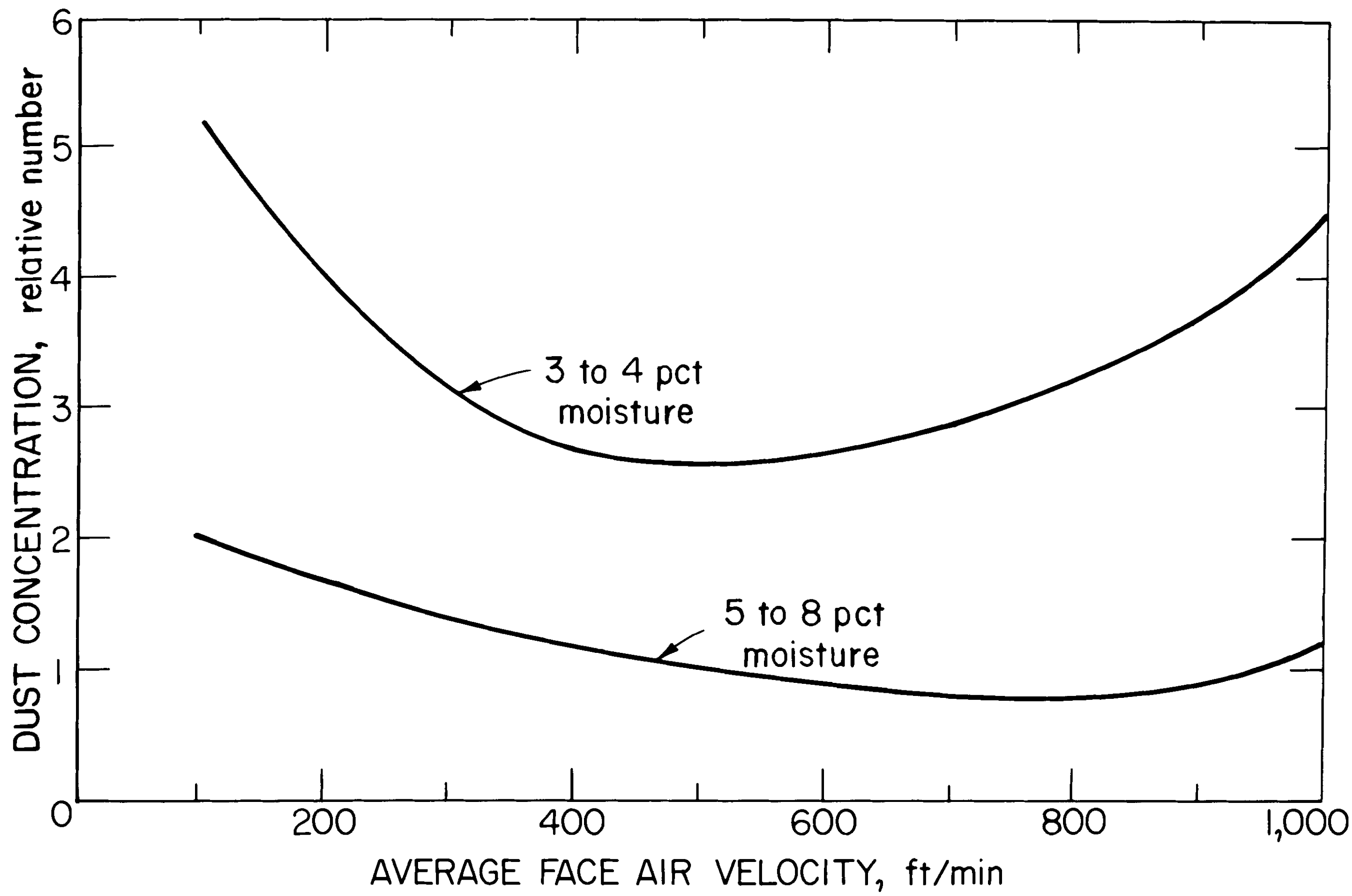

FIGURE 9. - Effect of moisture content of coal on dust.

panel, the moisture content of coal samples taken from the face had increased to 5.0 wt pct. Thus, if the German studies apply to the Lower Sunnyside Coalbed, face air velocities in excess of 500 ft/min (2.5 m/s) are possible before the dust entrainment effect begins to operate. These higher air velocities, in addition to reducing airborne dust levels by dilution, prevent the dust from "boiling back" over the shearer operator.

SUMMARY AND CONCLUSIONS

Water infusion is an effective and economical method of reducing the generation of respirable dust on longwalls. Dust reductions averaging 58 pct were demonstrated in the Lower Sunnyside Coalbed. This large reduction was due to the addition of only 1.7 gal/ton (9.1 L/m^3) of coal; in contrast, the spray system of the mining machine utilizes more than 5.5 gal/ton (29.4 L/m^3) of mined coal.

Seventy percent of double-drum shearer operations are not in compliance with the 2.0-mg/m^3 dust standard. The average exposure of the shearer operator is 2.6 mg/m^3; this can be reduced by water infusion well below the 2.0-mg/m^3 standard. Thus, coal production can be increased by changing from unidirectional to bidirectional mining with water infusion, without exceeding the 2.0-mg/m^3 standard. Increases in capital and operating costs associated with water infusion are insignificant compared to the 23-pct savings in operating costs caused by increased coal production.

Because water infusion increases the moisture content of the coalbed, ventilation velocities in excess of 500 ft/min (2.5 m/s) reduce dust levels further by dilution and prevent generated dust from "boiling back" over the shearer operator. German studies show velocities up to 900 ft/min (4.5 m/s) are possible before dust entrainment occurs when moisture content of the coalbed is increased.

The technology for infusion of water into retreating longwall panels has been developed. Drilling equipment is available commercially, and procedures and materials for effectively sealing water infusion holes are available. A Bureau-designed packer reduces the cost of sealing one hole from $50,000 to $250.

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