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A research contract report  
OCTOBER, 1991

# WATER — JET — ASSIST CUTTING EVALUATION AND CUTTING TRIALS

Contract J0145039  
Eickhoff Corporation

BUREAU OF MINES  
UNITED STATES DEPARTMENT OF THE INTERIOR



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16. Abstract (Limit 200 words) Mining coal using the longwall method is becoming increasingly popular in the United States. Unfortunately, the dust levels liberated by various longwall equipment can exceed the permissible limits and therefore reduce the productivity. In 1984, the Eickhoff Corporation was awarded Contract no. J0145039 to build and demonstrate a water-jet-assisted shearer for the multiple purpose of reducing the dust levels, increasing the material size, and improving the bit service life. Two shearers were built, of which one was operated for two panels in a United States mine. Dust measurements and bit wear measurements were conducted. The levels of the respirable dust were reduced by up to 52% and the service life of the bits was increased due to the cooling and lubricating effect of the water jets. <i>and included in the report.</i>			
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## \*\*\* FOREWORD

This report was prepared by Eickhoff Corporation, Pittsburgh, Pennsylvania, under USBM Contract number J0145039. The contract was initiated under the Dust Control and Ventilation Program. It was administered under the technical direction of the Pittsburgh Research Center with Ed Thimons acting as Technical Project Officer. Oliver H. Snyder II was the contract administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period March 1988 to October 1991. This report was submitted by the author on October 29, 1991.

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CONTENTS

Page

Abstract . . . . .

Introduction . . . . .

    Review of previous results . . . . .

    Objective of Phase V . . . . .

    Test site . . . . .

        General description and location . . . . .

        Coal condition, intrusions, and  
        adjacent strata . . . . .

Description of the test machine . . . . .

    General machine layout . . . . .

    High-pressure water system . . . . .

    Drum layout during first panel . . . . .

    Drum layout during second panel . . . . .

    Phasing valve . . . . .

        Spray pattern during first panel . . . . .

        Spray pattern during second panel . . . . .

    Spray nozzles . . . . .

    Cutting bits . . . . .

Dust sampling . . . . .

    Test procedure . . . . .

        Location of dust sampling devices . . . . .

        Test runs . . . . .

    Evaluation of samples . . . . .

Material sampling and screen analyses . . . . .

Page

Test procedure . . . . .

Evaluation of material samples . . . . .

Evaluation of wear on cutting bits . . . . .

Discussion . . . . .

Conclusion . . . . .

ILLUSTRATIONS

1. Dust levels measured comparing water-jet-assist  
with conventional water spray pressures . . . . .

2. EDW-380/440-L . . . . .

3. Haulage pull/speed diagram for operation with  
2-haulages . . . . .

4. Gear transmission of gearhead/haulage unit,  
sheet 1 . . . . .

5. Gear transmission of gearhead/haulage unit,  
sheet 2 . . . . .

6. Gear transmission of ranging arm . . . . .

7. Water distribution . . . . .

8. One-segment phasing valve, cut-away view . . . . .

9. Water-jet-assisted shearer cutting drum . . . . .

10. Phasing valve, sectional view . . . . .

11. Spray pattern of drums used during first  
panel . . . . .

12. Spray pattern of drums used during second  
panel . . . . .

Page

13. Nozzle used during high-pressure water tests,  
cut-away view . . . . .
14. Flow characteristics of nozzle versus  
pressure . . . . .
15. Typical arrangement of bit, sleeve, and  
bit holder . . . . .
16. Sample bits from tailgate drum after water-jet-  
assist cutting, 48 rpm: E: endring; C: center  
of drum; G: gobside . . . . .
17. Sample bits from headgate drum after water-jet-  
assist cutting, 48 rpm: E: endring; C: center  
of drum; G: gobside . . . . .
18. Sample bits from tailgate drum after low-pressure  
cutting, 48 rpm: E: endring; C: center of drum;  
G: gobside . . . . .
19. Sample bits from headgate drum after low-pressure  
cutting, 48 rpm: E: endring; C: center of drum;  
G: gobside . . . . .
20. Sample bits from tailgate drum after water-jet-  
assist cutting, 34 rpm: E: endring; C: center  
of drum; G: gobside . . . . .
21. Sample bits from headgate drum after water-jet-  
assist cutting, 34 rpm: E: endring; C: center  
of drum; G: gobside . . . . .

Page

- 22. Sample bits from tailgate drum after low-pressure cutting, 34 rpm: E: endring; C: center of drum; G: gobside . . . . .
- 23. Sample bits from headgate drum after low-pressure cutting, 34 rpm: E: endring; C: center of drum; G: gobside . . . . .

TABLES

- 1. Pressure and flow rate of water-jet-assist spray nozzle used during trials . . . . .
- 2. Results from first two test runs, made with drum speed of 48 rpm and original phasing system design . . . . .
- 3. Results from second set of test runs, made with drum speed of 34 rpm and redesigned phasing system . . . . .
- 4. Size distribution analysis for first shearer with drum speed of 48 rpm and original phasing system design . . . . .
- 5. Size distribution analysis for second shearer with drum speed of 34 rpm and redesigned phasing system . . . . .
- 6. Bit measurements for first shearer with drum speed of 48 rpm and original phasing system design . . . . .
- 7. Bit measurements for second shearer with drum speed of 34 rpm and redesigned phasing system . . . . .

## UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

fpm	foot per minute	m	meter
ft	foot	mg	milligram
g	gram	mm	millimeter
in	inch	$\mu$ m	micrometer
kg	kilogram		

WATER-JET-ASSIST CUTTING EVALUATION  
AND CUTTING TRIALS  
Underground Tests in an American Mine  
By Ulrich Neumann<sup>1</sup>

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\*\*\* ABSTRACT

Mining coal by employing a method called longwall mining is gaining more and more popularity in the United States since it offers many advantages over the conventional deep mining methods. Those advantages are a higher productivity, an almost total extraction of the mineral since no pillars must be left behind for support, and an increase in safety since the personnel are protected by the shield supports and rarely have to work near unsupported, exposed roof.

However, on some longwalls, the dust levels liberated by various equipment such as belt conveyors, chain conveyors, crushers, longwall shearers, and moving shield supports can exceed the maximum permissible limits and therefore have an adverse effect on productivity. Many attempts have been made over the past years to reduce the dust liberation by changing designs, installing various types of sprays or scrubbers, treating the mine water with wetting agents, or even using foam to catch dust before it becomes airborne.

In the year 1984, the Bureau of Mines awarded Eickhoff Corporation a contract to demonstrate a water-jet-assisted

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<sup>1</sup>Project Engineer, Eickhoff Corporation, Pittsburgh, PA.

cutting system for the multiple purposes of reducing dust levels, improving bit consumption, and increasing material size. During the previous phases of this contract, various trials were conducted aimed to design, build, and test a shearer loader to meet the objective of the contract.

In the early stages of the research program, it was expected to see a reduction in the overall power consumption of the machine due to the fact that the high-pressure water jet would pre-cut the mineral in front of the bit. This, in turn, would then reduce the bit wear. Since there is less cutting action performed by the bit, a reduction of the dust liberation and a reduction of product fines was sought.

### \*\*\* INTRODUCTION

#### REVIEW OF PREVIOUS RESULTS

The Bureau of Mines has conducted various studies in which the impact of moderate pressure water (800 psi to 12,000 psi) on the respirable dust concentration was investigated.<sup>2</sup> A reduction of the respirable dust concentration of around 40% was reached when inward-facing conical sprays were used.

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<sup>2</sup>Jankowski, R. J., K. L. Whitehead, D. J. Thomas, and A. L. Williamson. High-Pressure Inward-Facing Drum Sprays Reduce Direct Levels on Longwall Mining Section. Proceedings of Longwall USA Conference held in Pittsburgh, PA, June 19-22, 1989, pp. 232-242.

An initial underground test was carried out with a single drum shearer at the Auguste-Victoria coal mine near Marl, Germany. The longwall had the following parameters: face length, 919 ft; face height, 90 in. Many rock intrusions and a geological fault could be observed near the headgate. To gather baseline data, the first set of measurements was carried out using the original drum supplied with the shearer. This drum had a diameter of 63 in, a web of 33 in, and turned at 48 rpm. Water sprays in front of 41 out of the 55 available point-attack bits were used. The water pressure amounted to 340 psi and the total waterflow to the sprays was about 10 gpm.

After the baseline data were collected, the drum was replaced by a high-pressure water-jet-assisted drum and the gear ratio was changed. This drum had a diameter of 67 in, a web of 33 in, rotated at 23.6 rpm, and was equipped with 51 conical bits. Each bit holder featured a spray nozzle that directed a jet of water just a few millimeters in front of the bit tip. In order to conserve water and minimize turbulences in the airflow around the drum, the high-pressure water was phased in such a way that only those bits that were in contact with the coal received water.

All data were collected cutting in the bi-directional mode. The measurements required to evaluate the specific cutting energy were taken at a water pressure ranging from 340 psi to 10,000 psi. The subsequent regression analysis

of the collected data showed no reduction in the power consumption of the machine as a result of the application of high-pressure water jets. This proved that the water jets were not assisting the cutting tools.

The results from this test confirmed previous tests carried out in laboratories.

Figure 1 shows a comparison of the results from the dust measurements at Auguste-Victoria Mine.<sup>3</sup> At 1800 psi and a waterflow of 10 gpm to the high-pressure sprays, the concentration of the respirable dust a short distance downwind from the shearer was 3.5 mg/m<sup>3</sup> compared to 15.4 mg/m<sup>3</sup> with the conventional spray system operating at the same flow rate but only 340 psi of pressure. The reduction of the dust concentration amounted to around 80%.

The data in figure 1 also show that changing the water pressure to 7200 psi or increasing the waterflow by the factor of two while maintaining a water pressure of 1800 psi did not significantly reduce the level of the respirable dust concentration.

During each of those tests, coal samples were taken and a screen analysis was performed on each of them. The results showed an increase in grain size when the high-pressure

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<sup>3</sup>Thimons, E. D., K. M. Kinsella, U. Neumann. Underground Test Results with Water-Jet-Assisted Longwall Shearers. Proceedings of Longwall USA Conference held in Pittsburgh, PA, June 2-6, 1991, pp. 215-225.

# DUST LEVELS

## WATER-JET-ASSIST VERSUS CONVENTIONAL WATER SPRAY PRESSURES

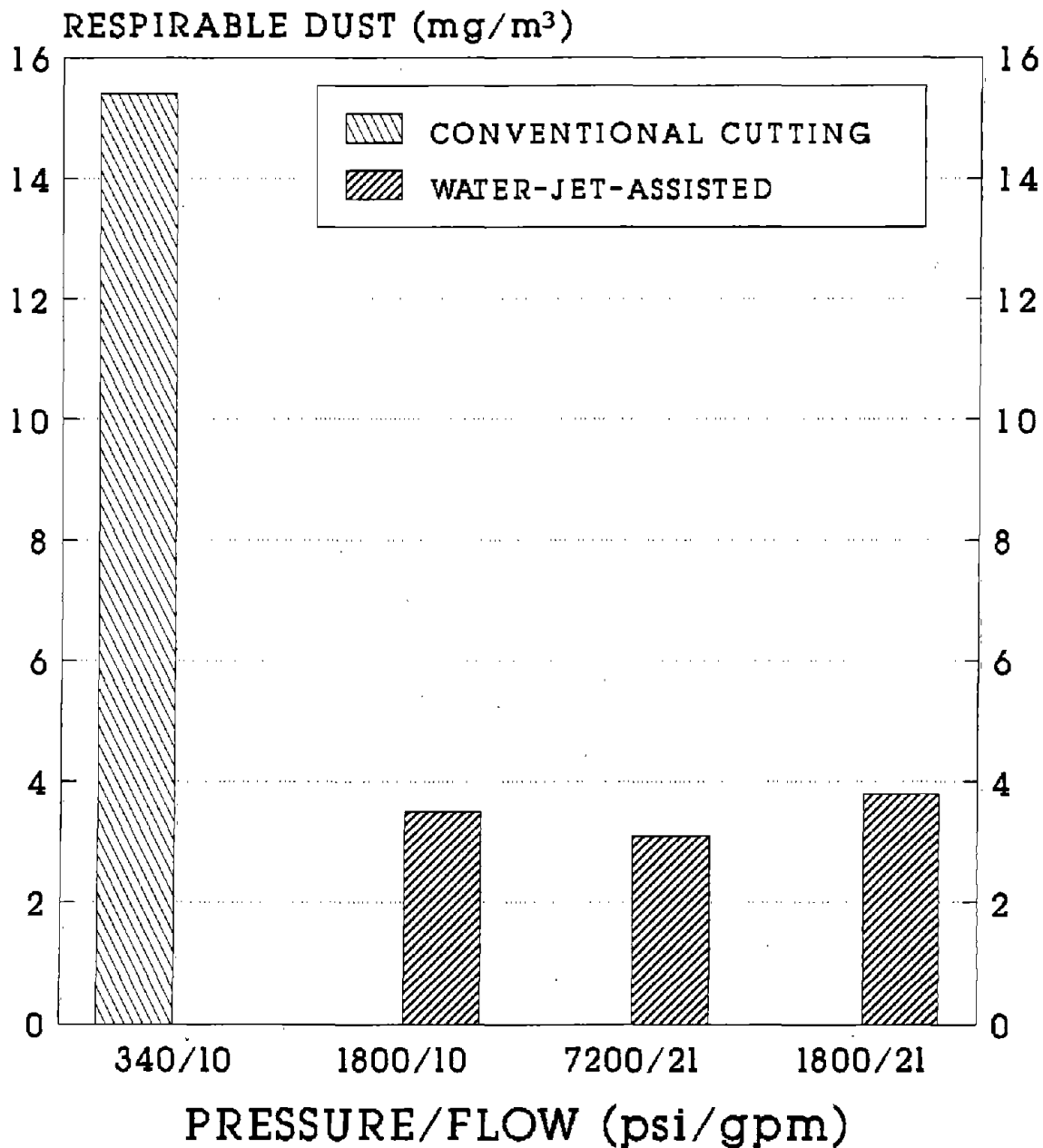


FIGURE 1. - Dust levels measured comparing water-jet-assist with conventional water spray pressures

water system was used. At 1800 psi, for instance, the amount of coal fines below 1/4 in. in size was reduced by around 10% compared to using low-pressure water of 340 psi.

Since the cutting conditions varied due to the changing geology along the longwall, it was not possible to actually measure the bit wear while using the different spray systems. However, the mine management as well as the operators on the longwall reported that the useful service life of the bits was significantly increased while employing the high-pressure water sprays. This was particularly visible while cutting rock bands and the geological fault. One possible and most likely reason for this finding is the cooling and lubricating effect of the water jet directed at the bit tip.

Another important finding of the high-pressure water tests was that at more than 5000 psi, coal and rock particles were projected from the face and thrown towards the operators. A full face shield was recommended to minimize the risk of injury. This hazard was not observed at pressures below 5000 psi.

#### OBJECTIVE OF PHASE V

The objective of Phase V of the contract was to build a double-drum shearer loader and test it in a United States mine. Furthermore, it was sought to confirm the results from previous laboratory tests and the underground trial at

Auguste-Victoria and gain experience with high-pressure water equipment on a full-production longwall.

#### TEST SITE

##### General Description and Location

The Kerr McGee Coal Company agreed to have a new shearer loader built with high-pressure water equipment. This shearer, Eickhoff's model EDW 380/440-L, was ordered to take up production in Kerr McGee's first longwall at the Galatia Mine, located near the town of Galatia in southern Illinois. This mine is Kerr McGee's first deep mine and had been operating for some time using the room-and-pillar method on the lower of the two minable seams.

The seam height varied from 62 in. to 68 in. The average unconfined compressive strength (UCS) was measured at 2693 psi, and the seam was well cleated with poor separation. The inherent moisture of the coal was determined at about 4%. Some sections of this particular seam contained intrusions of "Red Rock", which is petrified peat and has a UCS of 12,000 psi. The volume of the encountered Red Rock ranged from smaller lumps of about the size of a football to massive blocks replacing all the coal over long sections of the longwall. The Red Rock is spread out in a random pattern and so far there is no known precise method of predicting its presence. During the tests, some of this Red Rock was encountered.

The roof was sandstone and the floor was fire clay which became very soft when in contact with water.

\*\*\* DESCRIPTION OF THE TEST MACHINE

GENERAL MACHINE LAYOUT

The machine used for the tests was, as mentioned earlier, an Eickhoff EDW 380/440-L. This machine type can be best characterized as a low-profile, high-power shearer. It can mine in seams between 62 in. and 100.8 in. and has a total installed power of 664 hp. The ranging arms are 64.9 in. long, and the maximum distance between the drum centers amounts to 383.7 in. Figure 2 shows the general machine layout.

The machine was equipped with one centrally-mounted motor inside the Energy Distribution Box (EDB) that delivered 590 hp. The geartrain to either cutting drum was laid out to transmit the full load. The haulages, located in the gearhead units, were each powered by a 36.8 hp DC motor. The machine was capable of cutting at 39.3 ft/min and delivered a haulage pull at this speed of 55,056 lb. The maximum haulage pull amounted to 88,315 lb which could be maintained at a speed from 0 to 24.61 ft/min. These figures relate to a total haulage reduction of 235:1 (see figure 3). As a traction system, Eickhoff's latest, cast-type Eicotrack was utilized. The tailgate end of the machine was equipped with a lumpbreaker that was driven off the main cutter geartrain. At the headgate end the high-pressure water

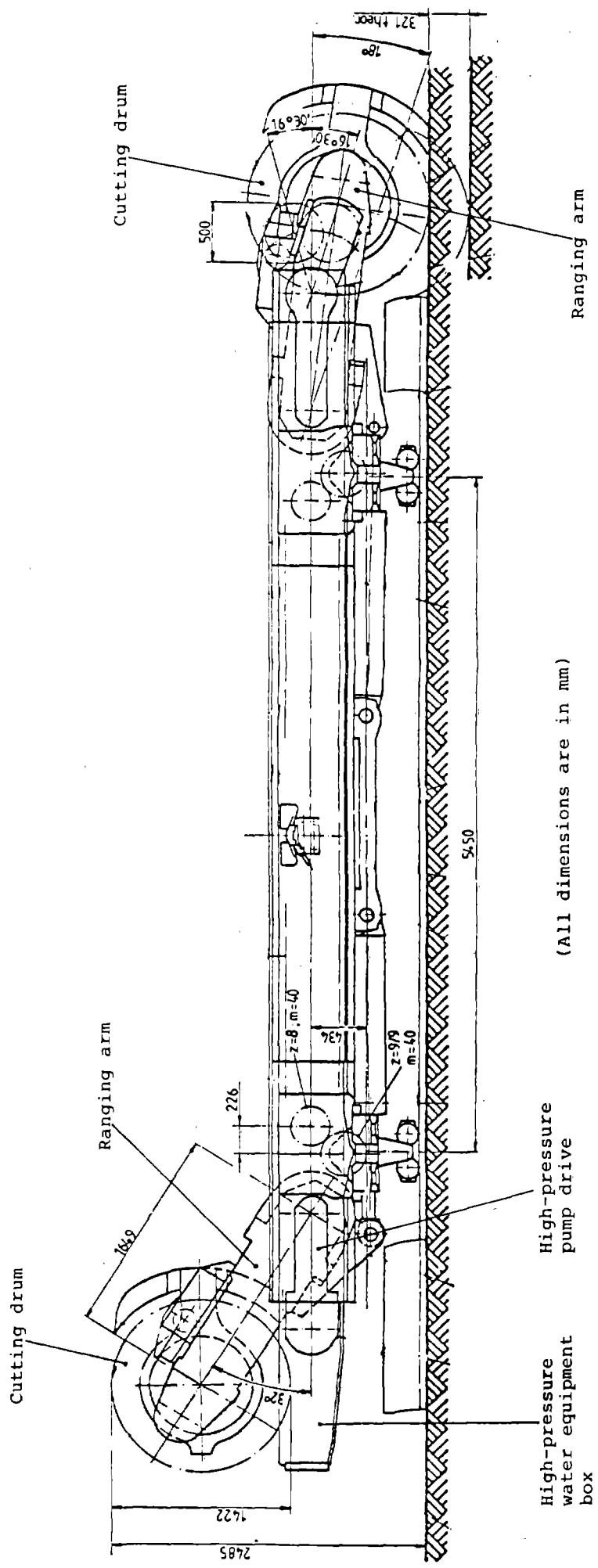
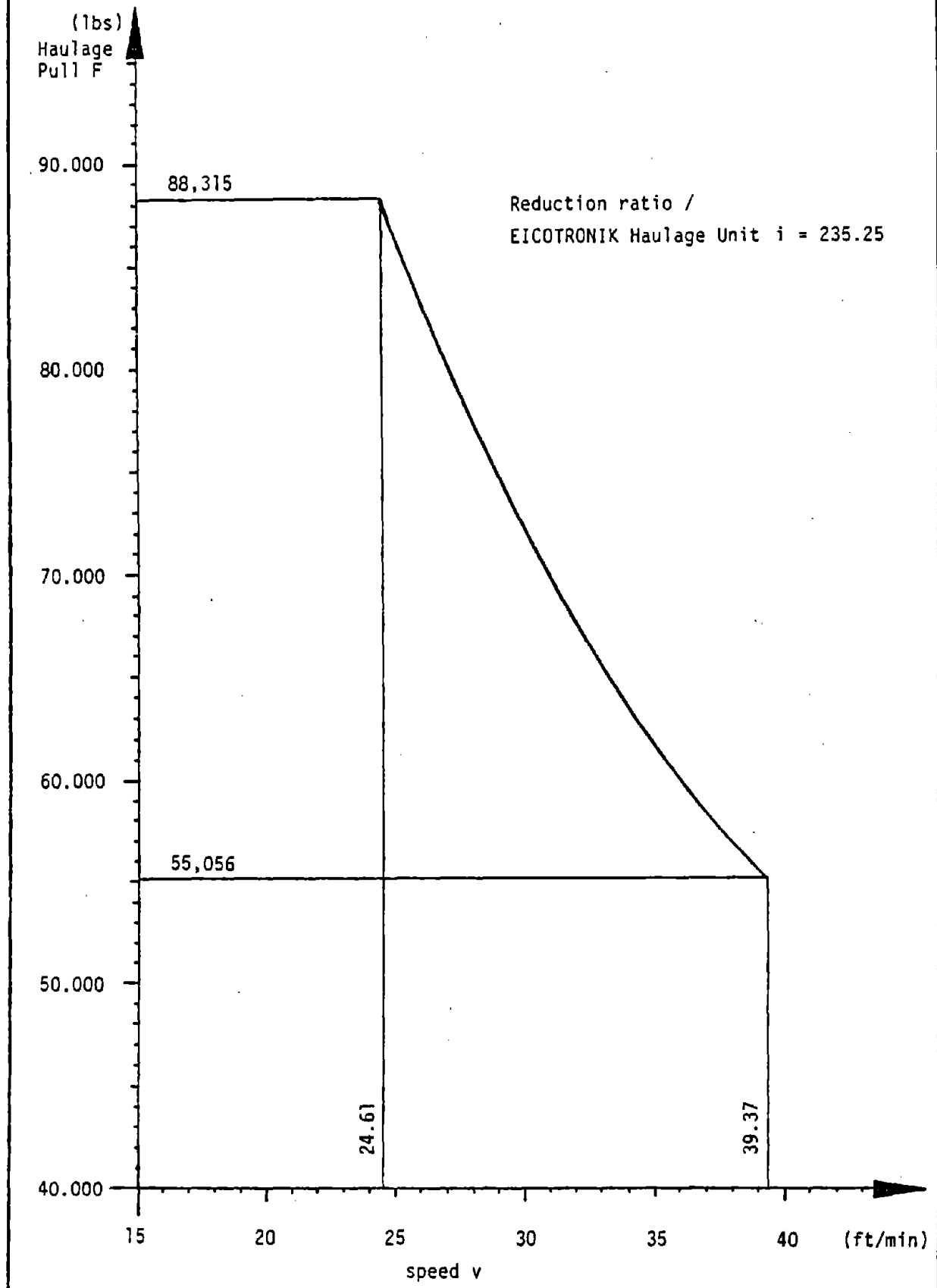



FIGURE 2. - EDW-380/440-L

Haulage Pull/Speed Diagram for Operation with 2-Haulage



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FIGURE 3. - Haulage pull/speed diagram for operation with 2-haulages

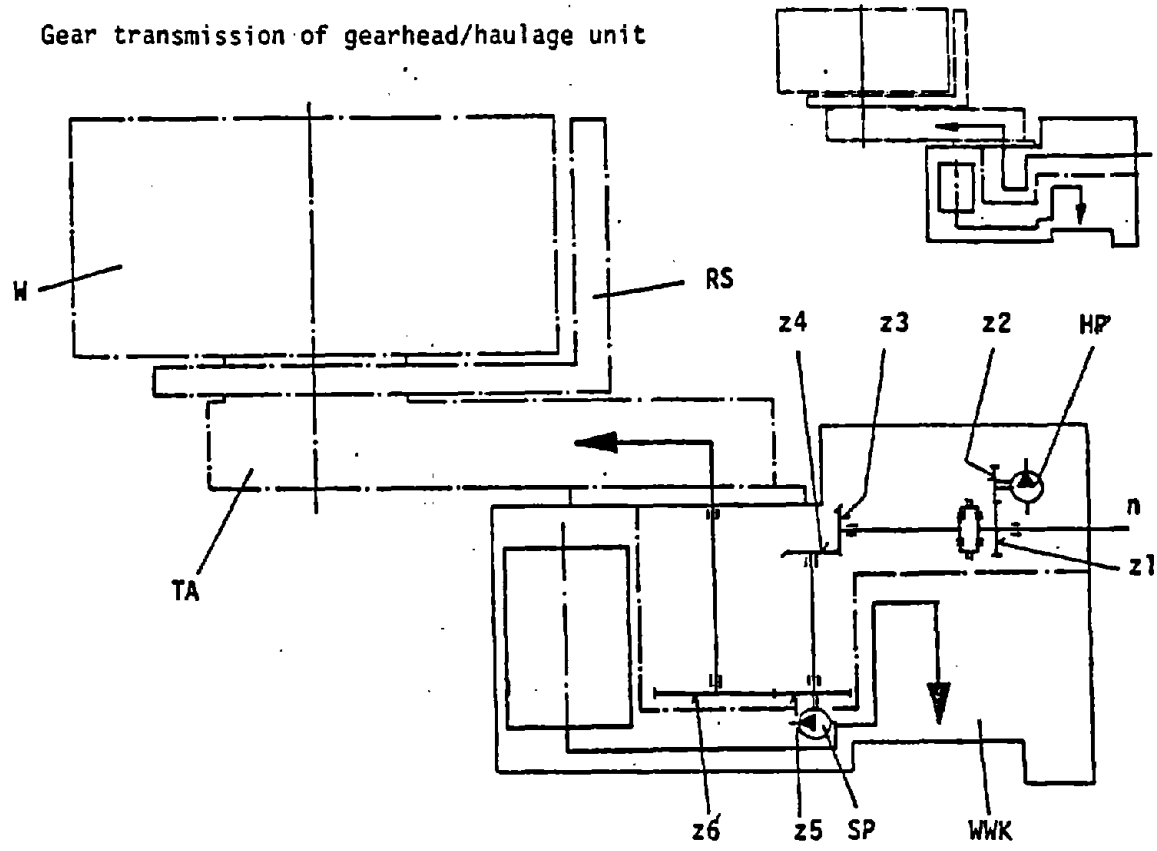
system was installed, which will be described in detail in the next section. Due to the unique design of the machine, no external hoses or cables needed to be protected, so the machine had no machine covers. Another unique feature of this machine type was the use of hydraulically-pretensioned tie rods to keep the machine body together. This system eliminated the need for an underframe and even under the most severe cutting conditions in the Red Rock, the components never shifted relative to each other.

Figures 4, 5, and 6 show the gear layout of the machine.

#### HIGH-PRESSURE WATER SYSTEM

The water was supplied to the machine via a flexible, steel-braided hose of the size DN40 (see figure 7). This permitted a maximum flow of 86.4 gpm. The water entered the machine via a four-position valve and a 100- $\mu$ m back-flush filter (1). Immediately behind the filter the water passed by a pressure-relief valve (2), which was set to limit the pressure to 320 psi. This valve was necessary to protect the cooling jackets of the electric motors and the oil coolers from damage due to overpressure. Behind this relief valve all water required for cooling purposes was branched off (3). The remainder of the water went through a flow meter with a check valve (4) that would close should there be any back pressure or back flow from the high-pressure pump. Since the maximum permissible intake pressure for the water pump was 116 psi, the water pressure was reduced by a

Gear transmission of gearhead/haulage unit



gear wheel	number of teeth	modulus (mm)	speed r. p. m.
z1	63	3	1774
z2	61	3	1832
z3	21	8	1774
z4	27	8	1379
z5	31	8	1379
z6	47	8	910

motor shaft n = 1774 r. p. m.

- RS = cowl
- SP = geared pump
- TA = ranging arm
- W = cutting drum
- WWK = gearhead/haulage unit
- HP = axial piston pump

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Gear Transmission

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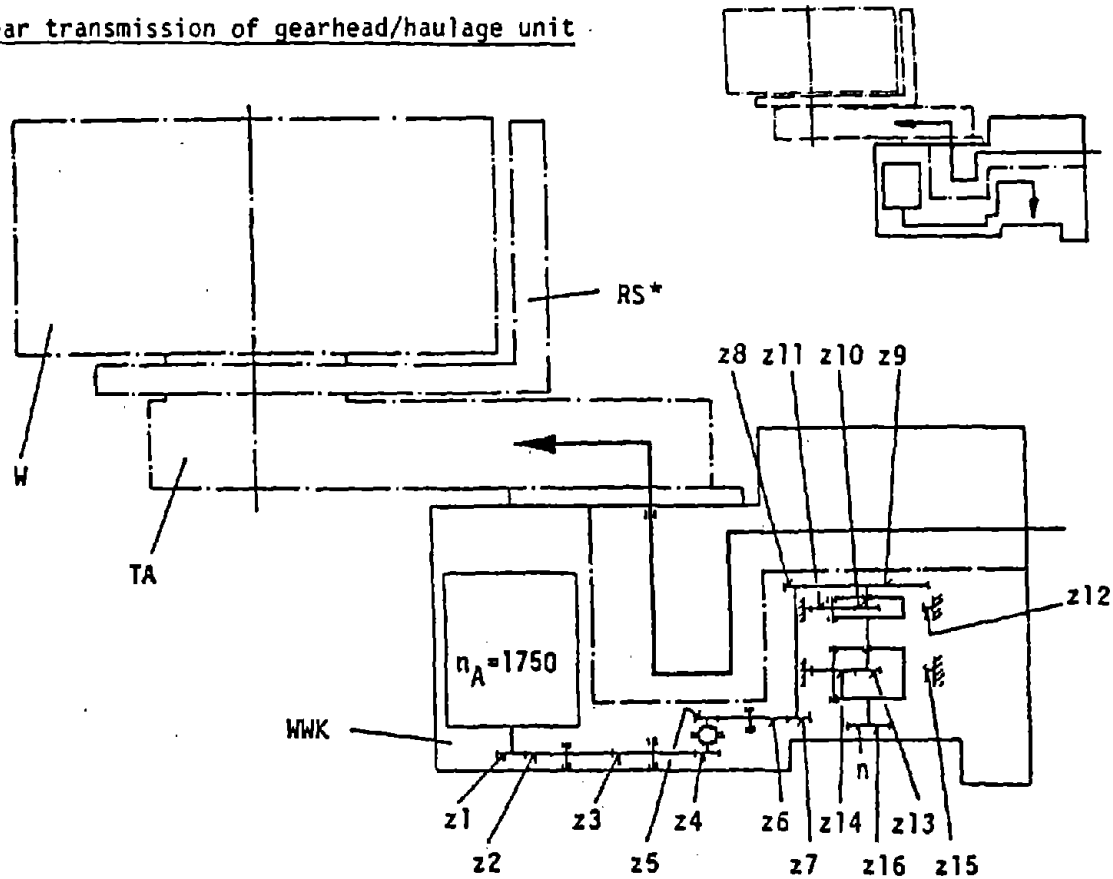
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FIGURE 4. - Gear transmission of gearhead/haulage unit, sheet 1

Gear transmission of gearhead/haulage unit



gear wheel	number of teeth	modulus (mm)	speed r.p.m.
z1	30	3	1750
z2	95	3	553
z3	91	3	577
z4	35	3	1500
z5	33	3,5	1500
z6	85	3,5	582
z7	39	3,5	1269
z8	25	4,5	1269
z9	89	4,5	357
z10	13	5	357
z11	31	5	-128
z12	77	5	0
z13	13	5	51
z14	31	5	-18
z15	77	5	0
z16	26	5	7,4

speed of input shaft  
 $n_A = 1750$  r.p.m.

speed of output shaft  
 $n = 7.4$  r.p.m.

HP axial piston pump

RS cowl\*

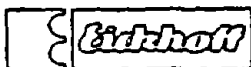
TA ranging arm

W cutting drum

WWK gearhead/haulage unit

\* depending on layout

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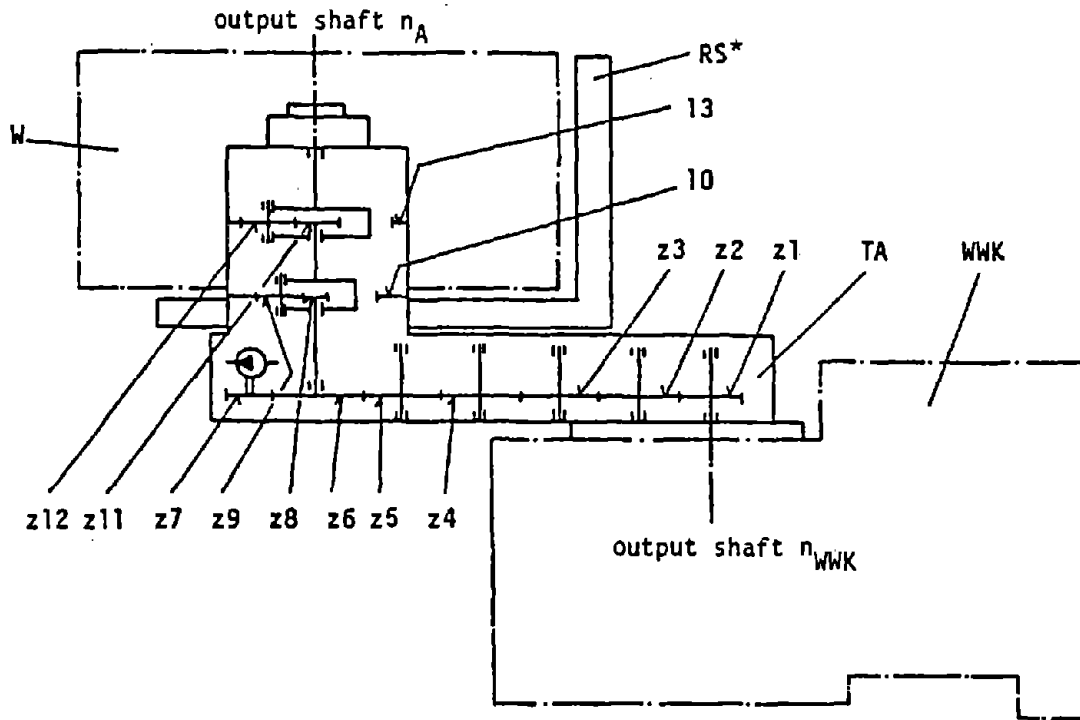
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FIGURE 5. - Gear transmission of gearhead/haulage unit, sheet 2

Gear Transmission of Ranging Arm



gear wheel	number of teeth	modulus (mm)	speed (r.p.m.)
z1	27	10	910
z2	33	10	744
z3	32	10	767
z4	33	10	744
z5	32	10	767
z6	35	10	702
z7	19	10	1293
z8	23	6	702
z9	29	6	-435
z10	82	6	0
z11	20	9	154
z12	23	9	-103
z13	67	9	0

Speed of output shaft  
 $n_A = 35$  r.p.m.

Speed of output shaft  
 $n_{WWK} = 910$  r.p.m. at 60 Hz

RS cowl\*

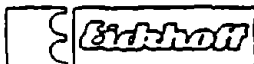
TA ranging arm

W cutting drum

WWK gearhead/haulage unit

\* depending on layout

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Gear Transmission

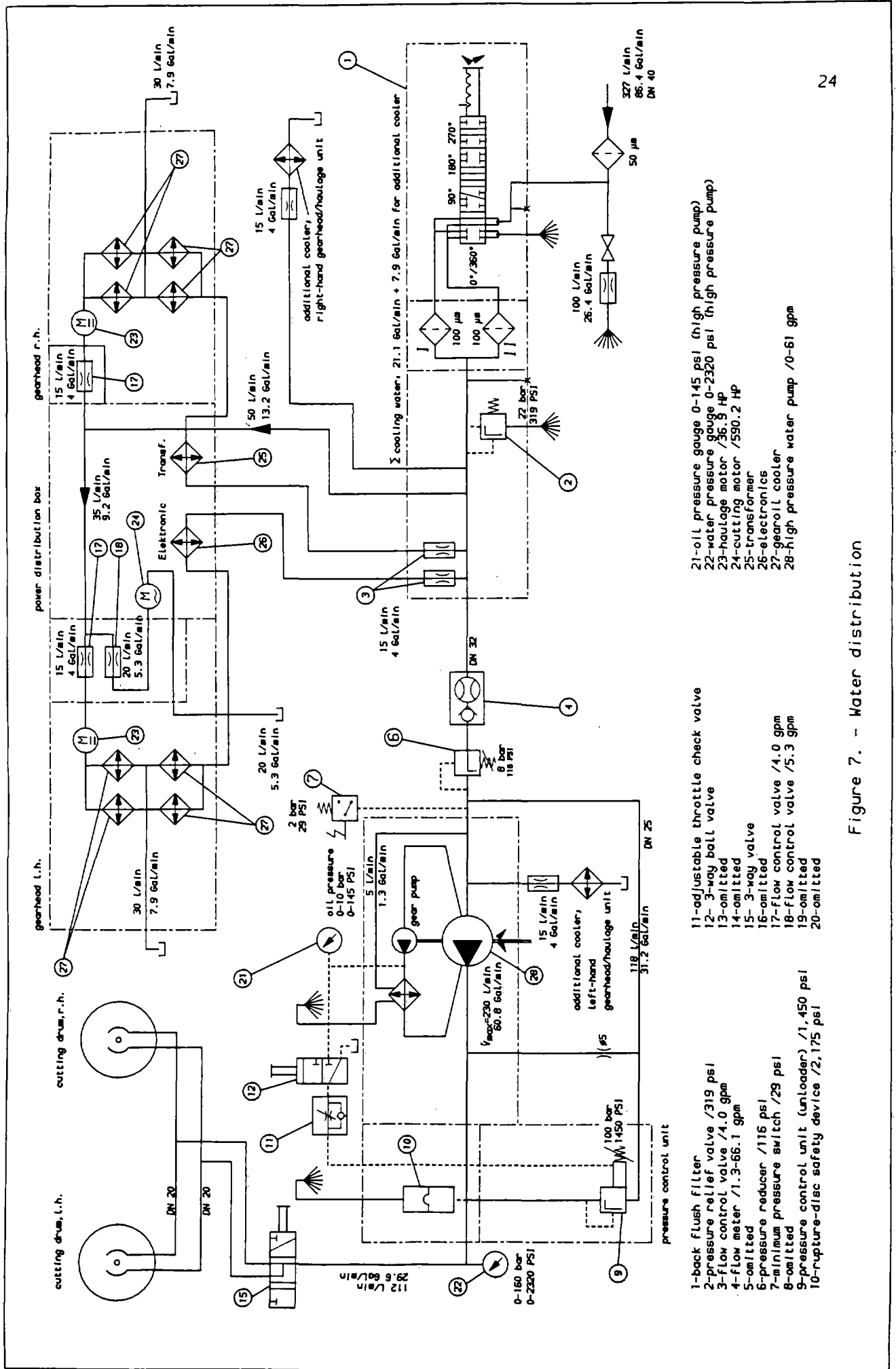
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FIGURE 6. - Gear transmission of ranging arm



- 1-back flush filter
- 2-pressure relief valve /319 psi
- 3-flow control valve /4.0 gpm
- 4-flow meter /1.3-66.1 gpm
- 5-omitted
- 6-pressure reducer /116 psi
- 7-minimum pressure switch /29 psi
- 8-omitted
- 9-pressure control unit (unloader) /1,450 psi
- 10-rupture-disc safety device /2,175 psi
- 11-adjustable throttle check valve
- 12-3-way ball valve
- 13-omitted
- 14-omitted
- 15-3-way valve
- 16-omitted
- 17-flow control valve /4.0 gpm
- 18-flow control valve /5.3 gpm
- 19-omitted
- 20-omitted
- 21-oil pressure gauge 0-145 psi (high pressure pump)
- 22-water pressure gauge 0-2320 psi (high pressure pump)
- 23-haulage motor /36.9 HP
- 24-cutting motor /590.2 HP
- 25-transformer
- 26-electronics
- 27-gearoil cooler
- 28-high pressure water pump /0-61 gpm

Figure 7. - Water distribution

pressure reducer to 116 psi (6). To avoid damage to the pump due to water starvation, a minimum-pressure switch set at 29 psi (7) was installed. This switch would interrupt the start-up pilot circuit of the machine if the water pressure in the intake manifold of the pump would fall below 29 psi. The high-pressure pump (28), a three-piston plunger type made by the Hammelmann Maschinenfabrik GmbH in Germany, delivered 60.7 gpm at a drive speed of 550 rpm. The pump had its own lubrication circuit, including an oil cooler, which made it a self-contained unit requiring only minimal care. The output pressure of the high-pressure pump of nominally 1450 psi was controlled by the pressure-control unit (9), sometimes also called the "unloader." It would allow a pressure build-up only if the lubrication pump of the high-pressure pump delivered sufficient oil pressure. Otherwise, the water was recirculated back into the intake manifold. By shifting the 2/2-way valve, the high-pressure pump discharge could be manually cut off and recirculated. The throttle-check-valve (11) assured a smooth operation of the unloader (9). In case the pressure unloader (9) should fail, a rupture disk (10) would burst at 2175 psi and relieve the pressure. The gauge (22) indicated the output pressure of the high-pressure pump. By shifting the 3-way valve (15), the high-pressure water could be directed to different segments of the drums.

Since the water had to travel a considerable distance from the output end of the pump through manifolds and the phasing valves, a pressure loss was unavoidable. The exact amount of pressure loss was never determined on this machine, but tests on the first trial machine in Germany indicated that the losses ranged at around 5%. In order to compensate for these losses, the unloaders of the second and third trial machines in the U.S. were adjusted to between 1520 psi and 1600 psi (105 to 110 bar).

#### DRUM LAYOUT DURING FIRST PANEL

The drums used to perform the first test had a diameter (bit tip to bit tip) of 62 in. and a drum speed of 48 rpm. This resulted in a bit speed of 779 ft/min. The effective cutting web of the drums was 36 in. The drums featured three starts and were equipped with 45 3-in.-gauge conical point-attack bits each. In front of each bit holder a spray holder was welded to the vane, where a 0.0236-in.-diameter jet nozzle was installed. This jet nozzle was aligned in such a way that the water jet would spray just a few millimeters in front of the bit tip.

#### DRUM LAYOUT DURING SECOND PANEL

After the first panel was mined out, the second machine that went into operation was equipped with a different gear ratio in the ranging arms that would reduce the drum speed from 48 rpm to 34 rpm. Since the overall dimensions of the three start drums remained unchanged, the bit speed was now

552 ft/min. Also, the number of cutting bits was reduced from 45 to 40 bits and 4-in. gauge bits were used. Along with these changes, the number of sprays was reduced accordingly.

The changes were done to study the effects on the dust liberation as well as to improve loading and product size.

#### PHASING VALVE

The purpose of the phasing valve is to distribute water to only one or several specific segments of the rotating drum. It is generally located in the face-side hub of the ranging arm planetary.

Figure 8 shows a cut-away view of a simple, one-segment phasing valve, similar to the style used on the trial machine at Auguste-Victoria.

The high-pressure water enters through the non-rotating shaft and exits through the crescent-shaped segment. The arc of this cutout and its alignment determine which segment of the drum will receive water and which will not. The rotating sleeve acts as a distributor and connects to the drum via hoses. As this sleeve revolves around the non-rotating shaft, the conduit holes pass over the crescent-shaped cutout and receive high-pressure water. Once they have revolved towards the solid part of the shaft, the water supply is cut off.

The problem with these valves is to find reliable seals and an erosion-proof material combination. As the conduit

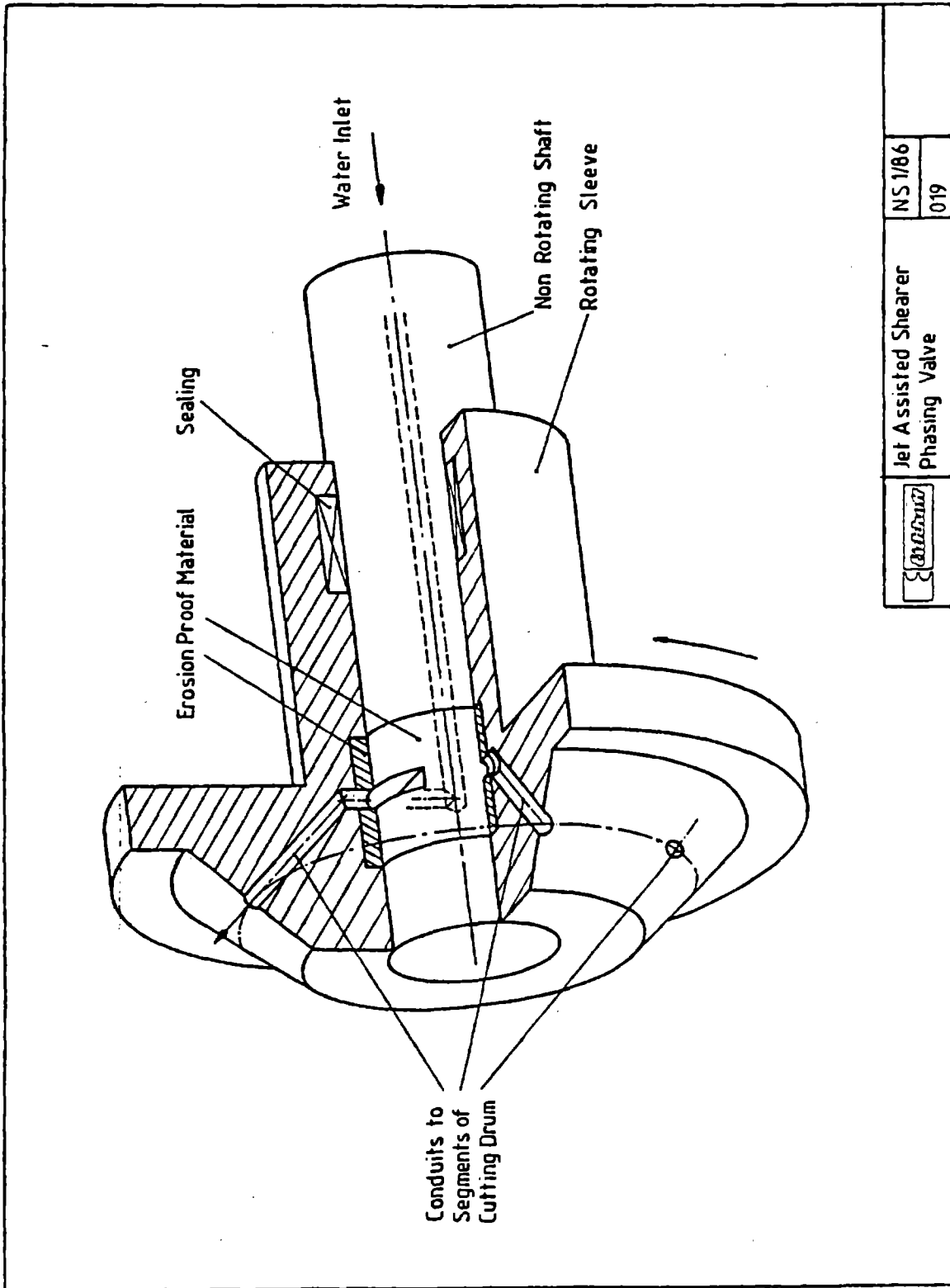
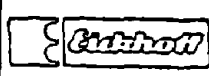
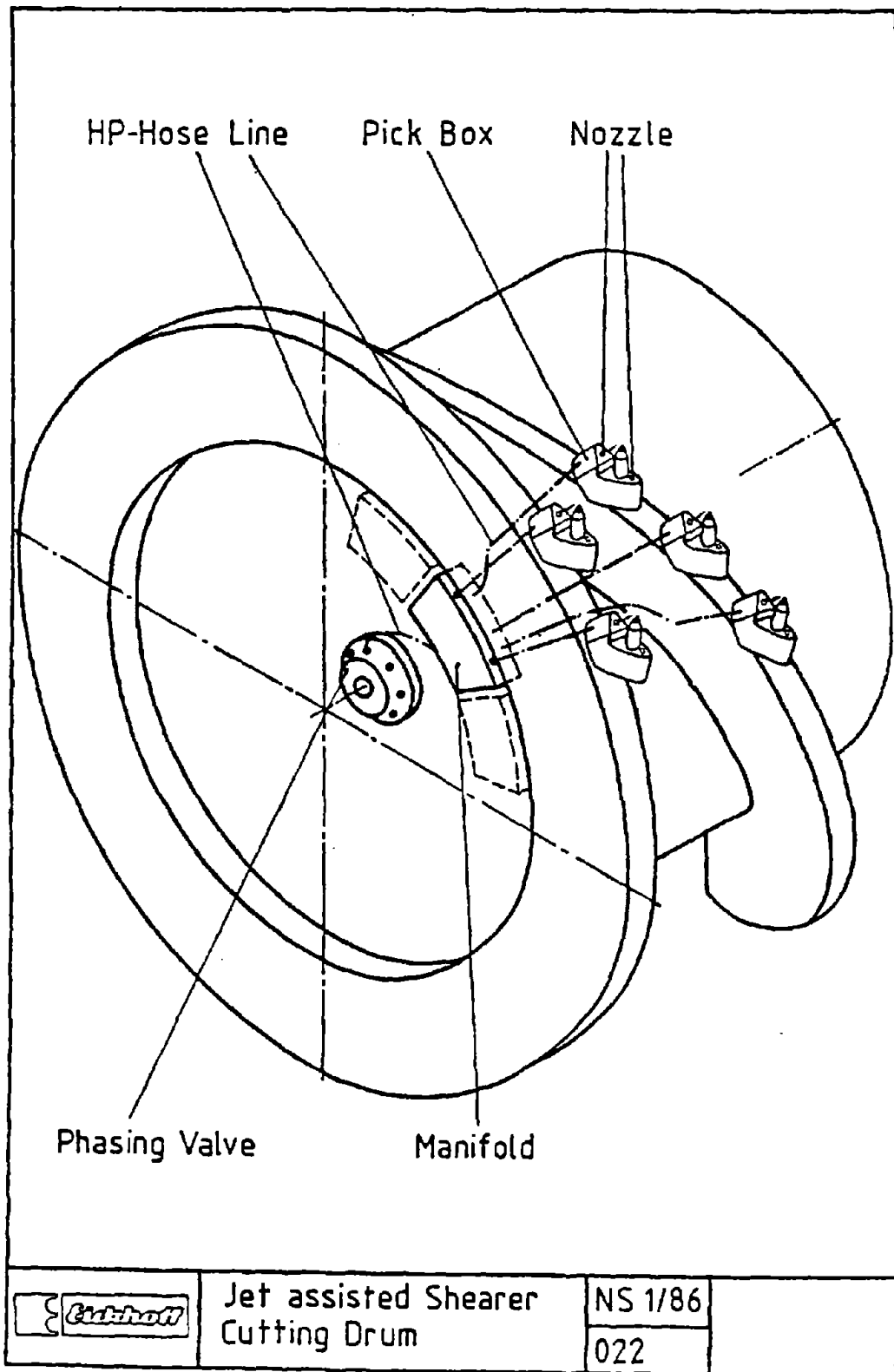


FIGURE 8. - One-segment phasing valve, cut-away view

hole approaches the end of the cut-out segment, the fluid velocity increases rapidly due to the increasingly reduced cross-section of the opening. Together with the increased speed comes a dramatic loss of pressure. This pressure reduction can be so great that it falls below the vapor pressure of water and small vapor bubbles appear. As those bubbles reach an area of pressure higher than the vapor pressure, they implode. This implosion creates a shock wave which travels with the speed of sound in water (around 5057 ft/s) until it hits the solid material, where the energy is converted into mechanical work. This process is called "cavitation" and can cause great damage to the surface of the seal area. Certain materials are erosion-proof but are extremely expensive or difficult to machine.

A second problem that greatly influences the service life of the phasing valve is the quality of the water filtration. The longwall at Kerr McGee was equipped with a 50- $\mu\text{m}$  filter located in the headgate. The machine was also fitted with two 100- $\mu\text{m}$  filter elements, which served as back-up during repairs to the waterline between the headgate filter and the machine in the event that dirt had entered the hose.

Figure 9 shows how the water is brought from the phasing valve into the drum. Each hose connects to one spray segment on the drum. All spray nozzles in this segment receive water if the hose is pressurized. Figure 10 shows a sectional view of the phasing valve used at Kerr McGee. On



Jet assisted Shearer  
Cutting Drum

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FIGURE 9. - Water-jet-assisted shearer cutting drum

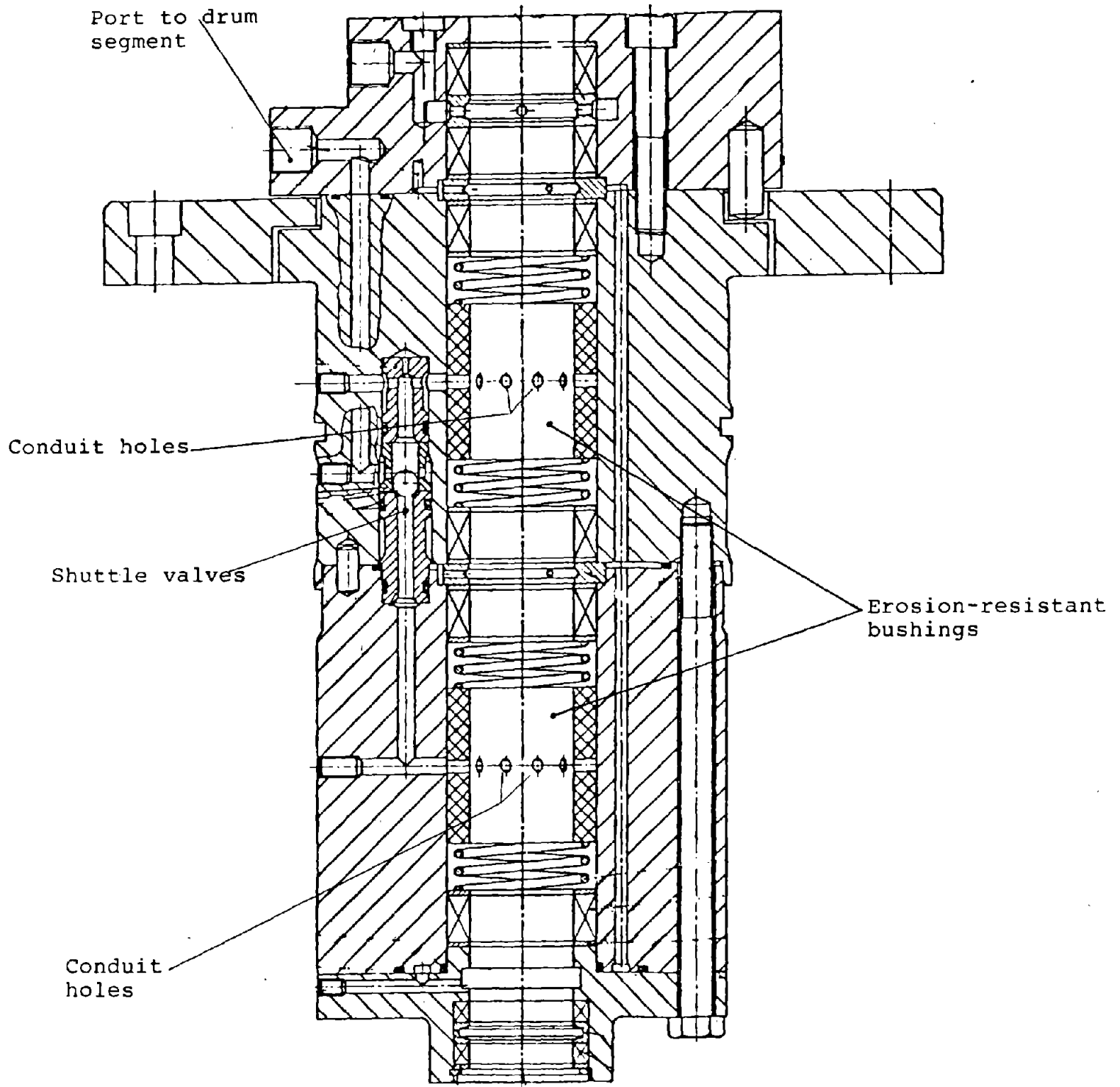


FIGURE 10. - Phasing valve, sectional view

this machine several segments of the drums were pressurized at the same time, thus, a more complicated design was required.

#### Spray Pattern During First Panel

Figure 11 shows the spray pattern of the drums used during the first panel. Cutting was done from the tailgate to the headgate, and a cleanup run was made going back to the tailgate. Since the drums rotated in the "English rotation," meaning that the bits would cut from the floor to the roof, the leading drum was always in the down position. At any given time, the high-pressure water was discharged over a 180° segment of the drums facing the direction of travel. The segments could not be individually controlled.

#### Spray Pattern During Second Panel

Figure 12 shows the spray pattern of the drums used during the second panel. The phasing valves and hence the spray pattern was modified. The high-pressure water was discharged constantly over a 30° segment on the top and bottom parts of each drum, and therefore the floor and the roof were constantly kept moist. The remaining 150° segments could be controlled individually. While cutting from the headgate to the tailgate, high-pressure water was discharged to the 150° segment of the tailgate drum that was actually doing the most cutting. On the cleanup run from the tailgate towards the headgate, only the four 30° segments received water. This prevented the high-pressure

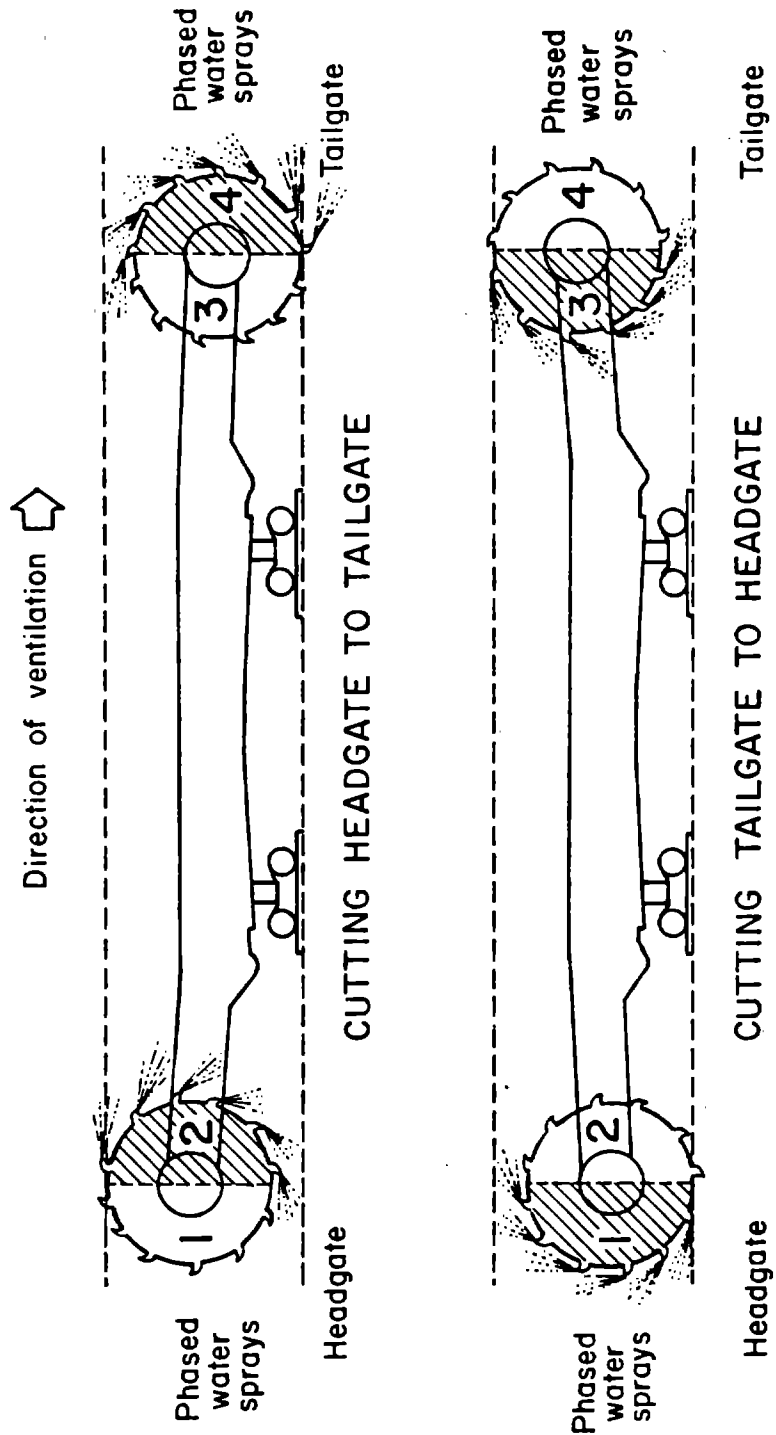


FIGURE 11. - Spray pattern of drums used during first panel

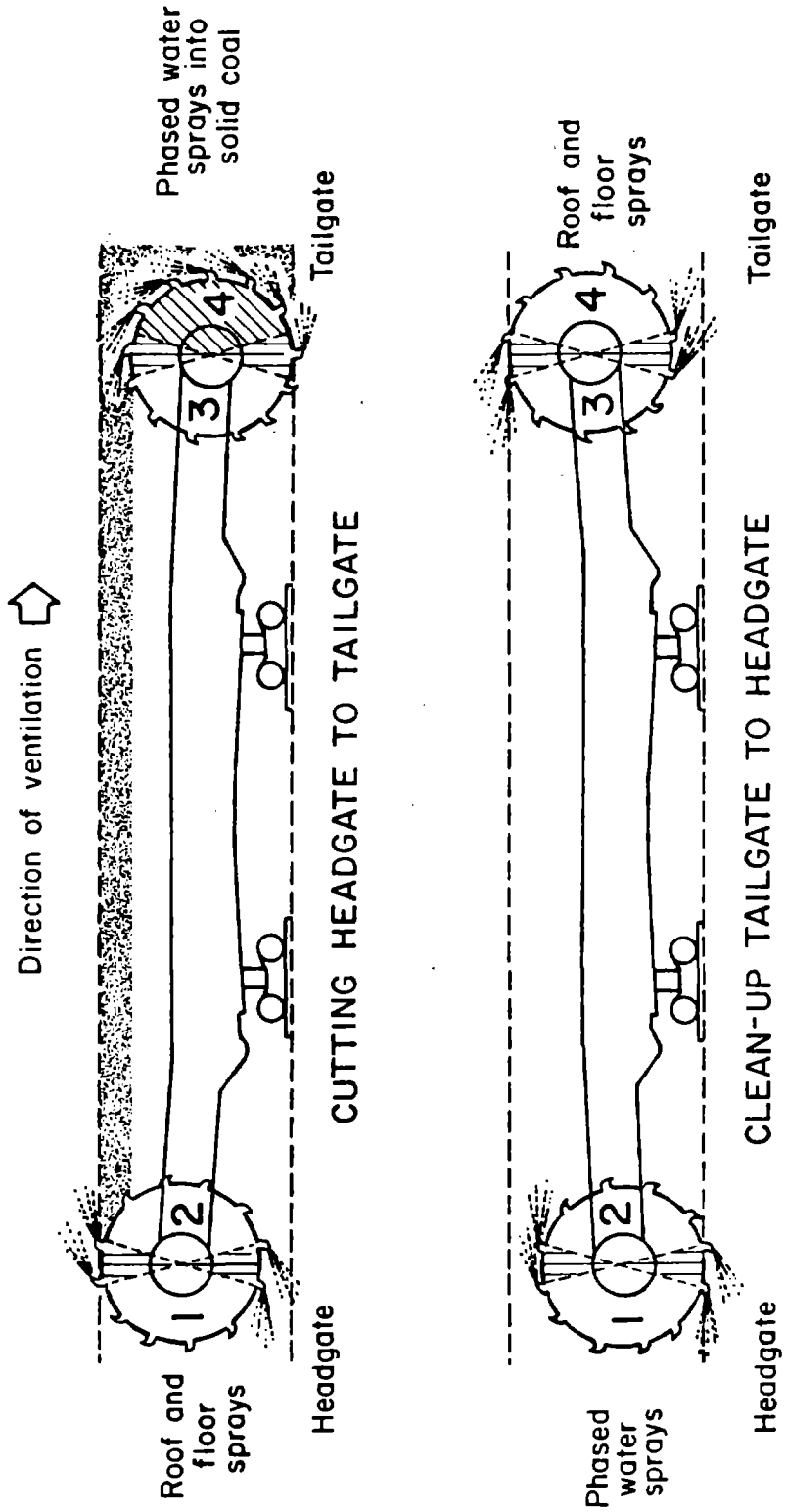


FIGURE 12. - Spray pattern of drums used during second panel

water jets from spraying into the open airflow and causing turbulences, which can result in dust rolling out into the walkway, where the operators are located.

#### SPRAY NOZZLES

Figure 13 shows a cut-away view of the nozzle used during the high-pressure water tests.

The material used for the nozzle body is a special stainless steel that is extremely erosion- and abrasion-resistant. The jet opening has a diameter of 0.0236 in. and is shaped in such a way that the water jet stays together as a solid stream rather than fanning out shortly after leaving the nozzle. The bottom part of the spray body is covered by a stainless steel screen with openings of around 0.0118 in. in size. This prevents the clogging of nozzles should mineral build-up or rust scale off within the high-pressure water system. The nozzle body is inserted in a spray receptacle and locked in by inserting a staple similar to the ones used in staple-lock hydraulic fittings.

Figure 14 and table 1 show the flow characteristics of the nozzle versus the pressure.

Whenever the machine was operated for test purposes without the high-pressure pump engaged, the nozzles were replaced by conventional spray nozzles of the solid cone type. The outer shape of these nozzles is identical since they had to fit into the same receptacle. At about 300 psi,

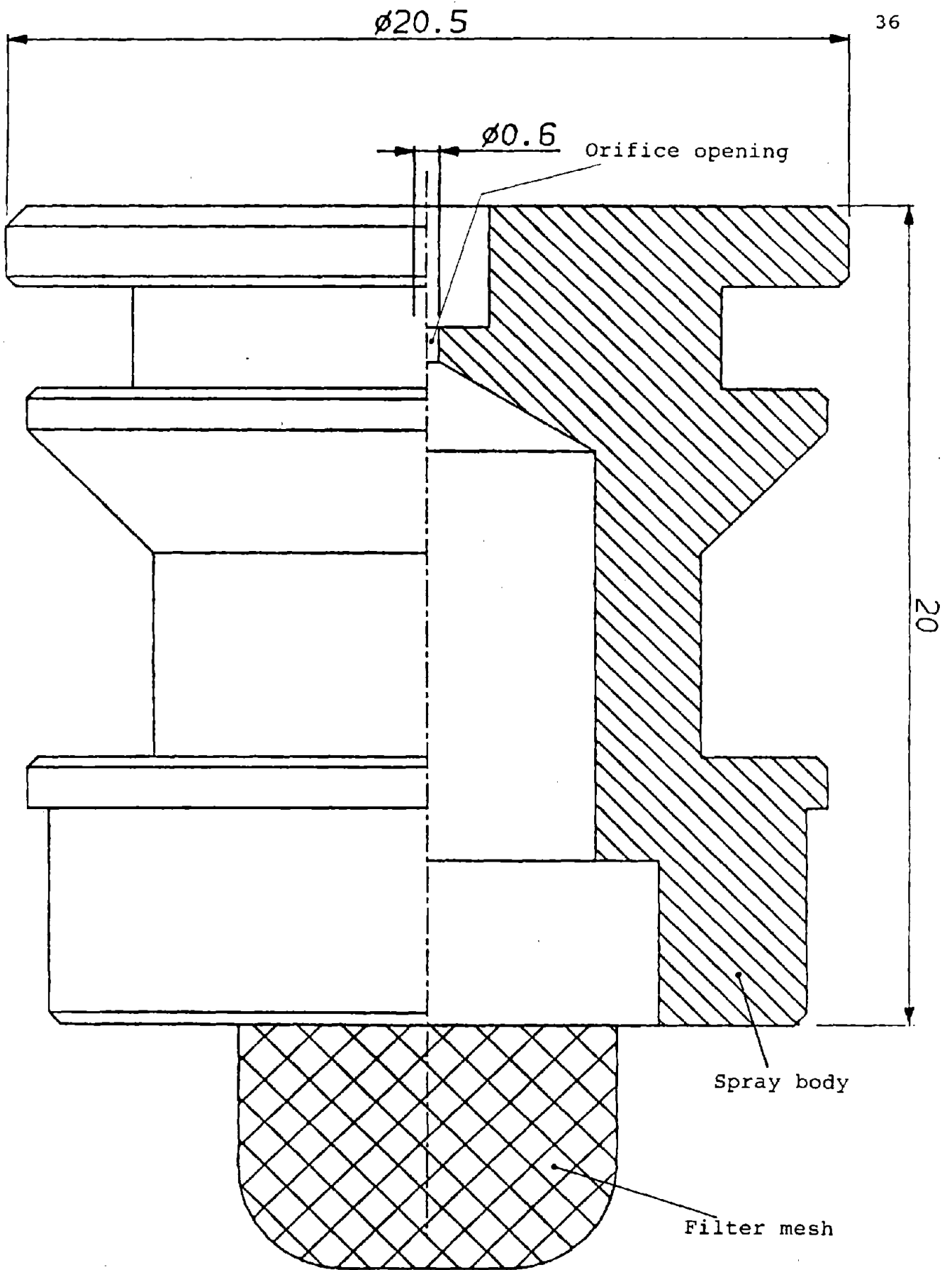


FIGURE 13. - Nozzle used during high-pressure water tests, cut-away view (all measurements are in mm)

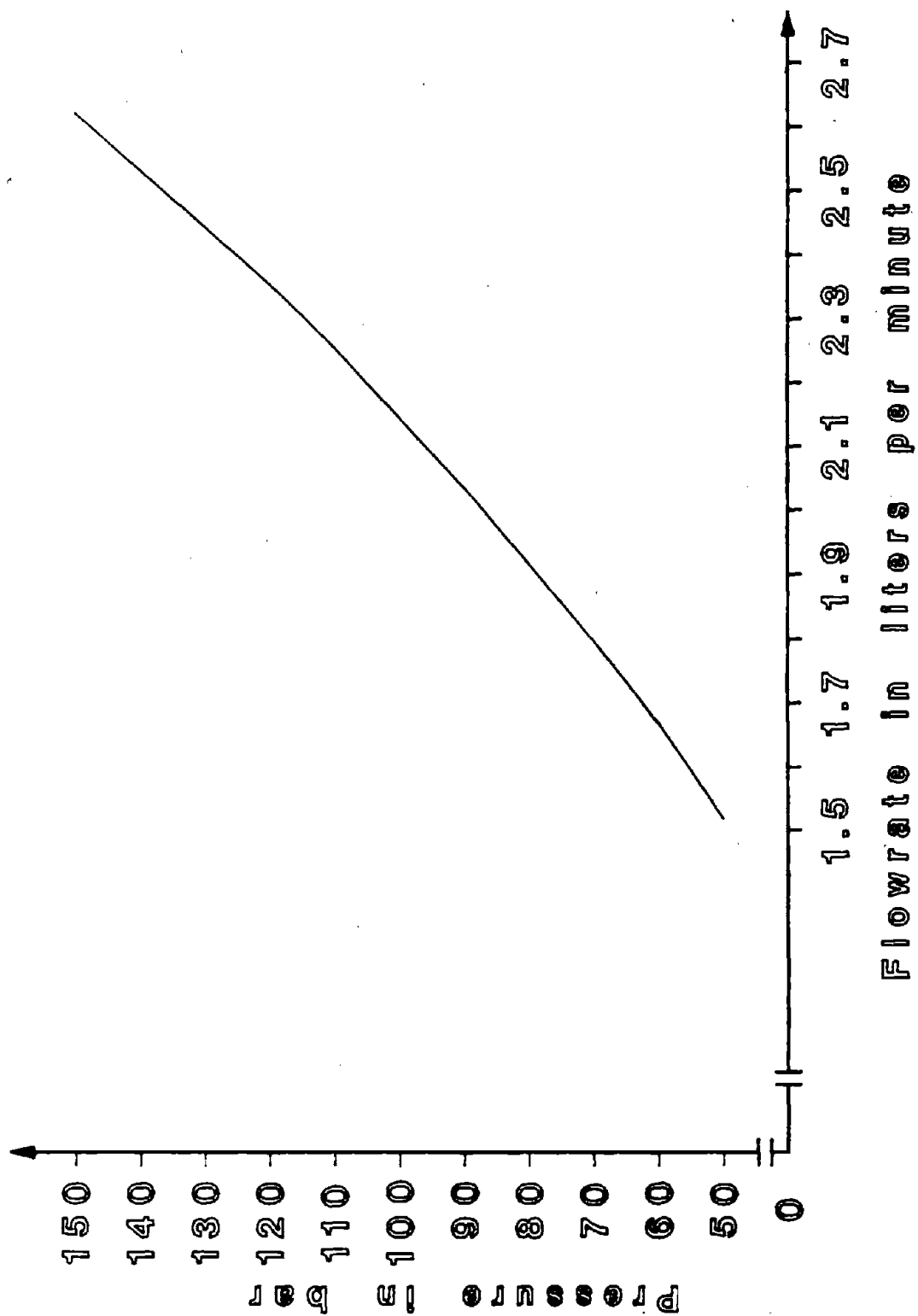


FIGURE 14. - Flow characteristics of nozzle versus pressure

TABLE 1. - Pressure and flow rate of  
water-jet-assist spray nozzle used  
during trials

psi	gpm
725	0.40
870	0.44
1015	0.48
1160	0.51
1305	0.54
1450	0.57
1595	0.60
1740	0.62
1885	0.65
2030	0.67
2175	0.69

the flow rate for this conventional nozzle amounted to approximately 1 gpm.

#### CUTTING BITS

The bits used throughout the trials were the conical, round-shank point-attack type. The length of the bit above the bit holder sleeve was 3 in. during the first trial and 4 in. during the second trial. The carbide tip had a diameter of about 5/8 in. The shank diameter amounted to about 1-3/8 in. To keep the bit securely in the bit holder sleeve, a loose and flexible springlock ring was located at the bottom end of the shank.

This type of bit was recommended by the drum manufacturer for the cutting conditions encountered at Kerr McGee.

Figure 15 shows the typical arrangement of bit, sleeve, and bit holder.

#### \*\*\* DUST SAMPLING

##### TEST PROCEDURE

In order to collect comparable sets of data, all test runs were made under conditions as similar as possible.

Each test consisted of measuring the cutter motor power consumption, the respirable dust levels, and the product fines while employing the low-pressure dust-suppression system and the high-pressure water-jet system. In addition, bits were removed from three locations on the drums after each completed test run in order to evaluate the effects of the water-jet-assist system on bit wear.

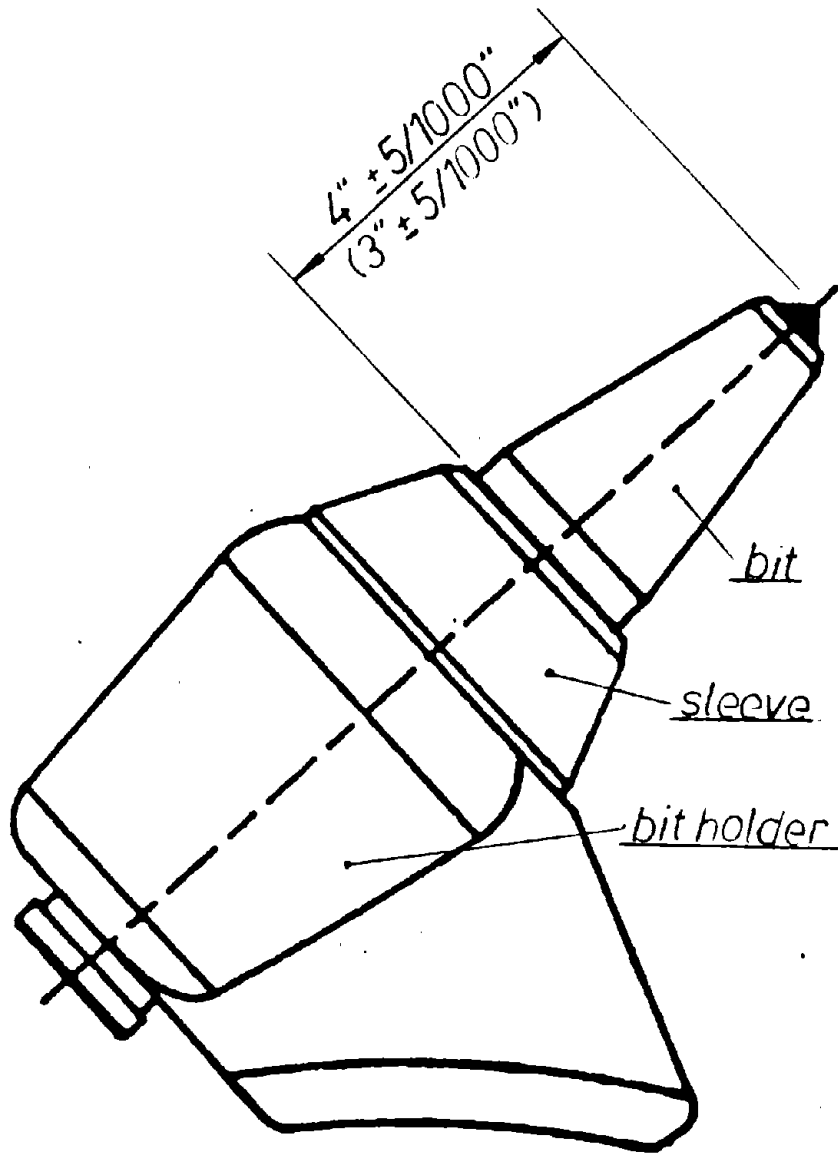


FIGURE 15. - Typical arrangement of bit, sleeve, and bit holder

### Location of Dust-Sampling Devices

To accurately measure the respirable dust concentration, standard personal sampling devices were used. The sampling devices were located in batches of four in three different locations. One batch was located at the headgate end of the machine, near the headgate operator. The second batch was mounted in the same way near the tailgate end of the machine in the area of the tailgate operator. In order to measure the dust level of the entire longwall, the third batch of sampling devices was located in the walkway near the taildrive. All sampling filter cassettes, which were furnished pre-weighed by the Bureau's Research Center in Pittsburgh, were actually mounted at eye-level height, on plastic tubes, cantilevered over the spillboard from the machine into the walkway while the vacuum pumps were stored in cardboard boxes on top of the machine.

### Test Runs

The data for each test condition were collected over four equal production passes. The parameters for each set of four production passes were:

#### 1st Shearer

- 1) 48 rpm drum speed, low water pressure with conventional solid-cone spray nozzles, 3-in.-gauge bits
- 2) 48 rpm drum speed, high-pressure water system engaged, 0.0236-in.-diameter nozzles installed, 3-in.-gauge bits

2nd Shearer

3) 34 rpm drum speed, low water pressure with conventional solid-cone spray nozzles, 4-in.-gauge bits

4) 34 rpm drum speed, high-pressure water system engaged, 0.0236-in.-diameter nozzles installed, 4-in.-gauge bits.

## EVALUATION OF DUST SAMPLES

Table 2 shows the results from the first two test runs, made with a drum speed of 48 rpm and the original phasing system design as seen in figure 11.

Table 3 shows the results from the second set of test runs, made with a drum speed of 34 rpm and the redesigned phasing system as seen in figure 12.

## \*\*\* MATERIAL SAMPLING AND SCREEN ANALYSES

## TEST PROCEDURE

During each test run a coal sample was collected. For this, the face conveyor was stopped for a short time and a vertical "slice" of the raw material was taken from the panline. Equal-size samples were taken for each test condition.

## EVALUATION OF MATERIAL SAMPLES

The coal samples were evaluated at the Bureau's research facility in Pittsburgh.

The screen analysis separated the material sample taken during the first shearer tests into six size classifications. The redesigned shearer samples were separated into seven size classifications by adding an even finer mesh to

TABLE 2. - Results from first two test runs,  
made with drum speed of 48 rpm and original  
phasing system design

Location	Conventional sprays 300 psi, 45 gpm mg/m <sup>3</sup>	Water-jet-assist 1450 psi, 26.6 gpm mg/m <sup>3</sup>	Reduction %
Headgate of machine	1.69	1.24	27
Tailgate of machine	5.67	4.11	28
Longwall tailgate	3.08	2.34	24

TABLE 3. - Results from second set of test runs,  
made with drum speed of 34 rpm and redesigned  
phasing system

Location	Conventional sprays 320 psi, 40 gpm mg/m <sup>3</sup>	Water-jet-assist 1450 psi, 22.8 gpm mg/m <sup>3</sup>	Reduction %
Headgate of machine	1.43	0.73	49
Tailgate of machine	2.41	1.16	52
Longwall tailgate	2.26	1.22	46

NOTE.--The differences in the flows and pressures shown in tables 2 and 3 are due to an increase in the mine's supply-line pressure and to the fact that the second drum had fewer sprays and a modified spray pattern.

the test. This allowed measurement of particle sizes below 1/1000 in.

Tables 4 and 5 show the results.

\*\*\* EVALUATION OF WEAR ON CUTTING BITS

Figures 16 to 19 show the 3-in.-gauge cutting bits taken off the drums after the low-pressure and the water-jet-assist test runs. These tests were conducted at a drum speed of 48 rpm with the original phasing system. Figures 20 to 23 show the 4-in.-gauge bits used during the second trial at a drum speed of 34 rpm using the redesigned phasing system after the low-pressure and the water-jet-assist test run. At the start of test, each bit was new and was used for only the four production passes comprising that test sequence. In order to create comparable conditions, the bits were always removed from the same bit holder -- one from the endring (E) of the drum, one from the center (C) of a vane, and one from the vane end or gobside (G) of the drum. According to the bit manufacturer, a "3-in.-gauge" bit measures 3 in. from the surface that rests on the sleeve to the tip of the carbide tip. The permissible deviation during the manufacturing process is  $\pm 5/1000$  in. (See figure 15.) The same applies to a 4-in.-gauge bit accordingly.

\*\*\* DISCUSSION

Longwall shearers with a water-jet-assist system have been tested under laboratory conditions and underground in two coal mines. The results showed that the water-jet system

TABLE 4. - Size distribution analysis for first shearer with drum speed of 48 rpm and original phasing system design

Mesh	Size, in.	Conventional sprays at 300 psi, g	High-pressure water-jet-assist at 1450 psi, g
+ 6	0.132 - 0.250	749.3	769.3
- 6 + 14	0.047 - 0.132	903.9	938.9
- 14 + 48	0.011 - 0.047	552.2	474.9
- 48 + 150	0.004 - 0.001	194.5	133.9
- 150 + 250	0.002 - 0.004	80.4	54.1
- 250	< 0.002	113.1	70.0
TOTAL		2593.4	2226.7

TABLE 5. - Size distribution analysis for second shearer with drum speed of 34 rpm and redesigned phasing system

Mesh	Size, in.	Conventional sprays at 320 psi, g	High-pressure water-jet-assist at 1450 psi, g
+ 6	0.132 - 0.250	1197.7	984.8
- 6 + 14	0.047 - 0.132	802.1	653.8
- 14 + 48	0.011 - 0.047	385.4	322.8
- 48 + 150	0.004 - 0.011	170.9	123.2
- 150 + 250	0.002 - 0.004	66.3	46.5
- 250 + 325	0.001 - 0.002	58.7	41.6
- 325	< 0.001	55.8	54.0
TOTAL		2736.9	2226.7

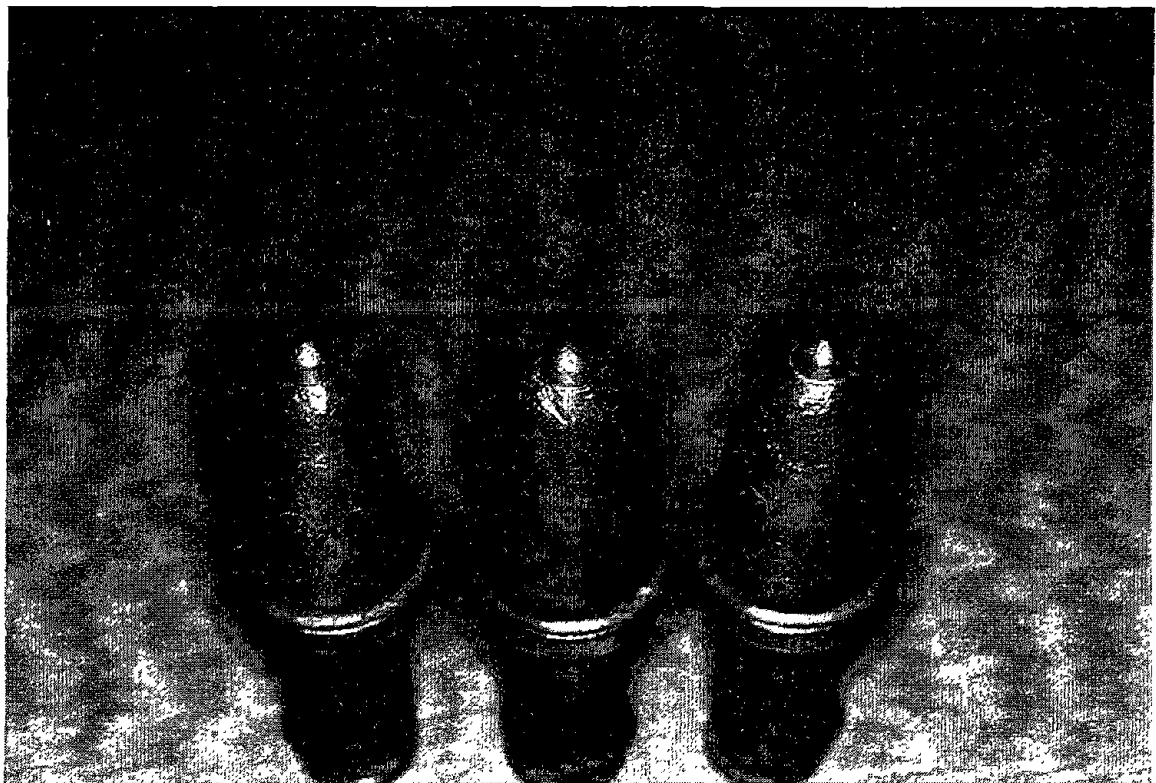
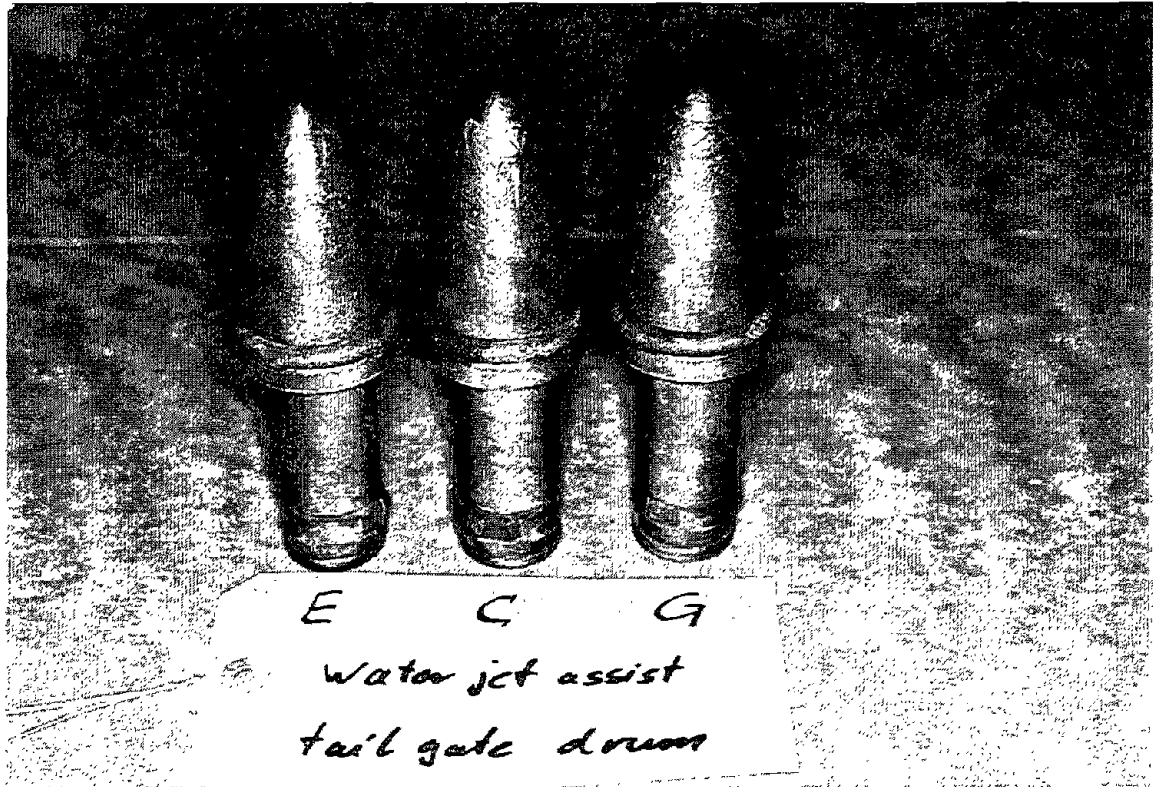


FIGURE 16. - Sample bits from tailgate drum after water-jet-assist cutting, 48 rpm: E: endring; C: center of drum; G: gobside

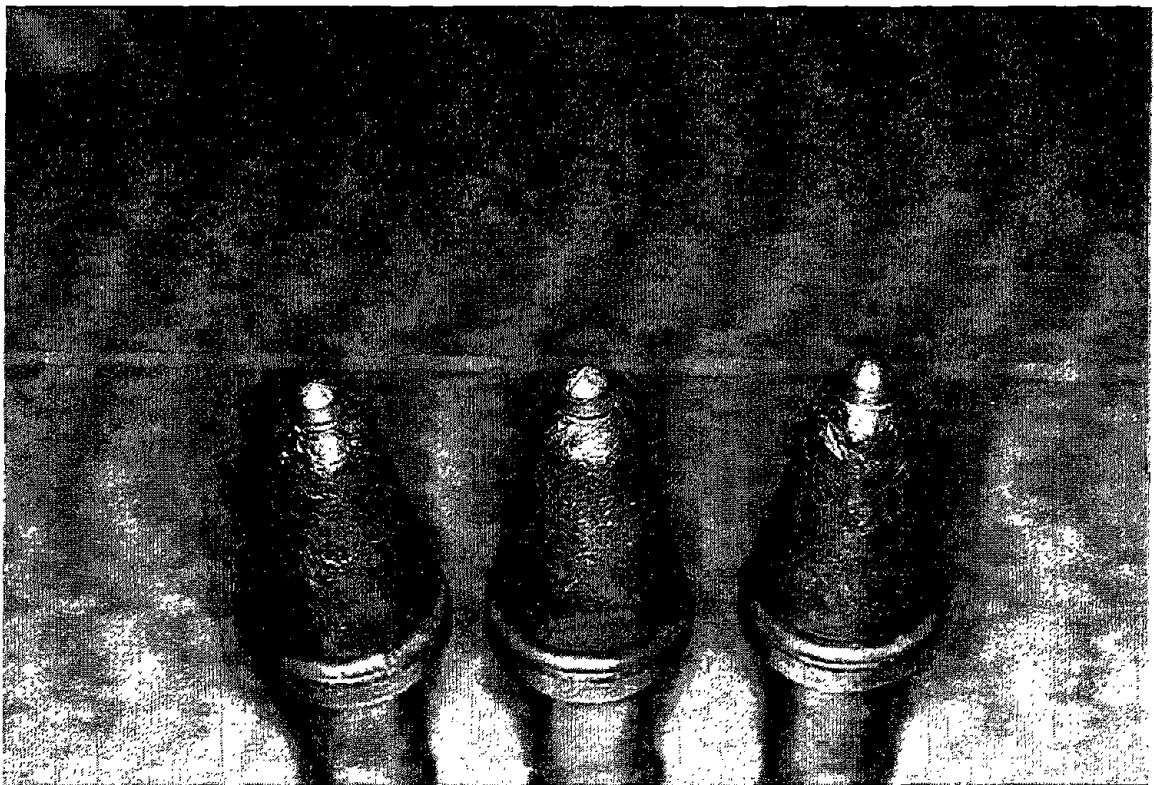
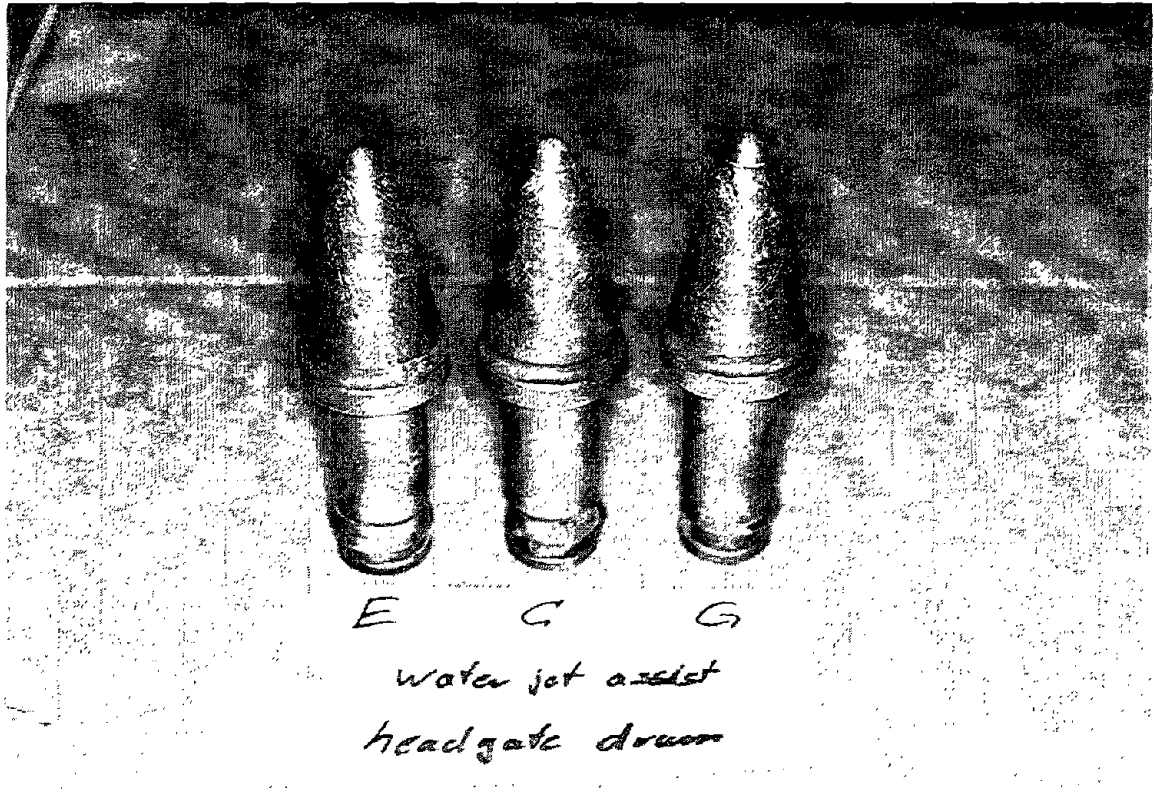


FIGURE 17. - Sample bits from headgate drum after water-jet-assist cutting, 48 rpm: E: endring; C: center of drum; G: gobside



FIGURE 18. - Sample bits from tailgate drum after low-pressure cutting, 48 rpm: E: endring; C: center of drum; G: gobside

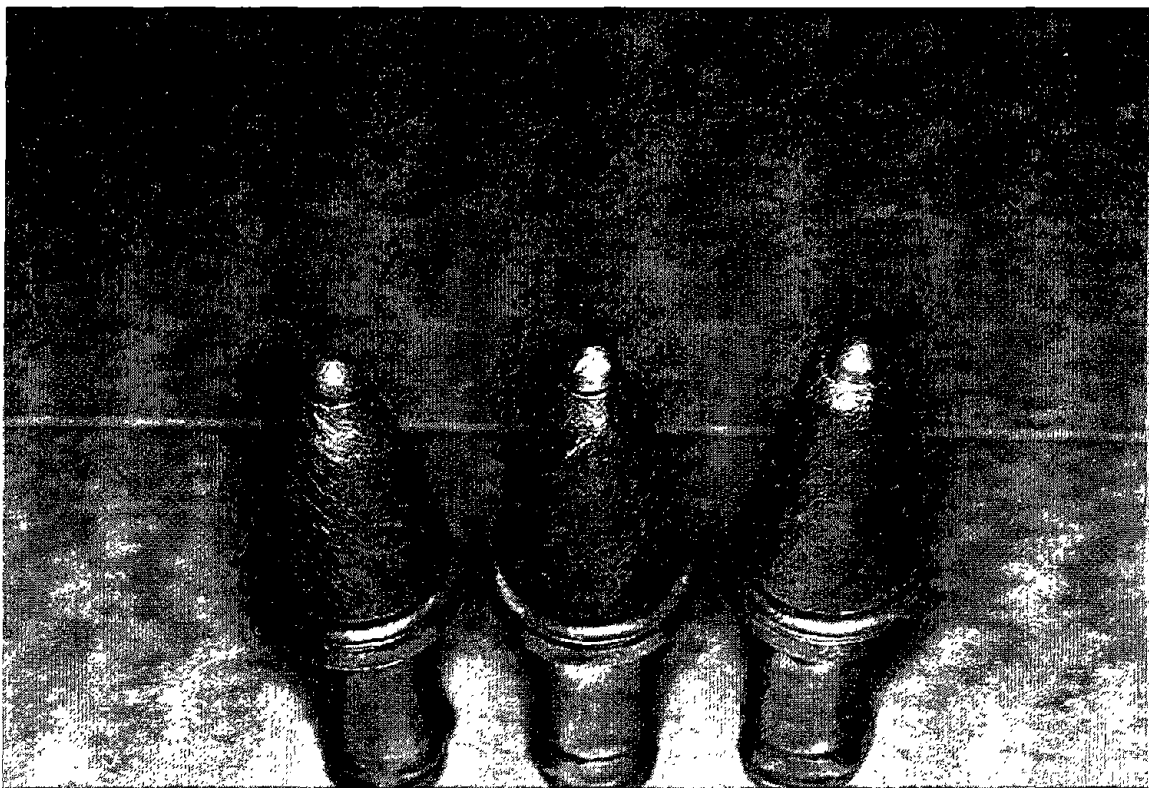


FIGURE 19. - Sample bits from headgate drum after low-pressure cutting, 48 rpm: E: endring; C: center of drum; G: gobside

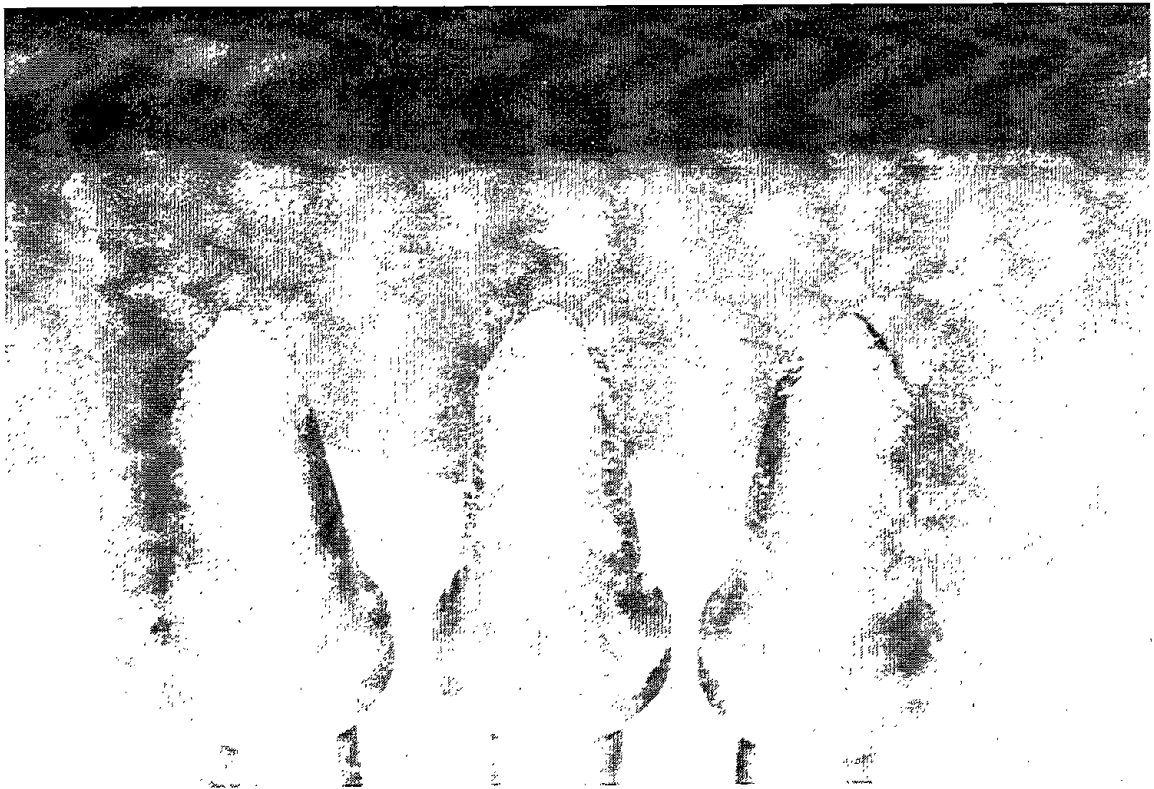


FIGURE 20. - Sample bits from tailgate drum after water-jet-assist cutting, 34 rpm: E: endring; C: center of drum; G: gobside

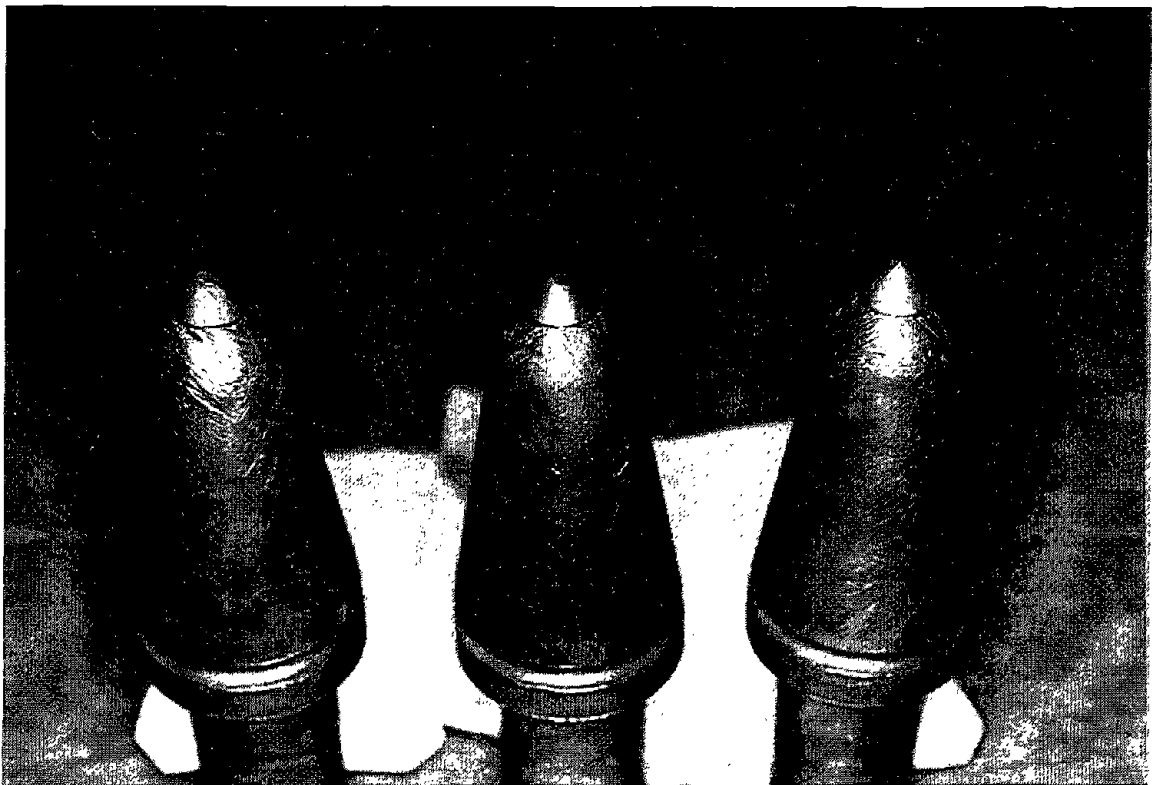


FIGURE 21. - Sample bits from headgate drum after water-jet-assist cutting, 34 rpm: E: endring; C: center of drum; G: gobside

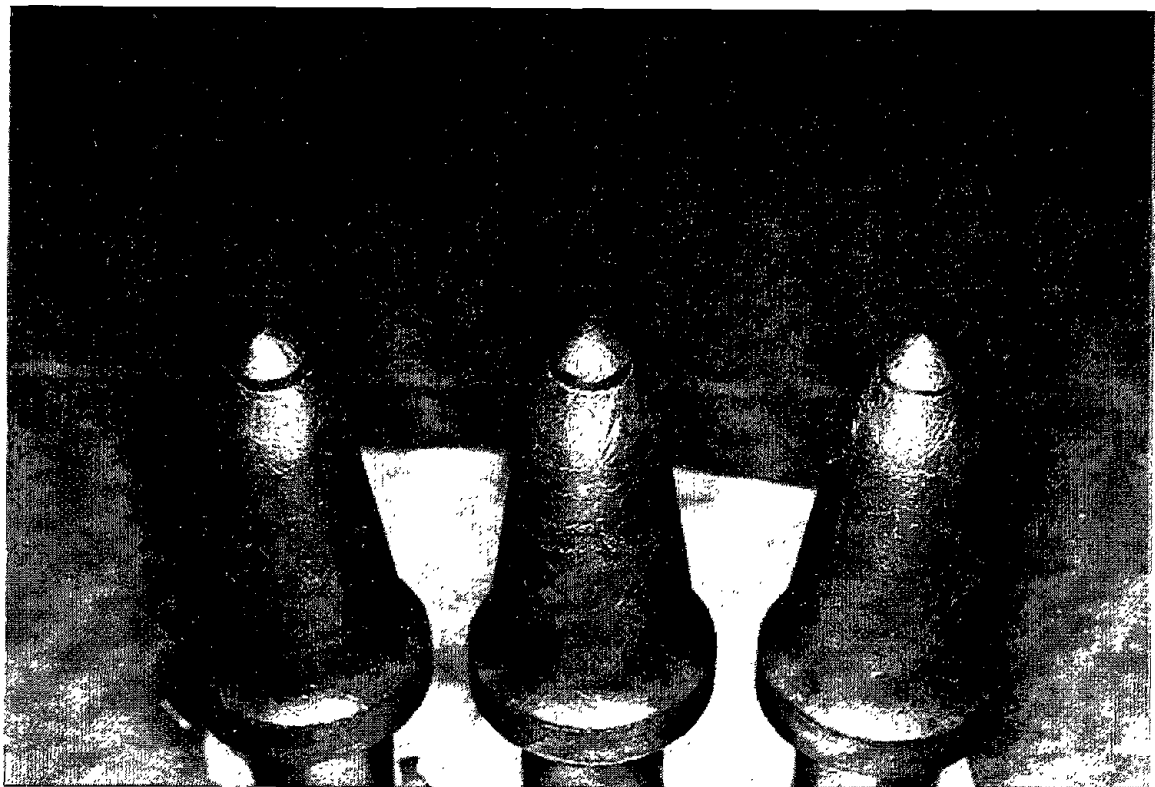


FIGURE 22. - Sample bits from tailgate drum after low-pressure cutting, 34 rpm: E: endring; C: center of drum; G: gobside

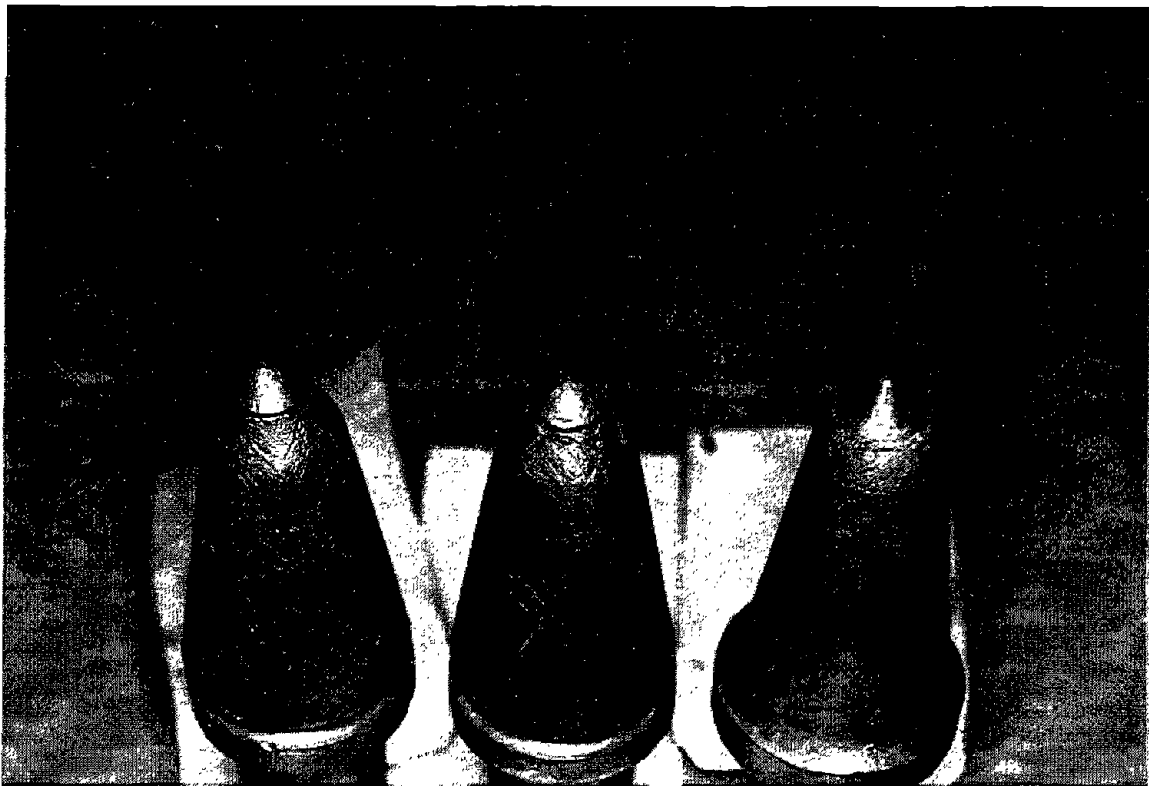
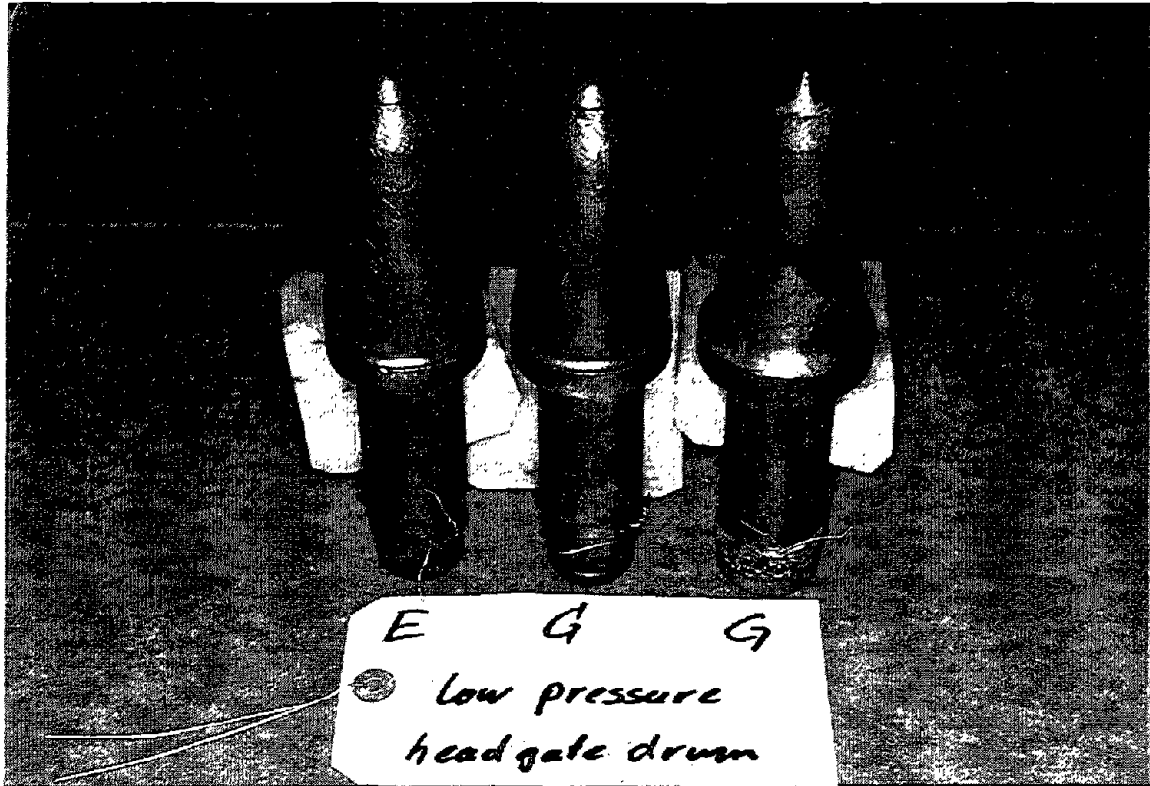


FIGURE 23. - Sample bits from headgate drum after low-pressure cutting, 34 rpm: E: endring; C: center of drum; G: gobside

did not reduce the machine's power consumption or increase its travelling speed as expected in the early stages of the research project. However, the impact of the high-pressure water-jet system on the reduction of the respirable dust levels was significant.

Comparing Tables 2 and 3 reveals two interesting findings: First, using the redesigned shearer in the second trial showed that the overall dust levels were lower no matter which dust-suppression system was used. Second, the reductions of the respirable dust levels reached with the redesigned shearer using the water-jet-assist system compared to the conventional system were about twice as high as with the first shearer. The high-pressure system on the first shearer reduced the dust levels by about 25%, whereas the second shearer achieved a reduction of 50%. The first finding can be attributed mainly to the changes made during the redesign of the shearer. These changes were a reduction in drum speed, a reduction in the number of cutting bits, an increase in bit size, and a modification in the phasing system and spray pattern. Furthermore, the change in the operational mode, cutting from the headgate towards the tailgate and not from the tailgate towards the headgate, helped.

The second finding, the dramatic performance improvement of the water-jet-assist system, must be credited solely to the redesigned phasing system. Avoiding the discharge of

high-velocity water jets into the open airflow, where they create turbulences and cause dust to roll over into the operator's area, and continuously spraying at the floor and roof with high-pressure water, was probably the biggest improving factor.

Comparing the figures in table 4, showing the results of the screen analysis for the original shearer, it can be seen that the amount of product fines below 1/4 in. in size was reduced by around 6% when the water-jet-assist system was utilized. The reduction increased to 22% for particles smaller than the 14-mesh size.

If the same comparison is made in table 5, showing the screen analysis of the redesigned shearer, the reduction in the same size class (fines under 1/4 in.) amounted to 18.5% with the water-jet-assist. However, it is assumed that the percent reduction in product fines reached by employing a water-jet-assist cutting system is dependent on the type of coal, the drum speed, and the type and location of the sprays.

One of the objectives of the research was to find out what impact the use of a high-pressure water-jet system would have on the bit wear. Comparing the data in table 6, showing the bit measurements of the original shearer, one can see that the bits are worn off 0.5 mm more if only the conventional spray system is being used. Unfortunately, all

TABLE 6. - Bit measurements for first shearer  
with drum speed of 48 rpm and original  
phasing system design

(Measurements in mm unless  
otherwise specified)

Water pressure: 300 psi		
LP TG gobside	:	broke
LP TG center	:	broke
LP TG endring	:	broke
		$\bar{x} = n/a$
LP HG gobside	:	77.0
LP HG center	:	76.5
LP HG endring	:	76.0
		$\bar{x} = 76.5$
Water pressure: 1450 psi		
HP TG gobside	:	77.0
HP TG center	:	77.0
HP TG endring	:	77.0
		$\bar{x} = 77.0$
HP HG gobside	:	77.5
HP HG center	:	77.0
HP HG endring	:	76.5
		$\bar{x} = 77.0$

HP High-pressure water-jet-assist test.

HG Headgate drum.

LP Low-pressure test.

TG Tailgate drum.

three test bits of the tailgate drum broke off during the low-pressure run, so a direct comparison is not possible.

The data in table 7 show a similar result. Considering that the bit taken from the gobside of the headgate drum after the low-pressure run still measured 102 mm and therefore had to be an outlier, the effect of the high-pressure water system can be clearly seen. If this bit is eliminated from the calculation of the average length,  $\bar{x}$  would amount to 99.5 mm. The bits all show between 0.6% and 0.8% less wear after only four production passes if the high-pressure water-jet system was used.

During the trial periods, many smaller problems with the high-pressure water-jet system occurred, of which most could be solved underground. The single biggest problem, however, was the failure of the three-piston plunger pump. This failure occurred mainly due to a mismatch of the output quantity of the pump and the much lower water consumption of the system. This constant recirculation of water put unnecessary strain on the pump and other vital components and caused them to fail. To operate future water-jet-assisted shearer loaders underground, a much more reliable and less complex water system is needed.

### \*\*\* CONCLUSION

The results of the described research project show that the application of high-pressure water jets definitely reduces the level of respirable dust in longwall mining and

TABLE 7. - Bit measurements for second shearer  
with drum speed of 34 rpm and redesigned  
phasing system

(Measurements in mm unless  
otherwise specified)

Water pressure: 320 psi		
LP TG gobside	: 100.0	
LP TG center	: 99.0	$\bar{x} = 99.33$
LP TG endring	: 99.0	
LP HG gobside	: (102.0)	$(\bar{x} = 100.33)$
LP HG center	: 99.0	$\bar{x} = 99.5$
LP HG endring	: 100.0	
Water pressure: 1450 psi		
HP TG gobside	: 100.5	
HP TG center	: 99.5	$\bar{x} = 100.0$
HP TG endring	: 100.0	
HP HG gobside	: 100.5	
HP HG center	: 100.5	$\bar{x} = 100.33$
HP HG endring	: 100.0	

HP High-pressure water-jet-assist test.

HG Headgate drum.

LP Low-pressure test.

TG Tailgate drum.

also causes a coarser distribution of cuttings.

Even though there is an encouraging trend visible, not enough data was collected to determine whether or not the application of high-pressure water jets does reduce the bit wear. Further research in this area is required.

