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Evaluation of Water-Jet-Assisted Cutting Capability on Longwall Shearers

By C. D. Taylor, E. D. Thimons, and P. D. Kovscek

BUREAU OF MINES

UNITED STATES DEPARTMENT OF THE INTERIOR

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

°C	degree Celsius	L/min	liter per minute
cm	centimeter	m	meter
ft	foot	m/min	meter per minute
fpm	foot per minute	mg/m^3	milligram per cubic meter
gpm	gallon per minute	mm	millimeter
hp	horsepower	µm	micrometer
in	inch	MPa	megapascal
kg	kilogram	pct	percent
kW	kilowatt	psi	pound (force) per square inch
kW•h/st	kilowatt hour per short ton	st	short ton
lb	pound (mass)		

EVALUATION OF WATER-JET-ASSISTED CUTTING CAPABILITY ON LONGWALL SHEARERS

By C. D. Taylor,[1] E. D. Thimons,[2] and P. D. Kovscek[3]

ABSTRACT

The U.S. Bureau of Mines evaluated water-jet-assisted longwall shearers in full-scale laboratory tests and underground. Both test programs showed that use of high-pressure water did little to reduce the shearer motor energy required to maintain a given cutting rate. However, three other major benefits were achieved with the use of water-jet-assisted cutting.

At a pressure of 1,800 psi, respirable dust levels were reduced about 80 pct compared with the dust levels of the conventional water spray system operating at 340 psi. Operating at higher pressures required for water-jet assist also resulted in an increase in the average size of coal cut, which translates into a decrease in product fines. Finally, although no controlled measurements of bit wear as a function of water pressure were made, mine personnel reported that the shearer bits lasted longer when water-jet-assisted cutting was used.

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INTRODUCTION

Since 1977, the number of U.S. longwall mining sections using double-ended ranging-arm shearers has more than doubled. Improved productivity is a primary reason for using the longwall mining method. Average U.S. longwall mining production is approximately 2,000 st per shift compared with 300 to 400 st per shift for room-and-pillar mining. To achieve these production levels, the average horsepower supplied to a longwall shearer has increased from 333 hp in 1977 to 403 hp in 1984 (*1-2*).[4]

Water-jet-assisted cutting was studied by the U.S. Bureau of Mines as a way to improve cutting efficiency and reliability of mining machines that use drag tools. This cutting technique uses moderately high-pressure, 2,000 to 10,000 psi (13.8 to 68.9 MPa), solid streams of water, called water jets, that are directed to strike near the cutting-bit tip. Prior testing with water-jet-assisted cutting was done in the laboratory at cutting-bit speeds less than 100 fpm (31 m/min) and depths of cut less than 0.5 in (1.3 cm) (*3*). During normal mining conditions, cutting speed normally exceeds 400 fpm (125 m/min) and cutting depth is greater than 1-1/2 in (3.8 cm). There have been few opportunities, under normal mining conditions, to compare the cutting efficiency of a mining machine operating with and without water jets. This report describes testing conducted on the surface and underground with shearers equipped for water-jet-assisted cutting. Full-scale laboratory tests were run at the Bureau's Pittsburgh Research Center, where a simulated coal block was cut. An underground evaluation of a water-jet-assisted shearer was conducted in Marl, Federal Republic of Germany, under a Bureau contract with Eickhoff Corp. The objective was to determine what effect water-jet-assisted cutting had on shearer motor energy if cutting rate was maintained constant and to evaluate how use of high-pressure jets affected the amount of dust generated and the size of the particles produced.

TEST CONDITIONS

SURFACE

Work was first performed at the Bureau's surface test facility in Pittsburgh, PA, which allowed operating parameters to be controlled more carefully than would be possible underground. A 60-ft-long (18.5-m) by 6-ft-high (2-m) coalcrete block, composed of coal, fly ash, and concrete, was used to simulate a longwall face. Because of its higher silica content, coalcrete is more abrasive than coal; however, when using conventional drag bits, coalcrete's cutting properties are similar. Overall, the simulated coal face was homogeneous.

The shearer used to cut the coalcrete was a Joy 1-LS1[5] double-drum machine (fig. 1). For each test, the shearer cut from right to left. Only the left hand, or leading, drum was supplied with high-pressure water and used for cutting during the tests. The right-hand drum was positioned so that it traveled within the cut made by the left-hand drum. A longwall face conveyor panline, adjacent to the coalcrete block, provided continuous removal of the cut material, as well as functioning as a support along which the shearer moved. The diameter for the cutting drum (bit tip to bit tip) was 54 in (137 cm), and the drum width was 28 in (71 cm). During the tests, web width (thickness of the cut) ranged from 25 to 29 in (63.5 to 73.5 cm). The machine tram rate was maintained at approximately 5 fpm (1.5 m/min). Drum rotation speed was 46 r/min with a bit-tip speed of 650 fpm (200 m/min). Radial attack bits were used.

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

[5] Reference to specific products does not imply endorsement by the U.S. Bureau of Mines.

Figure 1.–Shearer used for surface testing.

UNDERGROUND

The longwall site for the underground work was the Auguste Victoria Mine, located in Marl, Federal Republic of Germany (*4*). The face was 7.54 ft (2.3 m) thick, 919 ft (280 m) long, and mined on retreat. Two shearers were operating on the longwall face during testing. Figure 2 shows the relative locations of the shearers on the longwall face.

The shearer equipped with high-pressure water was a model EW-200/170-L single-drum Eickhoff shearer (fig. 3). The shearer cut the final 164 ft at the tailgate end of the longwall face. While data were collected, the shearer cut only the upper part of the face. Shearer tram rate and web width were maintained as constant as possible.

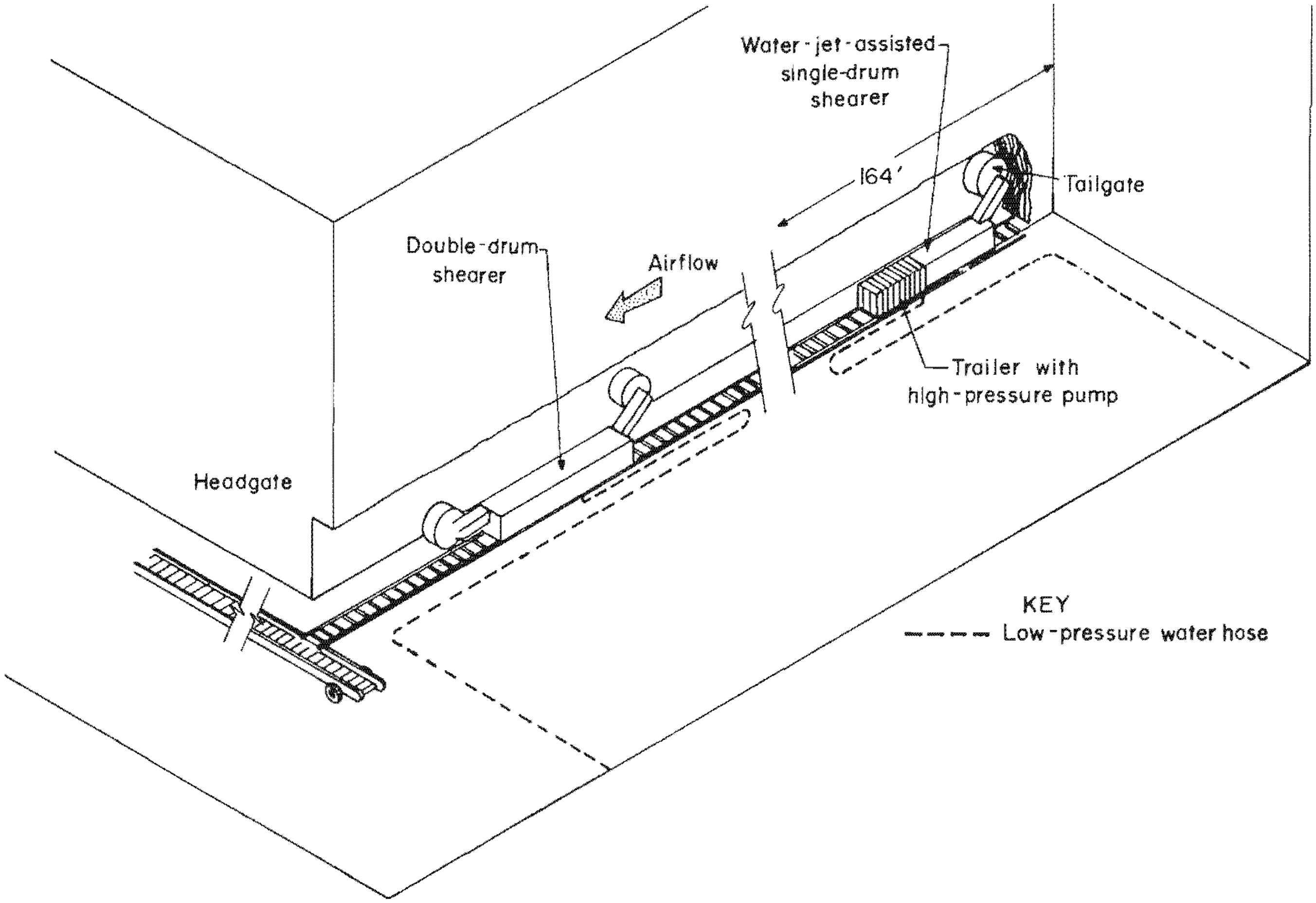

Figure 2.-Underground test area.

Underground testing at low pressure was conducted with the original drum supplied for use with the shearer. This drum was not designed for use with high-pressure water; therefore, a new drum had to be designed and built. Table 1 compares features of the two drums. The new design included a ranging arm with double-planetary gearing that provided a drum rotational speed of 23.6 r/min. The slower rotational speed allowed a more efficient distribution of fluid energy; i.e., more energy could be supplied per length of cut. However, another consequence of slower rotation speed was a deeper depth of cut. The bit lacing had to be changed to provide efficient cutting and loading at deeper cutting depths.

Table 1.-Comparison of cutting drums used during underground tests

	High-pressure	Low-pressure
Diameter . . . . in . .	67	63
Web depth . . . . in . .	33.4	33.5
Rotational speed . . r/min . .	23.6	48
Bits:		
Number	51	55
Type	Conical	Radial
Bit-tip speed . . . . . . fpm . .	413	791
Spray nozzle:		
Number	50	41
Type	Sapphire	Conical
Flow rate . . . . gpm . .	10-21	10

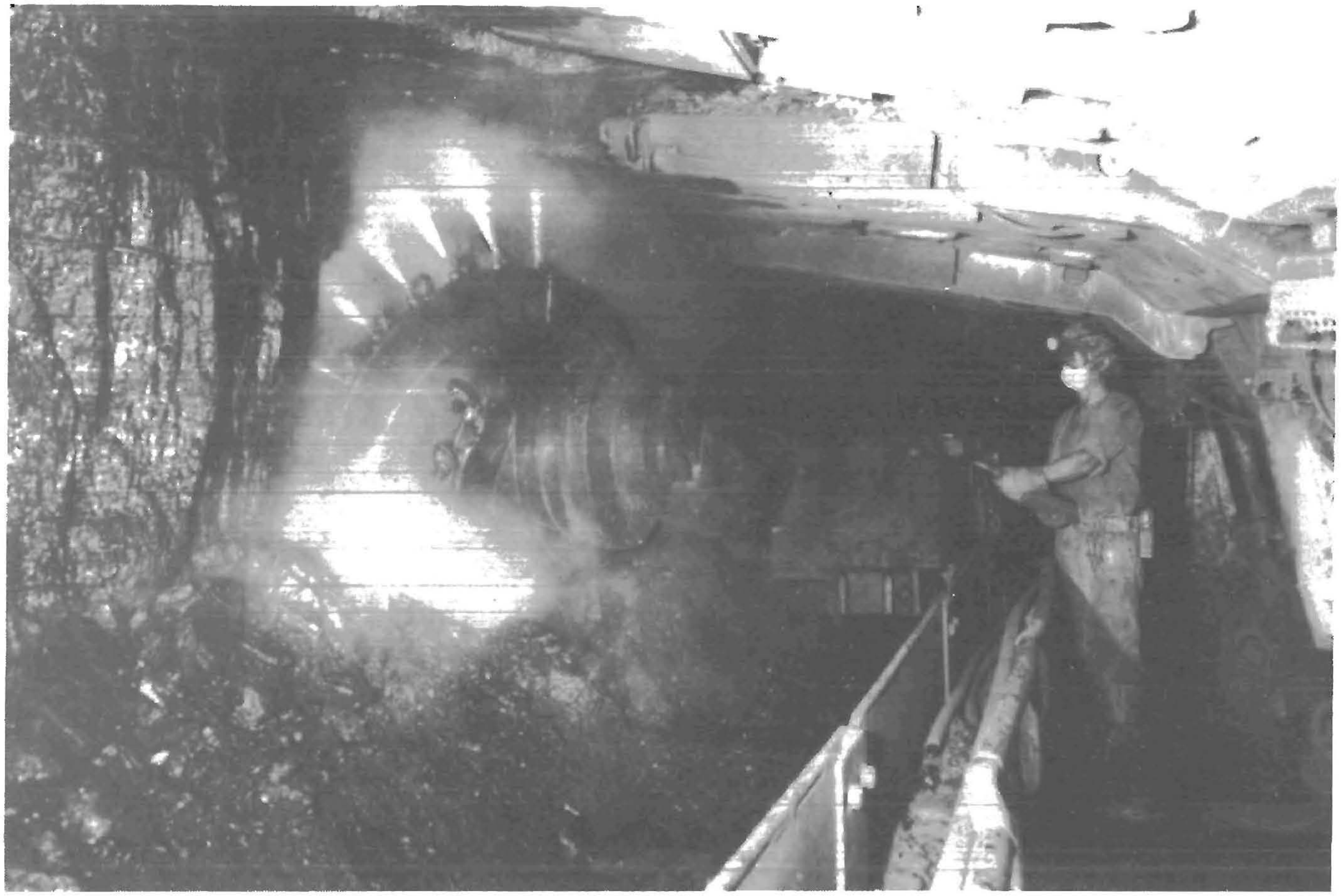

Figure 3.–Shearer operating underground.

WATER DELIVERY SYSTEMS

SURFACE

A 200-hp (112-kW) Aqua-Dyne triplex pump was used to supply water pressure to the shearer. The pump was placed adjacent to the coalcrete face, and water was delivered to the shearer through a 2-in (5.1-cm) flexible hose. Water pressure during the low-pressure tests was supplied at 190 psi, and during the high-pressure tests, the water pressure was varied from 1,000 to 6,000 psi (6.9 to 41.4 MPa). Water was passed into the cutting drum through a high-pressure Aqua-Dyne rotary seal, located in the drum hub. Six hoses were attached to the rotary seal. Each of the six hoses carried water to a sector of the cutting drum, which contained approximately one-sixth of the water-jet nozzles. The water-jet nozzles were located in front of each of the 32 cutting bits on the left cutting drum (fig. 4). No water phasing was used during the surface testing. All nozzles were operating during high- and low-pressure tests.

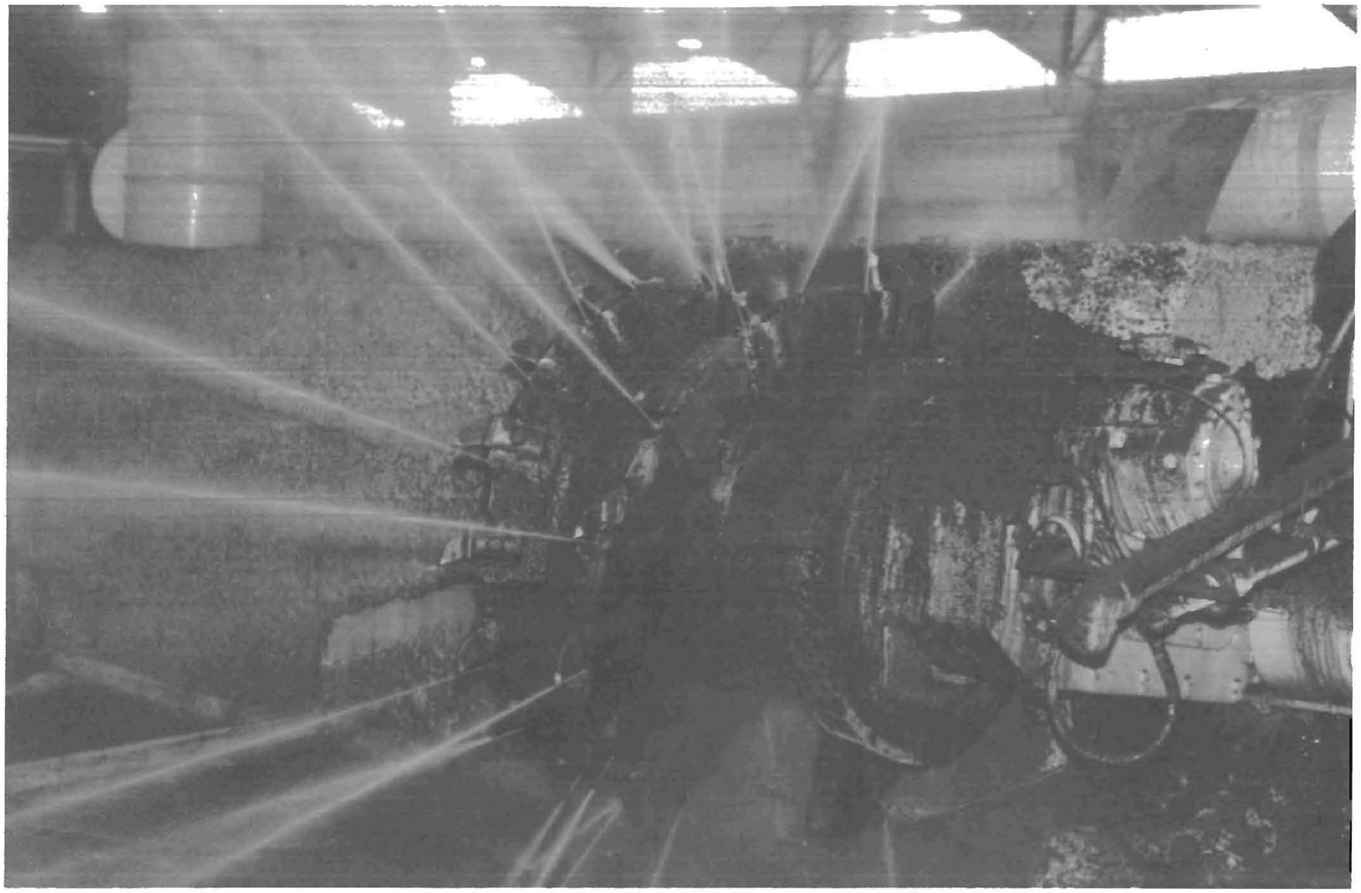

Figure 4.–Cutting drum equipped with high-pressure water.

Nozzles having a 13° Leach and Walker configuration (5) (fig. 5) were used for all tests. To maintain approximately the same flow rate during the high- and low-pressure tests, 0.024-in (0.6-mm) and 0.07-in (1.78-mm) orifices, respectively, were used. Nozzle flow rates for each test pressure are given in table 2. The nozzle delivered a solid stream of water to a location about 0.1 in (3 mm) in front of the bit tip. Distance from the nozzle to the bit tip averaged about 4 in (10 cm). The waterlines in the cutting drum were flushed frequently, and the water passed through 10-μm filters to reduce the possibility of nozzle blockage.

Table 2.–Water pressure versus flow rate for surface tests

Pressure, psi	*Flow rate, gpm*
High-pressure:[1]	
6,000	1.26
5,000	1.15
4,000	1.03
3,000	.90
2,000	.75
1,000	.54
Low-pressure:[2] 190	.90

[1]0.024-in orifice.
[2]0.071-in orifice.

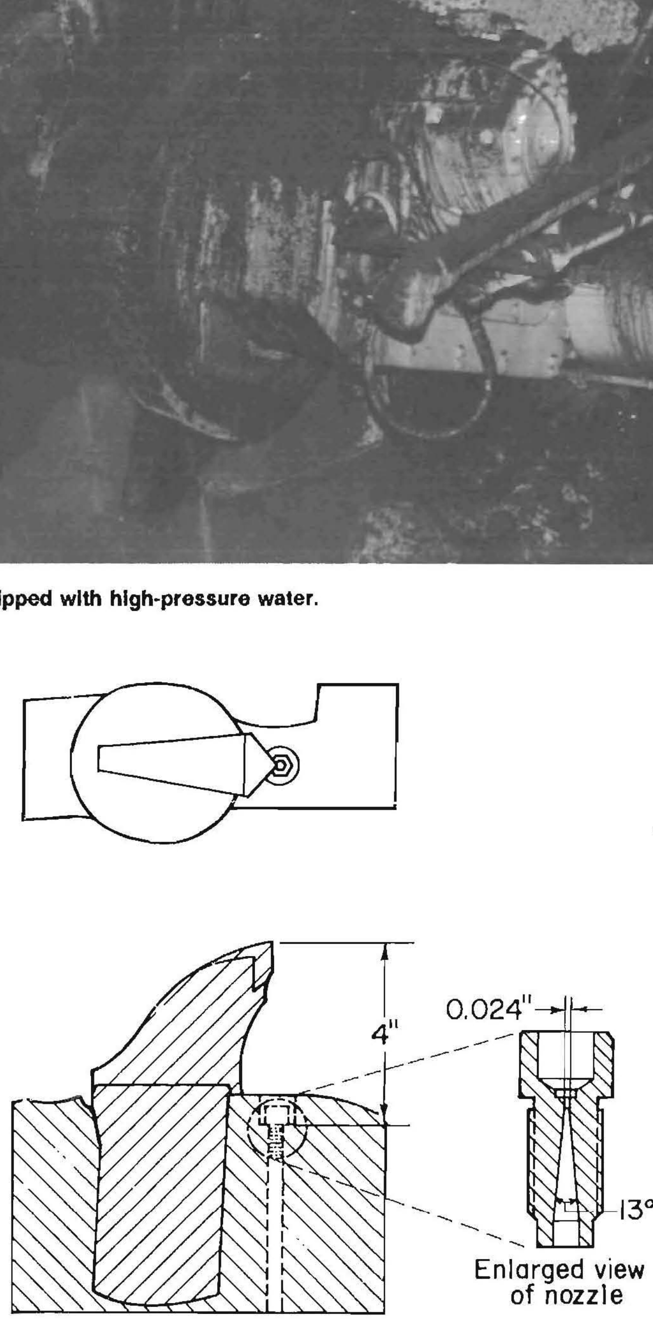

Figure 5.–Bit block and nozzle configuration for surface testing.

UNDERGROUND

During normal operations without water jets, head pressure was sufficient to supply water to the shearer at 340 psi (2.3 MPa) pressure. Forty-one conical spray nozzles mounted in the cutting drum were used for dust control. Total flow rate for this normal operating condition was approximately 10 gpm (38 L/min).

During water-jet-assisted cutting tests, water pressure was varied from 1,800 to 7,200 psi (12.4 to 49.6 MPa). The high-pressure water was supplied by a five-piston pump mounted on a trailer, which was pulled by the shearer. To reduce nozzle blockage, an improved water-filtration system was installed at the headgate. Nozzles with sapphire orifices were placed in the front of each of 50 specially designed bit blocks (fig. 6).

The drum, specially built for the high-pressure tests, was divided into 10 sectors. Water was directed to each sector through manifolds and high-pressure hoses (fig. 7). A phasing system was designed to feed the water to 5 sectors at a time. The average angle of the arc of rotation that was supplied with water was 195° (fig. 8). Using this phasing system reduced the required water by almost 50 pct.

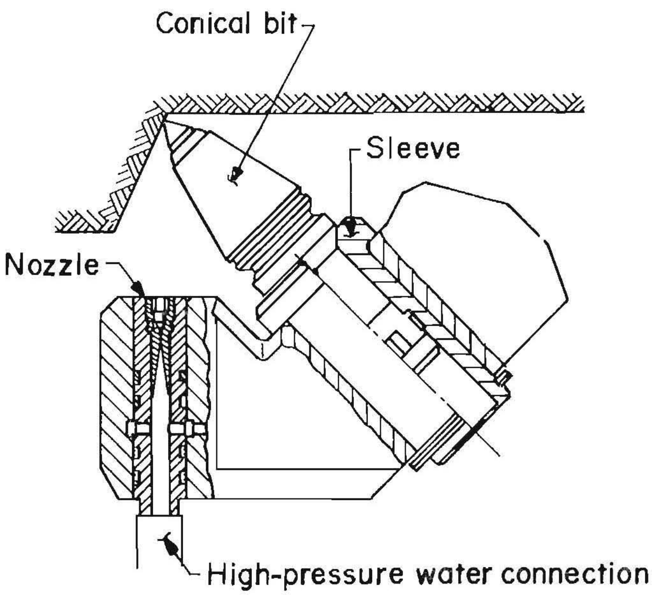

Figure 6.–Bit block and nozzle configuration for underground testing.

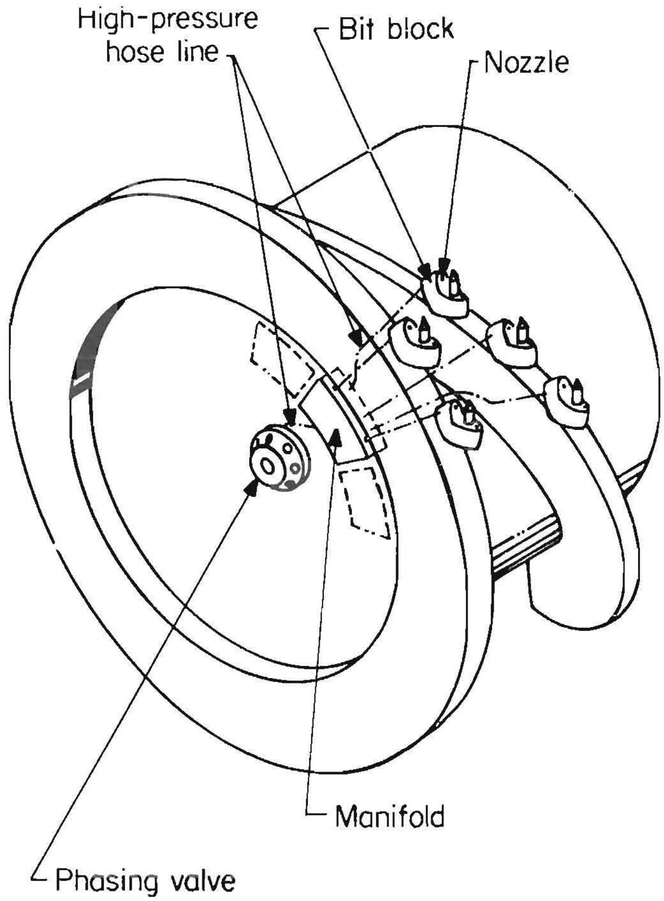

Figure 7.–High-pressure water supply to cutting drum.

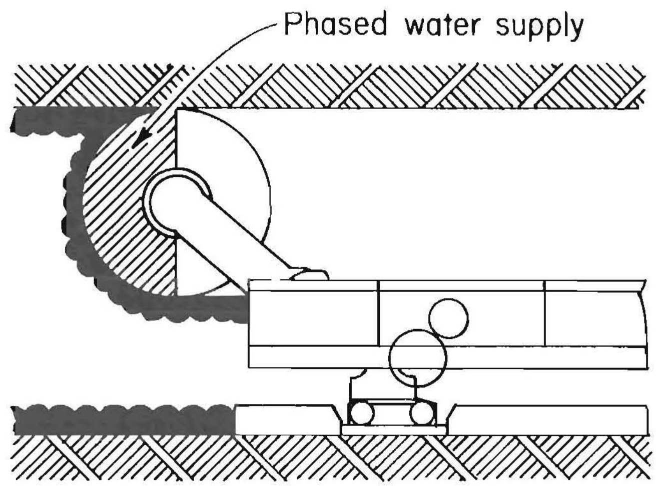

Figure 8.–Phasing system for underground testing.

PARAMETER MEASUREMENTS

The effectiveness of using water-jet assist was determined by comparing the shearer motor power requirements of high-pressure water cutting with that of low-pressure water cutting. A decrease in shearer motor power (while maintaining the same cutting rate) would indicate improved cutting efficiency. For the surface tests, machine power was determined by summing the power contributions of the left-hand cutter and shearer haulage motors. During the underground tests, cutting motor performance was determined by monitoring shearer motor amperage and voltage.

Respirable dust measurements were made during surface and underground tests. On the surface, dust sampling locations, 72 in (2.5 m) from the top and 24 in (0.6 m) from the bottom of the cutting drum, were selected. Dust concentrations at two locations, one upwind and the other downwind of the shearer, were sampled underground. To determine the concentration of dust generated by the shearer, the upwind measurement was subtracted from the downwind measurement. As much as possible, during underground testing, no other work that produced dust, such as moving the roof supports, was carried out upwind of the shearer. The dust generated by the second shearer, which operated on the headgate side of the test shearer, did not influence the dust readings, because airflow was from tailgate to headgate.

On the surface, particle size distribution information for the coalcrete was determined using approximately 4 lb (1.8 kg) of cuttings taken from the center of each test area. Samples taken underground for size analysis were taken from cuttings on the conveyor. All samples were dry sieved to determine the size distribution.

RESULTS

The shearer energies versus water pressures measured during surface tests are shown in figure 9. Statistical analysis of the data for these tests indicates that there are no significant differences in shearer motor energy when using water pressures between 1,000 and 6,000 psi (6.9 and 41.4 MPa). Regression analysis of the underground data shows that only a very slight reduction in shearer energy results from the use of high-pressure water.

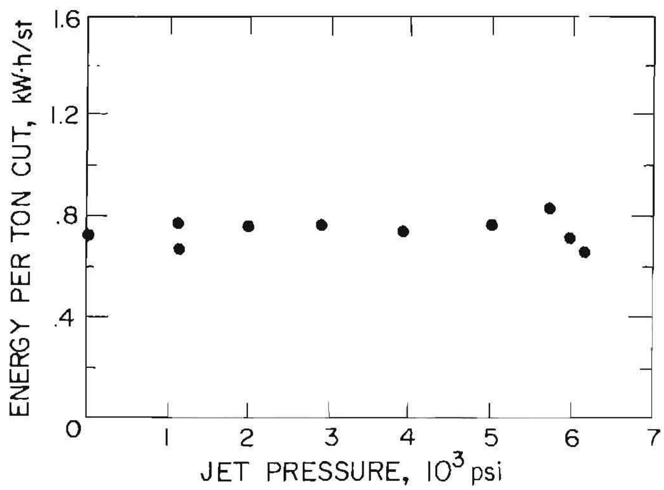

Figure 9.–Shearer energy versus water pressure for surface tests.

Airborne respirable dust levels were measured during the surface test while operating at water pressures from 1,000 to 6,000 psi (6.9 to 41.4 MPa). The averages for the dust levels measured at the two sampling locations were compared with the average levels generated while operating at a conventional water pressure of 190 psi (1.3 MPa). That is, the dust concentrations generated while operating at 190 psi (1.3 MPa) were taken as the baseline concentrations. The average dust levels and percentage dust reductions versus conventional spray operation are shown in table 3. At a water pressure of 3,000 psi (20.7 MPa), the dust levels were 79.2 pct less than when operating at 190 psi (1.3 MPa). Raising the pressure further from 3,000 to 6,000 psi (20.7 to 41.4 MPa) resulted in only small additional dust reductions.

Table 3.–Comparison of airborne respirable dust levels and reductions during high- and low-pressure operation

Pressure, psi	Dust level, mg/m^3	Dust reduction, mg/m^3
High-pressure:[1]		
6,000	21.8	80.4
5,000	17.0	84.8
4,000	21.9	80.4
3,000	23.2	79.2
2,000	40.3	63.9
1,000	106.8	4.2
Low-pressure:[2] 190	111.5	0

[1] 0.024-in orifice.
[2] 0.071-in orifice.

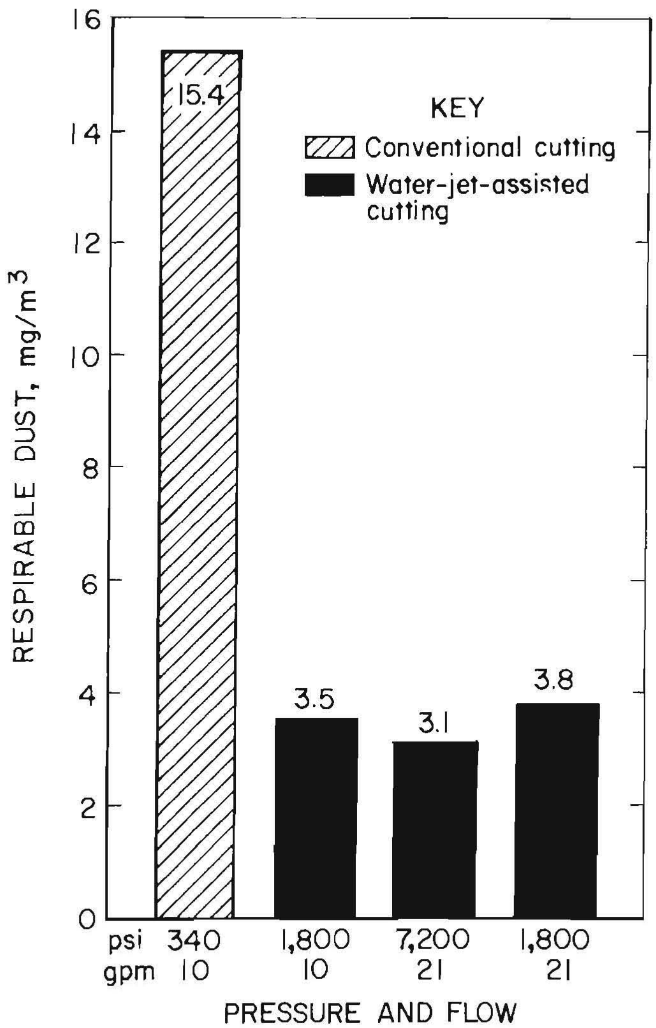

Figure 10.-Dust results from underground testing.

The underground respirable dust results are shown in figure 10. At a water pressure of 1,800 psi (12.4 MPa) and a water flow rate of 10 gpm (38 L/min), average dust levels were reduced almost 80 pct compared with dust levels measured while operating at 340 psi (2.3 MPa) and 10 gpm (38 L/min). Maintaining the water pressure at 1,800 psi (12.4 MPa) and increasing the flow rate to 21 gpm (80 L/min), by increasing the nozzle orifice size, resulted in no further reduction in dust. Additional reductions in dust level due to increasing the pressure to 7,200 psi (49.6 MPa), with a flow rate of 21 gpm (80 L/min), were not significant.

Figure 11 gives a plot of median particle size versus water pressure for the surface samples. In general, median particle size tended to increase with increasing water pressure. Similar results were obtained underground. For example, the percentage of particles less than 0.25 in (6.4 mm) was reduced from 37 to 28 pct at a pressure of 1,800 psi (12 MPa).

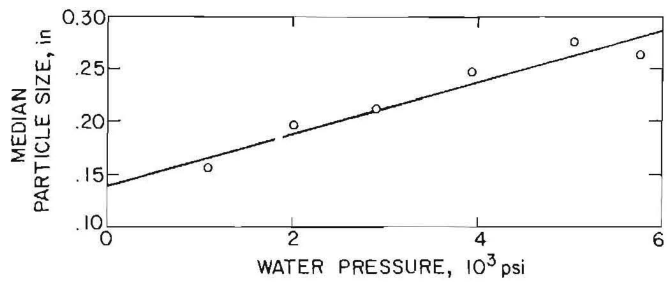

Figure 11.-Median particle size versus water pressure.

DISCUSSION

SHEARER MOTOR ENERGY

Because shearer motor energy is a relative indicator of the ease with which rock was cut by the mining machine, improved mechanical cutting efficiency would be indicated by a reduction in shearer motor energy. The average motor energy measured while operating at 6,000 psi (41.4 MPa) was 0.717 kW•h/st, and the average motor energy measured while operating at 1,000 psi (6.9 MPa) was 0.720 kW•h/st. The highest and lowest motor energy values measured from all the tests were 0.860 and 0.640 kW•h/st, respectively, and were recorded while operating at a pressure of 6,000 psi (41.4 MPa). The range of motor energy values from all the tests is within the average motor energy range measured while operating at 6,000 psi (41.4 MPa). Therefore, the data show no significant change in shearer motor energy as the water pressure was varied.

Preliminary results from this longwall shearer work were presented at the Third U.S. Water-Jet Conference (*6*). At the conference, it was stated that, based on data from only the first pass, shearer cutting efficiency was improved when the water pressure was increased from 1,000 to 6,000 psi. Subsequent data analysis, contained in this report, includes information from additional tests at pressures of 1,000 and 6,000 psi. Statistical analysis of the data for these replicated tests indicates that there is no significant difference in shearer cutting efficiency when using either of the two pressures.

Similarly, the use of high-pressure water jets underground had only a minimal influence on the shearer motor energy. As noted in the section "Test Conditions," high- and low-pressure tests were conducted with different cutting drums operating at different revolutions per minute. Bit-tip speed for the high- and low-pressure tests was 413 and 791 fpm (126 and 241 m/min), respectively. Concurrent trials by Bergbau-Forschung GmbH showed that when high-pressure water jets are used, bit forces are reduced as the bit speed decreases. However, if the shearer tram rate, and therefore the mining rate, is maintained constant, the depth of cut increases. Since increasing the depth of cut tends to decrease water-jet effectiveness, the overall effect of reducing revolutions per minute on shearer motor energy is uncertain.

FLUID ENERGY

A large part of the total energy supplied during water-jet-assisted cutting was supplied by the water jets. The phasing system used underground reduced the water energy supplied by about one-half. During the surface tests, water was supplied to all 32 sprays continuously because a suitable phasing system wasn't available. To more realistically reflect the fluid energy that was directed to bits that were cutting, the total fluid energy supplied during surface tests was divided by 2. Using these calculations, at 190 psi (1.3 MPa) operating pressure, the fluid energy accounted for less than 2 pct of the total energy used during cutting. At 6,000 psi (41.4 MPa), almost 33 pct of the total energy supplied during cutting was provided by the water jets. During underground testing, a similar proportion of the total energy was supplied by the water jets.

DUST LEVELS

Use of water-jet-assisted cutting reduced the amount of airborne dust generated by the cutting action of the shearer. The water applied while mining reduces dust primarily by–

1. Capturing airborne dust particles.
2. Wetting the dust particles before they can become airborne.

The surface study results showed that increasing the water pressure from 190 to 1,000 psi (1.3 to 6.9 MPa) did not significantly reduce dust levels. Dust levels decreased rapidly as the water pressure was raised from 1,000 to 3,000 psi (6.9 to 20.7 MPa). Any further decrease in dust level, as the water pressure was raised from 3,000 to 6,000 psi (20.7 to 41.4 MPa), was small. Additional information concerning the effect of water pressure on dust level is given in the appendix.

Raising the water pressure underground from 340 to 1,800 psi (2.3 to 12.4 MPa) reduced airborne dust levels 70 to 80 pct. There was no significant additional reduction in dust level when the pressure was raised from 1,800 to 7,200 psi (12.4 to 49.6 MPa). The fact that there is a maximum pressure above which no further dust reductions take place further confirms the results of the surface study and the work performed by other researchers with roadheaders (*7-8*).

Interpretation of the underground dust data is complicated by the fact that during the high-pressure tests, a different cutting drum was used and the drum's revolutions per minute were reduced. Cutting depth was increased because the tram rate was kept constant. Reduced drum revolutions per minute and increased cutting depth have been shown to reduce airborne dust levels (*9*). It is not possible to determine how much each factor–reduced revolutions per minute, deeper cutting, or water-jet assist–contributed to the reduction in dust levels. For optimum dust control, high-pressure water should be used along with reduced drum speed and deeper depth of cut.

Dust generation by the shearer during surface cutting of the coalcrete was similar to dust generation by a shearer operating underground. However, the airflow pattern on an underground longwall face, which has a significant effect on the distribution of the dust around the shearer, could not be simulated during surface testing. Also, the amount of dust generated while cutting coalcrete versus coal would not be the same, owing to physical differences in the two materials. Because of these differences, the dust levels measured during surface testing cannot be directly related to the amount of dust generated underground. However, as verified by the underground study, the relative reductions in dust resulting from use of the high-pressure sprays are typical of what can be achieved underground.

Mining conditions during underground testing were representative of a typical longwall operation. However, the dust results were obtained for a specific face, and the same results cannot be expected for all mining operations. The amount of dust generated during the underground tests was extraordinarily high, perhaps due to cutting in a faulted zone. Use of high-pressure water for dust suppression can be effective for dust control on all longwall faces.

SAFETY

The safety of workers is a concern when high-pressure water is used in a confined area such as the longwall face. In order to reduce danger underground, a system for automatically shutting off the water when the shearer reached the end of the longwall face was provided. The switchoff system ensured that the machine could not enter, under any circumstances, the roadway with the high-pressure water supply operating.

Danger from high-pressure water leaking from broken hoses or pipes on the shearer was practically eliminated by positioning all pipes and hoses under solid covers. The high-pressure hose that connected the ranging arm to the pump was fitted with a sheath for protection against wear.

Underground experience showed that the risk of danger did not result as much from the high-pressure water jets as from the coal and rock particles that were carried along by the water jets. This problem was reduced when the water pressure was decreased below 5,000 psi (34.5 MPa). Also, owing to the phased water supply system used underground, the danger of workers' being struck by a coal particle only arose while they were working ahead of the machine. During cutting, the shearer operator had to wear protective glasses and the workers had to keep a safe distance of about 13 ft (3.5 m) ahead of the cutting drum. A similar problem of rock particles propelled from the face by the water jets was experienced during surface testing. A clear plastic shield was installed between the operator and the drum to deflect most of the particles.

BIT WEAR

During the surface study, no work was done to evaluate the effect of high-pressure water on bit wear. Previous work conducted by the Bureau has shown that cutting efficiency can be adversely affected by dull bits (*10*). Cutting efficiency can be improved if bit wear is reduced. For most laboratory tests, however, the duration of cutting has not been long enough for variation in bit wear to be significant.

In conjunction with the underground study, bit trials were carried out using a single bit provided with water-jet assist. The results of this study showed that the high-pressure water-jet assist has a considerable effect on bit-tip

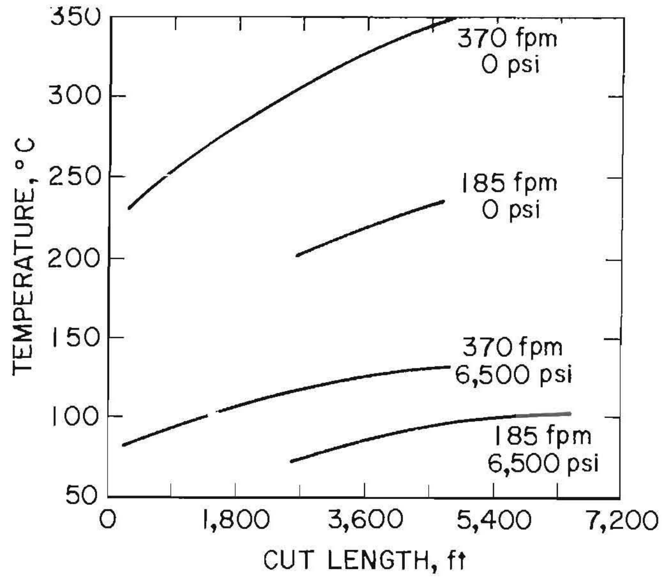

Figure 12.–Bit temperature as function of bit speed and water pressure.

temperature. At a bit speed (370 fpm) typical of a mining operation, the bit-tip temperature was reduced from 350° C while cutting dry, to 120° C while using high-pressure water (fig. 12). Reducing the bit-tip temperature decreases the rate of bit wear.

Because of the variations in cutting conditions underground, the effect of water-jet use on bit wear could only be qualitatively examined during the shearer tests. Due to a rock-band cut during the tests, bits had to be replaced more often than normal. However, the workers noted that the bits could be used about twice as long before being replaced when water-jet assist was used.

PARTICLE SIZE

A valuable benefit of using water-jet-assisted cutting is increased particle size. Fine coal particles are often unwanted by coal buyers, and increasing the particle size can reduce problems in cleaning plants. A primary factor affecting the size of particles formed during cutting is the amount of material recrushing that occurs between the bit and the unbroken rock surface. Cleaning or removing this material by the water jet before it can be further crushed can contribute to improved cutting efficiency. Not only is material crushing reduced, but also, without the "cushion" of broken material, the bit is able to apply more force onto the unbroken rock. For the underground cutting, the percentage of particles below 0.25 in (6.3 mm) in diameter was reduced from 37 to 28 pct. The larger particle size can be attributed to both the use of high-pressure water and the lower drum revolutions per minute, which increased the depth of cut.

CONCLUSIONS

The cutting efficiency of the shearer was determined by comparing shearer motor energy while operating with and without high-pressure water. For the surface tests, the results do not indicate a significant difference in shearer motor energy when operating dry or at a conventional low water pressure of 190 psi (1.3 MPa) and at high pressures. Likewise, underground there was no significant effect on shearer motor energy when the water pressure was raised from 340 to 7,200 psi (2.3 to 49.6 MPa).

During surface testing, dust levels decreased significantly when the water pressure was raised from 190 to 3,000 psi (1.3 to 20.7 MPa). However, only small additional reductions in dust occurred when the pressure was raised from 3,000 to 6,000 psi (20.7 to 41.4 MPa). Underground dust levels were reduced 77 pct when the water pressure was raised from 340 to 1,800 psi (2.3 to 12.4 MPa). Reduced drum revolutions per minute and increased cutting depth may also have helped achieve these reductions. Water pressures up to 3,000 psi (20.7 MPa) seem to be reasonable for the high-pressure water supply system where the required water quantity approximately equals that of a conventional dust-suppression system.

The median size of particles formed increased with increasing water-jet pressure, indicating that the water-jet-assisted cutting could reduce coal fines and thereby decrease coal processing costs.

A second underground trial will be conducted on a longwall face in the United States. During this test, a double-ended ranging-arm shearer will be equipped with a high-pressure water supply system.

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APPENDIX

During the water-jet-assist tests, the tram rate and depth of cut were maintained relatively constant. Therefore, the specific energy supplied by the sprays can be directly related to the fluid horsepower. The quantity, P × V/1,714, can be used to calculate fluid horsepower, with P being the pressure (psi) and V the flow rate (gpm). In figure A-1, fluid horsepower has been plotted versus dust level for the seven different water pressures evaluated during surface testing. The data points have a correlation coefficient of 0.90 for the power curve ($y = ax^b$) shown. These data do not indicate whether increased flow or increased pressure is more important in causing changes in the dust level. There is probably a combined effect of pressure and flow, depending on the range of operating conditions.

Increasing the water pressure from 190 to 1,000 psi (1.3 to 6.9 MPa) did not significantly change dust levels at either sampling location. Although the pressure increased, because of the difference in nozzle orifice sizes, flow rate at 190 psi (1.3 MPa) and 1,000 psi (6.9 MPa) was 0.90 and 0.54 gpm (3.41 and 2.04 L/min), respectively. The total fluid power supplied by the sprays operating at 190 psi (1.3 MPa) and 1,000 psi (6.9 MPa) was 2 and 7.5 kW, respectively. However, the added energy was not sufficient to significantly affect either wetting of the coal or airborne particle capture.

Dust levels were reduced 78 pct when the pressure was raised from 1,000 to 2,000 psi (6.9 to 13.8 MPa). The additional fluid horsepower supplied by the sprays operating at 2,000 psi (13.8 MPa) resulted in improved dust control. Higher pressure resulted in increased flow, which improved wetting. Higher water pressures may have contributed to further dust reductions for the following reasons:

1. Water directed at the coal at high pressure penetrates a short distance into the coal surface, traveling along natural fracture planes in the coal and wetting the generated dust before it is exposed to the ambient airflow.
2. Chips and rock debris are flushed from the region ahead of the bit by the jets, and thus the material is wetted before it is removed from the face.
3. Material cut by the longwall drum "circulates" for a short time between the uncut coal face and the drum before the screw action of the drum vanes pulls it onto the panline. Water from the water jets penetrates the cut material more quickly and mixes more thoroughly as the material circulates. This results in a more uniformly moist mined material.

At pressures above 1,000 psi (6.9 MPa), airborne dust capture may have been a factor in reducing the airborne dust. Studies, such as those of Tomb (*11*),[1] have shown that capture of airborne dust by water droplets increases with increased water flow and pressure. Pressures of 100 psi (0.7 MPa) or higher are necessary before the effects of the capture become significant. Airborne dust capture is not effective unless the dust can be confined for a short time within a closed space. During cutting with the shearer, small water droplets within the kerf may strike and remove a portion of the dust that becomes airborne in this space. A British study (*12*), conducted on a longwall section being mined, suggests that the effectiveness of the high-pressure water may be due to better penetration of the material being cut or to atomization of the water stream into fast-moving fine droplets. It is not possible to determine from the data collected if the spray within the kerf affected dust levels more by improved wetting or by airborne capture.

There was only a small decrease in dust as the water pressure was raised from 3,000 to 6,000 psi (20.7 to 40.4 MPa). This was probably because the section of coalcrete cut at 3,000 psi (20.7 MPa) was thoroughly wetted by the quantity of water applied at this pressure. The additional water supplied at the higher pressures could not be absorbed. Any additional dust reductions due to increased pressure were minimal.

[1] Italic numbers in parentheses refer to items in the list of references preceding the appendix.

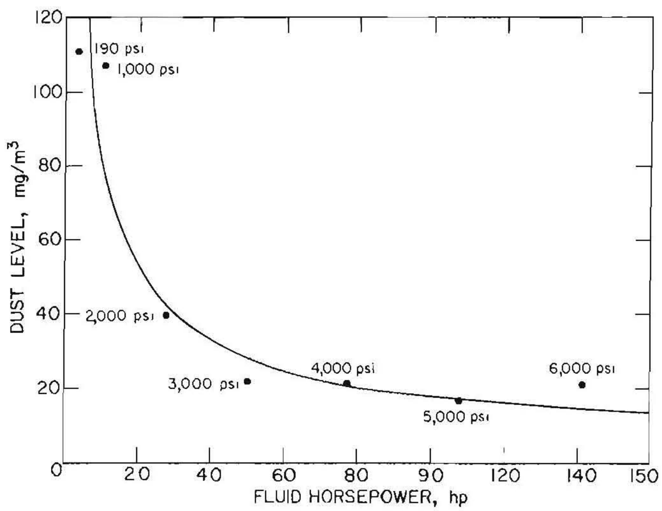

Figure A-1.–Fluid horsepower versus dust level for various water pressures.

A longwall shearer would not be operated without water sprays because of the high levels of dust that would be generated during dry operation. However, during surface testing, one test was conducted without any water. The average dust level while operating dry was about 30 pct higher than when using the conventional water pressure of 190 psi. The lower dust level was mainly due to wetting of the coal surface. However, at the sampling location, 72 in from the cutting drum, dust levels were slightly lower when cutting dry. The higher dust level while using water can be attributed to airflow turbulence. Prior tests by the Bureau (*13*) have shown that, in addition to wetting, water sprays can cause airflow turbulence that can have a significant effect on dust levels measured in the vicinity of a longwall shearer. If water-spray nozzles mounted on the shearer body are not properly oriented, the resulting airflow can carry dust to the shearer operator's position. Although only drum-mounted sprays were used during these tests, in tests where the web width was less than the drum width, the sprays nearest the shearer body sprayed outside the coalcrete block. At 190 psi (1.3 MPa), these unshielded sprays created air turbulence that increased the amount of airborne dust at one of the sampling locations.

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