DESIGN, DEVELOPMENT AND DEMONSTRATION OF A TECHNIQUE TO WATER-FLUSH THE BITS ON A FIXED DRUM CONTINUOUS MINING MACHINE

(BCR Report L-747)

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UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

By

BITUMINOUS COAL RESEARCH, INC.
350 Hochberg Road
Monroeville, Pennsylvania 15146

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7. Author(s)
John A. Kost, Felix du Breuil, and Robert D. Saltsman

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Bituminous Coal Research, Inc.
350 Hochberg Road
Monroeville, PA 15146

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16. Abstracts Control of the dust produced by continuous-mining machines in coal mines is conventionally attained by water sprays from fixed nozzles mounted on the frame of the machine behind the cutting head. In the tests conducted under this contract a so-called "wet-head" machine was used, where the spray nozzles were mounted on the rotating head itself, close to the coal-cutting bits. The tests were conducted at the Robena mine of U.S. Steel Corp., using Lee-Norse machines. Operating the wet-head machine and a conventional spray machine in turns in the same section, the wet-head produced approximately 25 pct less respirable dust and 60 pct less total airborne dust than the conventional spray machine. The wet-head also greatly improved the visibility of the cutting bits from the machine operator's position. Several difficulties had to be overcome before meaningful tests could be conducted, including excessive pressure drops in the piping system and plugging of the nozzles from internal water contamination. The major obstacle, however, was the rotating water seals on the wet-head, which leaked excessively after only a few hours of operation. Only after several changes and plant and laboratory tests was a design found which permitted conducting the underground tests without appreciable water leakage.

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FOREWORD

This report was prepared by Bituminous Coal Research, Inc., Monroeville, Pennsylvania, under USBM Contract No. H0210050. The contract was initiated under the Coal Mine Health and Safety Program. It was administered under the direction of Twin Cities Mining Research Center, with Mr. Kelly Strebig acting as the Technical Project Officer. Mr. David J. Askin was the contract administrator for the Bureau of Mines.

This report is a summary of the work completed as part of this contract during the period June 18, 1971 to February 1976, and was submitted by the authors in March 1976.

Revisions suggested by the Technical Project Officer were completed in July 1976.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

Preceding page blank

LIST OF FIGURES (Continued)

BITUMINOUS COAL RESEARCH, INC.
SPONSORED RESEARCH PROGRAM

DESIGN, DEVELOPMENT AND DEMONSTRATION
OF A TECHNIQUE TO WATER-FLUSH THE BITS
ON A FIXED DRUM CONTINUOUS MINING MACHINE
(BCR L-747)

I. INTRODUCTION

On June 18, 1971 Contract No. H0210050 was awarded to Bituminous Coal Research, Inc., (BCR) by the U.S. Department of the Interior, Bureau of Mines, for the following purpose: "design, develop, and demonstrate a technique to water-flush all the bits on a fixed-drum continuous mining machine and determine how much respirable dust generation can be reduced using this technique as compared to continuous mining machines using only boom-mounted sprays." (Sec. 1.2)

The technique referred to here is that first advanced by the British to control the dust generated by the shearer drum on longwall faces. Instead of spraying water at the face and on the drum from fixed nozzles mounted on the main body of the machine, the water is piped to the drum itself through a rotary seal and distributed around the drum surface to each of the cutting bits. The technique is now widely used in British coal mines, where shearers are the most common machines for coal extraction, and several manufacturers of shearers provide "wet" drums as a standard option.

In the United States the Eickhoff shearers, in use in a number of mines, are provided with water nozzles right on the drum. BCR, under USBM Contract H0230031, has just completed an evaluation of dust control at a longwall face using various nozzle configurations on the drum of an Eickhoff machine.

In the case of a continuous mining machine, dust generation is normally controlled by water sprays from fixed nozzles mounted on the machine boom directly behind the rotary cutting elements. These sprays, in fact, do three things: they wet the coal face above the machine head; they wet the coal which has been cut below the head, and they wet the bits themselves as these complete their rotation out of the coal and up past the nozzles. Additional sprays are located at the sides of the machine and along the path of the coal as it is loaded and carried back on the machine conveyor. Applying the flushed-bit principle to the continuous mining machine replaces the fixed nozzles behind the cutting head by nozzles mounted right on the cutting head and in the vicinity of each bit. Thus, rather than wetting the coal face before it is cut, then wetting the broken coal after it has been cut, the water is continuously applied to the bit and its vicinity while it is cutting. Hopefully this wets and catches the dust as it is generated and before it is airborne, thus reducing the dust concentration around the machine.

Introducing water to the cutting head is more difficult to accomplish in a continuous mining machine than in a shearer. In the first place, the head is considerably wider, perhaps ten feet versus two, made up of two or three or four separate elements. It requires more water, and more water seals, thus increasing the chance of failure. Second, while one end of the cutting drum of a shearer is always in the open, providing a free end to both support and power the drum, and introduce the water, the problem is much more complex for the rotating head of a continuous miner, which has to cut at both ends as well as along its full width.

In the contract awarded to BCR, the Bureau limited the investigation to the so-called "fixed-drum" (non-oscillating) continuous mining machine which has become popular in recent years. In these machines the cutters or cutting wheels or drums are generally lined up on a common shaft perpendicular to the axis of the machine, and, except for elevation of the boom, in a fixed position relative to the body of the machine. Prior to the fixed-drum or solid-head machine, oscillating-head machines had been built by the Lee-Norse Co. with water piped into the cutting wheels. There were mechanical problems, and the effectiveness of the sprays was never clearly established.

As proposed in the contract, the first objective was to design a cutting head with piped-in water, referred to as a "wet" head, or more specifically, to obtain from each manufacturer of a fixed-drum machine a design of a wet-head which would fit his own machine. In fact, each major manufacturer had already designed and built some kind of wet-head, or partial wet-head. Unfortunately, only a few had actually been put in operation, and because of early failure, no evaluation of their effectiveness had been made. These designs were reviewed with the manufacturers and modified to suit the objectives of the contract. In Section III of this report these designs are compared; in addition, the basis for the selection of the Lee-Norse machine for actual underground tests, and of the Robena mine for the site of the tests, is detailed. At the time the selection was made it was recognized that the different manufacturers' machines were not identical machines, and that all wet-head designs proposed had good points as well as weaknesses. Hence, it was recommended to the Bureau that each machine be eventually evaluated in actual mine operation.

Subsequently, the Bureau awarded contracts for underground evaluation of the wet-head concept as applied to the Joy and Jeffrey machines. Final reports on these projects are available from NTIS, identified as follows:

"Effectiveness of respirable dust control by water through the drum on an 11CM Joy continuous miner." Report on Contract H0232061, May 1974, U.S. Comm. NTIS PB 236-652/AS

"Respirable dust control on a Jeffrey 120 M HELIMINER by water piped through the head." Report on Contract H0232060, August 19, 1974, U.S. Comm. NTIS PB 236-584/AS

Section IV of the report deals with the specifications of both the test machine and the conventional machine to which it was to be compared at Robena Mine of U.S. Steel Corporation. It also covers the first underground trials, August and September 1972, and the initial experience with the Lee-Norse wet-head machine. After only one shift of operation, major difficulty was encountered with plugging of the head nozzles. There was also some indication of possible seal leakage.

With a filter at the machine inlet and vinyl-coated water passageways to prevent corrosion, the only expected nozzle plugging of concern had been that from coal particles being pushed into the nozzles. As it turned out, this was an optimistic expectation for nozzles with only a 1/32-inch orifice. No system can be perfectly clean, and it takes very little to plug a small orifice. Furthermore, the coating did not hold well; it flaked off and contributed to the plugging. Several restrictions along the water passageways caused further plugging problems, along with excessive pressure drops which resulted in too low a pressure at the nozzle itself.

The head of the machine had to be returned to the factory. The corrective measures taken are covered at the end of Section IV.

In Section V the series of underground tests which took place in January and February 1973 is described. The quantity of water and pressure available at each nozzle were no longer a problem in these tests. However, the small 1/32-inch orifices still plugged because the small strainers added to each spray did not have enough area for the quantity of dirt carried by the water in the first hours of operation. Thorough clean-up had been planned, but local conditions did not permit it. Therefore, use of the small nozzles at the base of the bits was abandoned and the alternate larger nozzles with integral strainers were used. This eliminated the plugging problem. What became a problem then was the water seals, one or the other of which would leak intermittently. Because of eventual seal failure, operation of the wet-head test machine was discontinued after 28 shifts.

The conventional machine to which the wet-head machine was to be compared turned out to be a new wet-head machine itself, although with only about half as many nozzles on the head as the test machine. This machine was operated wet for 9 shifts, until its seals failed, too; thereafter, 13 shifts were sampled using only the fixed sprays on the front of the boom.

At the conclusion of this series of tests it was agreed that it would be futile to attempt to continue any further wet-head tests until a more satisfactory seal could be found. The head was returned to the Lee-Norse plant, and a test rig was set up so that other seal materials and shapes could be roughly compared to the unsatisfactory seal rings used so far.

In the same period BCR was awarded Bureau Contract No. H0232055 for the specific purpose of studying seals which would be satisfactory for wet-head application. These seal tests are reviewed in Section VI of this report.

As a result of this effort a seal was found which, at least under laboratory conditions, had several times the life of any other seal tested. In February 1975 a set of this type of seals was ordered with appropriate seal holders; and arrangements were made to reassemble the head of the test machine. In August 1975 the head had been completed and tested at the plant and was shipped to Robena mine. The last series of underground tests was conducted during October and November 1975 and is the subject of Section VII of this report.

The new type of rotary seal lasted through the whole series of tests with no significant water leakage. Since completion of the tests, the machine has been left in operation. One of the seals failed two weeks later. A second one failed four weeks after the first. These two failures forced discontinuance of the water feed to three of the four cutters. The seal set for the last cutter head finally failed 15 weeks after the end of the dust sampling tests.

The Summary and Recommendations Section which follows immediately highlights the main findings of this investigation.

II. SUMMARY AND RECOMMENDATIONS

The evidence clearly indicates that a wet-head fixed-drum continuous mining machine achieves better dust control than a similar machine equipped only with the conventional boom-mounted sprays. The fall, 1975, series of underground tests with a Lee-Norse HH-105 indicates a reduction in respirable dust of some 25 percent and a reduction in total airborne dust of 60 to 70 percent. It is likely that these figures could yet be increased by an optimization of the location and type of nozzles on the head in order to wet all the cutting bits.

One of the first principles for good dust abatement is to wet the coal adequately immediately at the face to prevent further generation of airborne dust at every transfer point; i.e., up the conveyor on the mining machine itself, into the shuttle car, out of the shuttle car, etc. However, one cannot tolerate "free" water at the face because it may soften the bottom and make it untrackable for the mining equipment, as well as creating a very uncomfortable working environment. This is often what limits the conventional fixed-spray systems. On the other hand, a wet-head machine very efficiently mixes water with the coal as it is mined so that one can effectively add larger amounts of water than one can with fixed sprays without creating a wet working place. This advantage by itself can be a sufficient justification for use of a wet-head machine.

A very important secondary benefit of the wet-head system is the improvement in visibility. Because the operator can clearly see the head, he can operate his machine more efficiently and safely. Furthermore, because of this visibility advantage, he will keep the wet-head sprays on at all times, unlike the fogging type of spray tried on some machines, which the operator has to turn off once in a while if he wants to find out where he is going. It should also be pointed out that no water is sprayed back onto the operator, as had been feared at one time.

It had been said that nozzles on a rotating cutting head were not practical because they would soon become plugged with coal. This is not the case at all. Functioning nozzles on the head stay open; and, because they are close to the bits, enough water washes the bits themselves to keep them free to rotate in their holders and thus avoid destructive wear of the tips on one side only.

There is, of course, wear and tear on the nozzle body, and a recessed protected mounting of the nozzles is necessary. However, there is no more, and possibly less, wear than there is on fixed nozzles mounted on the boom below the cutting head. Because of this high wear rate, and because it is difficult to replace nozzles under the boom (without mentioning the safety hazard if proper precautions are not taken), it is common to find machines with conventional fixed sprays operating without these bottom sprays. This is unfortunate because it has been found in some Bureau studies that bottom sprays are more effective than top sprays to abate the dust. There is no similar problem with the wet-head. All nozzles are equally effective and they can easily be checked and replaced if necessary whenever the cutting bits are checked and replaced. Proper maintenance is thus not a difficult task and is likely to be performed as needed.

As with any other sprays, head sprays cannot be effective without a proper water supply. Unfortunately, this is a sadly neglected area in many mine sections. Available water pressure is sometimes too low, but generally the failing is more a lack of sufficient cross section--pipe size, hose size, fitting size are all too small, both in the supply to the machine and on the machine itself. Even if sizes were adequate when equipment was new, smaller sizes are often substituted when repairs are made. The trailing hose in particular, due to its length, will contribute a large pressure drop if too small. As a very minimum, 25 gpm should be available to any machine, and a 1-1/4-inch ID hose provided. The manufacturers should have equivalent hoses and passageways on the machines to allow the same flow to the nozzles with no more than 20 or 30 psi pressure drop.

As important as proper hose and pipe sizes is proper filtration of the water. Although, as pointed out earlier, there is no plugging of nozzles from material being forced in from the outside, it takes only a few small particles in the water to plug the orifice of a nozzle. Even if the mine water supply is clean and filtered, there is always some scale from the pipe walls and there is dirt every time a pipeline is extended or a hose repaired. Cartridge filters of 100-mesh size were found adequate in this project, both in the section at the feed end of the trailing hose and on the machine itself. If the quantity of solids in the water is high, a cyclone-type solid remover such as the Krebs "desander" should be used to avoid frequent changing of the filter cartridge (see USBM Technology News No. 20, January 1976). Finally, a back-up strainer behind each nozzle is a must, because even with a good filter on the machine, some scale can be picked up between it and the nozzles, some repairs on the water system are inevitable, and some dirt will even be introduced when changing the filter. These back-up strainers will seldom need cleaning if the main filters are checked regularly, but it should not be concluded from this that they are not necessary. They are absolutely essential.

The advantages of the wet-head appear sufficient to recommend to the manufacturers development work on the one single item which up to now has prevented continued use of wet-head machines, namely, the rotating water seal. After much effort a seal was designed and built under this contract and Contract H0232055 which permitted the completion of the underground tests planned, but its longevity is still far from sufficient for a machine in regular production. Retrofitting present machines may be too ambitious a goal. But certainly new heads should be designed by manufacturers with the water seal in mind from the beginning, so that a suitable location may be found to keep seal surface velocity low, to make seal replacement easy, and to make sure that no other machine parts would be damaged in case of seal failure. Such a design effort, in conjunction with proper selection of water-compatible seal elements, should make possible dependable wet-head systems.

A wet-head cannot be considered the one answer which alone will resolve all dust problems. It has been stated by others that when it comes to dust, it is necessary to apply simultaneously more than one control method. No perfect solution exists. Although improvements come slowly, a bad dust situation can develop very quickly. Changing natural conditions, sloppiness in maintaining the established dust-control plan, decreasing efficiency of the water supply as supply lines lengthen, changes in equipment or operating procedures--all can be causes. One needs several lines of defense. The wet-head is one. Others should be pursued at the same time, such as feasibility of using fewer bits, lower bit-tip velocity, faster penetration, water infusion of the seam, or machine-mounted scrubbers. Any method has some drawbacks, and developing a wet-head with practical seals does not appear to be a more insurmountable problem than solving the problems presented by any of the other dust control methods.

Typical values obtained during the underground tests of October-November 1975 are shown in Table 1. These tests are discussed in detail in Section VII.

TABLE 1. EVALUATION OF WET-HEAD CONTINUOUS MINING MACHINE: AVERAGE DATA FROM UNDERGROUND FIELD TESTS

	Conventional Spray System	Wet-head (1-inch Nozzles)
No. of shifts	6	11
Average production, tons	299	315
Average spray water flow, gpm	25.2	24.2
Average airflow*, cfm	13,300	12,700
Average dust weight*, mg		
respirable, MRE	2.50	1.98
respirable, personal	1.02	0.68
total airborne	45	20
Dust reduction, percent		
respirable, MRE	--	21
respirable, personal	--	33
total airborne	--	55

* Average dust weight of samples located in return air behind line brattice, average airflow at same location.

III. SELECTION OF CONTINUOUS MINING MACHINE TO BE USED IN FIELD TESTS

Designs for wet-head continuous mining machines of the fixed-drum type were obtained from four manufacturers: National Mine Service Co., Jeffrey Mining Machinery Co., Joy Manufacturing Co., and Lee-Norse Co. The models and main characteristics of the machines proposed are listed in Table 2.

It may be noted that all designs except the Lee-Norse machine used one or two cutting chains to cut clearance for the gear cases. All the machines proposed except the Jeffrey machine had cutting drums retractable by 12 inches to reduce the width while tramming. Jeffrey proposed a model with fixed head width for this research program, to eliminate the mechanical problem of piping water to movable end drums.

None of the proposed designs achieved spraying all the bits on the head: water cannot be piped through the cutting chains, and Lee-Norse did not attempt to pipe the retractable cutter discs at both ends of the head.

A. Criteria Used in the Selection of a Machine for Research Program

The following criteria for selection were discussed in Technical Letter Report No. 5 (BCR L-438) dated November 26, 1971, and are reproduced here for simplicity of reference:

> It may be appropriate to restate that the basis for selection of a machine or a design for this research program is not exactly the same as the basis which would be used to select a production machine. The purpose of the research program is to compare the control of airborne dust with a wet-head machine to that of a machine with a conventional type of fixed spray. It is not the purpose of the program to compare, say, the different means used to bring the water to each bit of the rotating head. As long as water is available at the bits long enough for meaningful dust measurements to be made, it does not initially matter if the means used are somewhat impractical or expensive.
>
> If the research program proves that dust suppression is greatly improved by a wet-head system, further research should find ways to do this on a commercial, reliable basis. A step in this direction, for instance, would be an in-plant durability testing of the kinds of water seals which could be used; but it is hardly worth spending large efforts in that direction before knowing if the wet-head principle is sound.
>
> The following areas were particularly evaluated in making the selection:
>
> 1. Cutting bits flushed:
>
> In view of the difficulty of making airborne dust surveys, and since dust in a section is created at other sources than

TABLE 2. SPECIFICATIONS OF CONTINUOUS MINING MACHINES PROPOSED FOR WET-HEAD TESTS

	Model Proposed	Maximum Cutting Height	Maximum Cutting Width	Retracted Head Width	Tram Height	Tram Width	Approximate Cutting Chain(s), Width	Approximate Percent Width of Head with Water Sprays	Cutting Drum Speed, RPM	Drum Diameter at Bit Tips	Bit Tip Velocity, FPM
National Mine Service	3080 Drum Miner	8' - 0"	11' - 0"	10' - 0"	30"	10' - 6" (Loading Boom)	2 Chains, 13" each	80 Percent No Sprays on Chain Bits	83.5	30"	655
Jeffrey	120 H Heliminer	8' - 6"	10' - 10"	Non-Retractable	46"	10' - 10" (Cutting Head)	2 Chains, 9-1/2" each 9-1/2" apart	78 Percent No Sprays on Chain Bits or Between Chains	81 60	36-3/4"	780 575
Joy	11 CM	7' - 6"	10' - 10"	9' - 10"	33"	10' - 2" (Cutter Boom)	30"	77 Percent No Sprays on Chain Bits	70 Approximate	32-3/4"	595 Approximate
Lee-Norse	HH 115* Hard Head	11' - 8"	9' - 8"	8' - 8"	49"	9' - 0" (Loading Boom)	None	85 Percent No Sprays on Retractable End Cutter Discs	58 Approximate	38"	575

* Other Models Available

the cutting head of the continuous mining machine, it is preferable to have the largest possible difference between the "wet" and "conventional" heads to be compared. In other words, as many bits of the wet-head as possible should be wetted. A head which incorporates a chain is at a disadvantage since it does not appear possible to individually spray the bits of the chain. It is also difficult to wet some bits on the extensions at both ends of the cutting drums. None of the machines proposed could offer 100 percent flushing of the bits. (See Table 2.)

2. Other sources of dust in addition to cutting bits:

As stated above, in order to observe differences in airborne dust created by the cutting head, it is of advantage to keep the other sources of dust at a minimum. Aside from the bits it carries, the cutting chain(s) itself might be a source of dust. Thus, a "chainless" head is an advantage (again for the proposed test, but not necessarily as an efficient coal production machine). The only "chainless" machine proposed is the Lee-Norse.

Another source of dust is the loading process: testing wet-head cutting vs. conventional-head cutting should give clearer results in a hard-to-cut seam than in a very friable one where the machine does more loading than cutting. For example, Pittsburgh seam should be preferred to a Pocahontas seam.

3. Availability and characteristics of "control" machine:

Since it is planned to compare wet-head and conventional-head by operating alternately in the same section two machines, one with a wet-head and the other with a conventional one, it is of course desirable that the two machines be as much identical as possible. Thus all factors besides the head should remain constant regardless of which one of the two machines is used. One important factor may be the manner in which the operator handles the machine: this is another reason for using identical machines. Identical machines would also facilitate the task of the section crew and maintenance personnel, an important point since the tests are to be performed in an otherwise normal production section.

It is also important that the control machine be fitted with a reasonably efficient set of conventional sprays, capable in particular of handling the same amount of water as the wet-head. If any improvement in dust control is found with the wet-head, it has to be clearly due to the wet-head principle. No suspicion should exist that perhaps, if the control had been better, no improvement would have been shown.

4. Phasing of the head sprays:

Phasing, i.e., feeding water to the cutting head nozzles only when they are spraying the coal face (wetting the bits only when they are cutting coal), has obvious operational advantages. However, it presents mechanical problems, so the immediate question is whether the disadvantages of not phasing are such that the concept of the wet-head could not be proven without phasing. These disadvantages are: (a) the machine operator will not keep the head sprays on if they get him wet or hinder too much his view of the face, (b) excess water running back under the machine may soften the bottom and render tramming impossible, (c) enough water may not be available at the section to allow for some to be wasted, (d) not phasing means larger pumps and bigger piping or larger pressure drops, since more water has to be pumped to the head than is effectively used: this difficulty has to be weighed against that of phasing.

Only the National Mine Service proposals include phasing.

5. Rotary water seals:

A desirable seal would be of small diameter, have a low face velocity, stand several hundred pounds pressure, not be damaged if run dry, be capable of resisting the corrosive water available, and be easy to replace in case of damage. Further, in case of failure, the water should not run into a gear case or other critical area, and the machine should be able to continue operating with the conventional water sprays.

Some of the above requirements are contradictory, if one considers the machines on which they have to be installed. Trade-offs are unavoidable. Some characteristics of the seals proposed and their manufacturers are shown in Table 3. Based on the drawings submitted by the manufacturers, the seal evaluation made by Banks Engineering, the comments of mine maintenance people and of the manufacturers themselves, a number of points might be made.

All the designs provide for double seals, with drains (vents) in between, to avoid contamination of the gear case or hydraulic system by water, in case of failure. Of course this assumes that the drains are not plugged by the time the water seal breaks. The Lee-Norse seal location appears the best in this respect, but the location results in a very large diameter seal.

Most of the seals proposed are seals normally applied to reciprocating motion (piston rings), and their manufacturers have little or no experience with rotary motion at the large diameters required, especially with water. Although rated at 2,000 or 3,000 psi for oil in a piston, 200 or 300 psi might be the maximum feasible with water in a rotary seal.

TABLE 3. CHARACTERISTICS OF PROPOSED WATER SEALS

	Seal Diameter, Inches	Seal Velocity FPM*	Water Connections Body to Cutting Head: No. of Connect-ions	Water Connections Body to Cutting Head: No. of Seal Rings	Approx. Cross-Section (Radial x Axial) and Type of Seal Ring	Seal Material	Seal Manufacturer and Trade Name
National Mine Service IA	9	195	2	4	1/4 x 1/4 U-cup on Steel Spring	80% Teflon 15% Glass 5% Moly	Aeroquip "Omniseal"
National Mine Service IB	9	195	2	4	.250 x .272 Piston-ring	Teflon, Carbon Blend Filled, Rubber O-ring Expander	Halogen "Style 16" Piston-ring
National Mine Service IIA	16-3/4	365	4	16	.250 x .272 Piston-ring	Teflon, Carbon Blend Filled, Rubber O-ring Expander	Halogen "Style 16" Piston-ring
National Mine Service IIB	16-3/4	365	4	16	1/4 x 1/4 U-cup on Steel Spring	80% Teflon 15% Glass 5% Moly	Aeroquip "Omniseal"
Jeffrey I	19	405 300	2	4	1-1/2 x 2 Chevron Packing	Duck Rubber and Teflon Rings (Steel Adapter Rings)	Anchor Packing Co. "Ankorflex"
Jeffrey II	20	425 315	2	4	.610 x .495 Piston-ring	Teflon 25% Glass-filled Iron Ring Expander	Koppers "K-30B" Piston-ring
Joy	8	145	2	4	3/16 x 1/4 U-cup on O-ring	Polyurethane	Parker "Poly-Pak" "Molythane"
Lee-Norse	22	335	4**	8	.840 x 3/4 U-cup	Polyurethane	Parker "Poly-Pak" "Molythane"

*Function of cutting drum RPM selected **May be redesigned to 2 (4 rings total)

Surface finish is another problem: a desirable surface friction-wise is not necessarily corrosion resistant during shutdowns, and the inevitable dirt particles in the water are better tolerated by some materials than others. Furthermore, the rotary motion of the sealing ring has to be controlled, so that the intended rubbing and sealing surfaces or edges retain their intended function.

None of the seals proposed is actually claimed to be able to run dry. A material like teflon could run dry, but water is necessary to carry away the heat generated by the friction of the seal. Otherwise the heat will destroy the seal material. The Jeffrey Design II (Koppers piston rings) attempts to get around this by depending solely on water pressure to keep the seal closed: in this fashion, with no water pressure, the radial rubbing surfaces should barely touch each other, and should not generate any heat. However, with no initial tension there might be difficulties at times in seating the seal in the first place.

This lack of experience with seals for this application indicates the need for a testing program on seals alone. Jeffrey is doing this at the present time on a test rig in their plant, duplicating the HELIMINER seal arrangement. National Mine Service has indicated that they would start such tests immediately, should they receive the order for a wet-head.

Due to this lack of experience with the seals proposed, and the poor experience with the seals of the few wet-head machines which have been operated in the mines, all concerned have expressed great interest in the National Mine Service Design I. This design locates the seals at the outboard ends of the cutting drums, where they can easily be replaced. On all the other designs it is necessary to remove the end drum, on some even the whole cutting drum, a one- to two-shift operation in the best of conditions. However, locating the seals at the outboard end of the cutting drum requires a special strut to hold the fixed half of the seal and carry the water to it from the frame. This strut, by design close to the rib, may be too exposed and too easily damaged to be practical. The seal cartridge itself is in a vulnerable position; therefore, this whole concept needs testing.

6. <u>Corrosion resistance of water passages</u>:

Corrosion produces scale, which in turn tends to block the small orifices of the spray nozzles. Hence, corrosion of the water passages through the machine should be minimized. This is true for conventional fixed spraying systems as well as wet-heads; but it may become a very acute problem for a wet-head. If there is to be a spray for each bit, and total amount of water is limited, each spray orifice has to be very small and becomes very susceptible to plugging. Maintaining high pressure to obtain a penetrating jet compounds the problem by also requiring very small jet orifices.

The proposals received generally call for plating small parts, or making them out of noncorrosive materials. For the passages drilled through frame or drum, National Mine Service proposes an "electroless" nickel plating process, and Joy and Lee-Norse an epoxy coating.

7. Size of water passages:

Here again trade-offs are necessary. In order to have sufficient pressure available at the spray nozzle itself, it is desirable to have a minimum of pressure drop through the piping on the machine. On the other hand, space is usually at a premium so that hose diameter is kept small. Holes drilled through frame members or shafts cannot be too large without mechanically weakening these parts. Hence, large pressure drops through the piping may be tolerated as a compromise.

For our particular test program, pressure available at the spray nozzle may be an important factor in the effectiveness of the wet-head. Thus a machine offering relatively low pressure drop, everything else equal, would be preferred.

The Lee-Norse and National Mine Service proposals offer the least restricted passageways.

8. Accessibility of manufacturer and mine to BCR:

Easy access to the manufacturer's plant and to the mine by all personnel involved in the test program, while not entering into the technical evaluation, is an important practical item. Numerous consultations are going to be necessary even in the construction stage of the test machine. Some modifications are likely during the test period itself. In case of breakdowns, proximity of the machine supplier to the mine is an asset.

B. Machine and Mine Selected for Underground Tests

BCR suggested and the Bureau agreed that the combination of a Lee-Norse continuous mining machine and a U.S. Steel mine in Southwestern Pennsylvania best satisfied the greatest number of these criteria for evaluation.

As noted in paragraphs A-1 and A-2, a machine without a cutting chain was preferable, other things being equal. Also, the trend of the industry was shifting to chainless machines, a reenforcing argument for using a chainless machine in the tests.

The National Mine Service design for an easily replaceable seal appeared ahead of the other designs. It was also the only design which offered phasing. However, the machine itself was only in the design stage, and it was not judged prudent to depend on a relatively unproven machine to test the wet-head concept.

The combination of Lee-Norse/U.S. Steel satisfied almost perfectly the requirements for a suitable "control" machine, since U.S. Steel already had two Lee-Norse machines on order for their Robena mine, to be delivered very shortly. Thus the machines could be maintained "identical" almost before leaving the factory. A mine in the Pittsburgh seam was also advantageous, as discussed in paragraph A-2. Both companies in the past have shown more interest than most in the wet-head concept, and U.S. Steel in particular had persistently attempted to use machines with sprays in the rotating head.

Furthermore, although the tests were to be directly under BCR's general direction, constant consultation with both the mine operator and the machine manufacturer appeared essential, and would be much easier to accomplish with all three parties in the same geographical area.

IV. SPECIFICATIONS OF LEE-NORSE HH-105 CONTINUOUS MINING MACHINES SELECTED Initial Experience and Consequent Machine Modifications

A. Specifications of Lee-Norse Test Machine

After agreement was reached on test site and test machine, representatives of U.S. Steel, Lee-Norse, and BCR jointly established the detailed specifications of the test machine (Figure 1) to make it as identical as possible to the machine ordered by U.S. Steel which was to serve as a basis for comparison.

The machines ordered were the lower model HH-105 rather than the HH-115, to provide more clearance above the machine (both models have the same cutting head). Both were specified with the same number of Prox bit blocks in the same lacing pattern, with 1200 rpm motors and low-speed gearing. With this gearing the cutters rotate at 49 rpm; and, with a diameter of 38 in. at the bit tips, the cutting bit tip speed is 490 fpm. Operator protective canopies were built and installed by U.S. Steel. The same headlights, conveyor sideboards, fire protection system, methane monitor, and other optional features were selected for both machines to avoid operator bias and to facilitate the work of the maintenance men.

Unfortunately, duplication of the two machines could not be completely maintained for the last series of tests (Fall 1975). By then the cutters of all HH-105 machines at Robena had been replaced by cutters with pin-on bit blocks instead of the original Prox blocks on the wet-head machine. It is difficult to know whether this had any effect on the dust generation. The bits themselves were essentially the same in all cases. The cutting diameter had been increased from 38 to 42 inches at the bit tips. The number of bits was increased from 11 to 13 on each inner cutter and from 13 to 18 on each outer cutter, which increased total bits (excluding those on end cutters) from 48 to 62.

B. Spray Nozzle Arrangement on the Wet-head

Most of the bits on the inner and outer cutters of the test machine were provided with two water nozzle positions, as shown in Figure 2. The Prox bit block was specially machined to provide space for a nozzle, as shown in Figure 3. Because of space limitation and to avoid excessive weakening of the base of the bit block, relatively small setscrew nozzles, 3/8 - 24 UNF, had to be used. In the second position ahead of the bit block is a larger nozzle, 1-1/16 - 12 UNF, Lee-Norse part no. 0-011965, the same nozzle as used for the fixed front boom sprays on the standard machine. Dimensions of this nozzle referred to as the "1-inch" nozzle are given in Figure 4, and it is shown in Figure 5. Samples of the two sizes of nozzles are shown in Figure 6. (The cylindrical strainer on the small nozzles was not devised until mid-1975.) The effect of the jet of water from the 3/8-inch nozzle impinging on the bit is shown in Figures 7 and 8, while the spray from the larger nozzle is shown in Figure 9.

The bit blocks are welded on top of the 1-turn scroll which encircles each cutter, as shown in Figure 10. A channel is cast on top of the scroll,

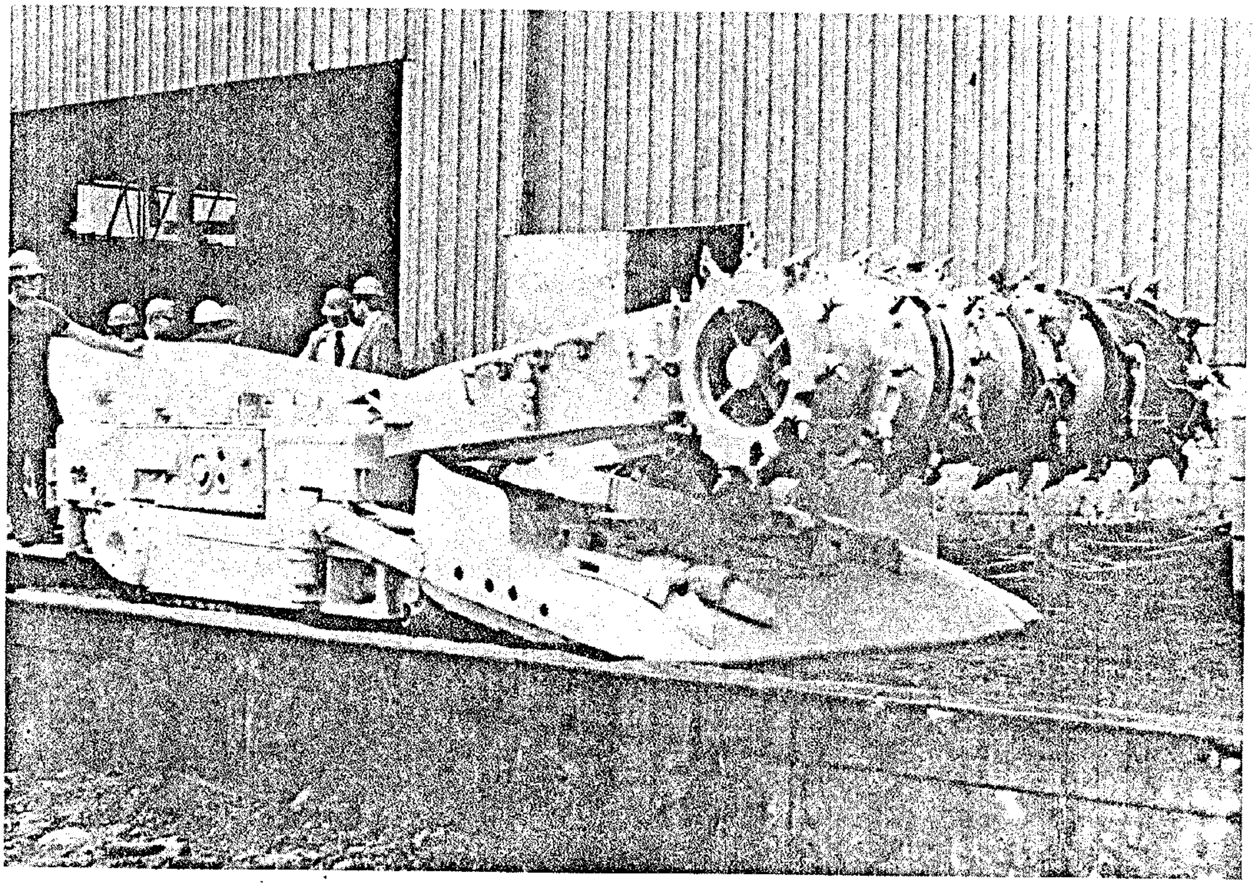

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Figure 1. Lee-Norse HH-105 Test Machine

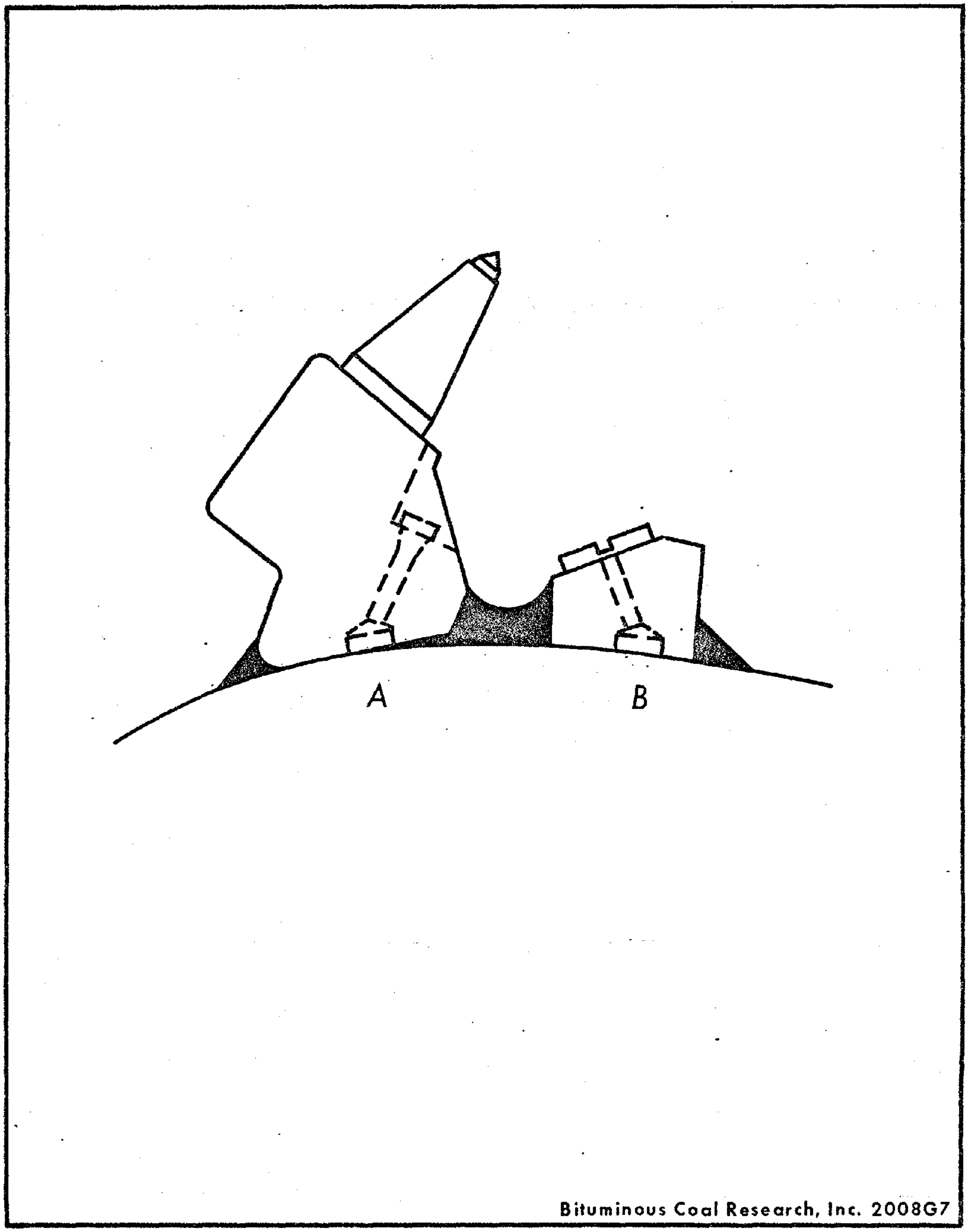
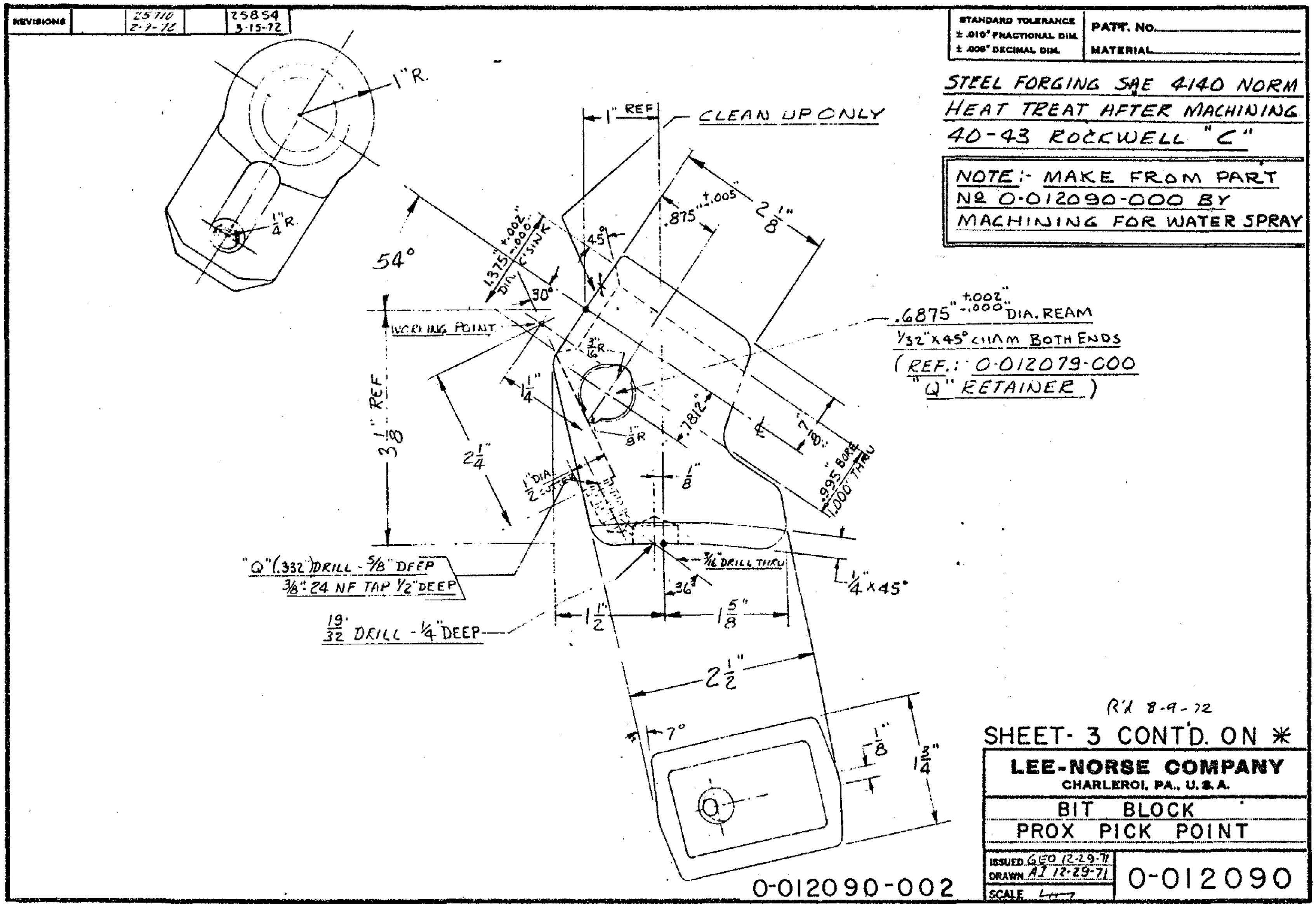
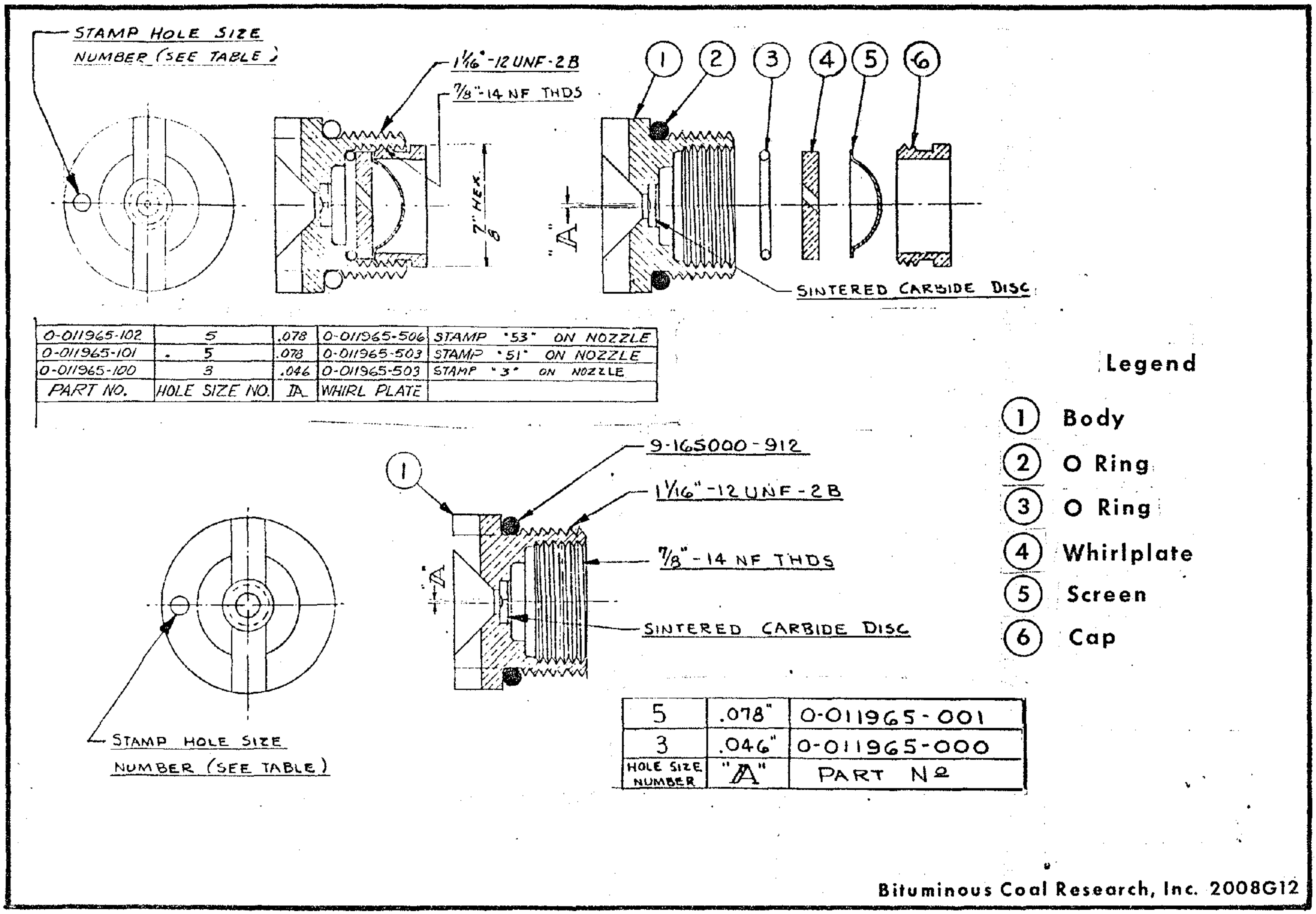


Figure 2. Alternate Spray Locations on Cutter Drum for the Lee-Norse HH-105 Test Machine



Bituminous Coal Research, Inc. 2008G6

Figure 3. Prox Block with Base Drilled and Tapped for 3/8-Inch Setscrew Nozzle



PART NO.	HOLE SIZE NO.	"A"	WHIRL PLATE	
0-011965-102	5	.078	0-011965-506	STAMP "53" ON NOZZLE
0-011965-101	5	.078	0-011965-503	STAMP "51" ON NOZZLE
0-011965-100	3	.046	0-011965-503	STAMP "3" ON NOZZLE

HOLE SIZE NUMBER	"A"	PART No
5	.078"	0-011965-001
3	.046"	0-011965-000

Figure 4. Large Nozzle Used on Test Machine Cutters

2008P27

Figure 5. Prox Bit Block on Cutter Scroll and Large Nozzle

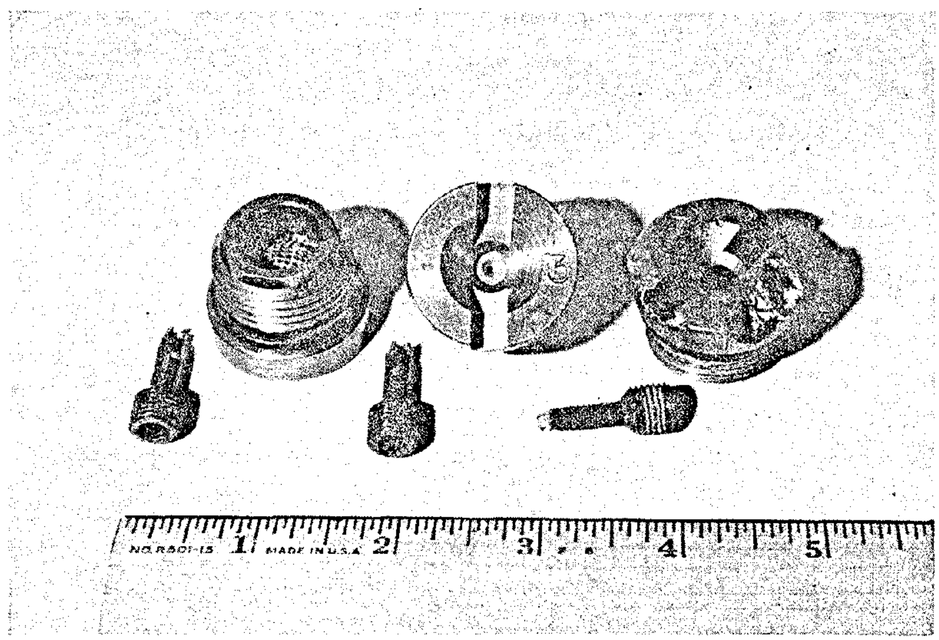


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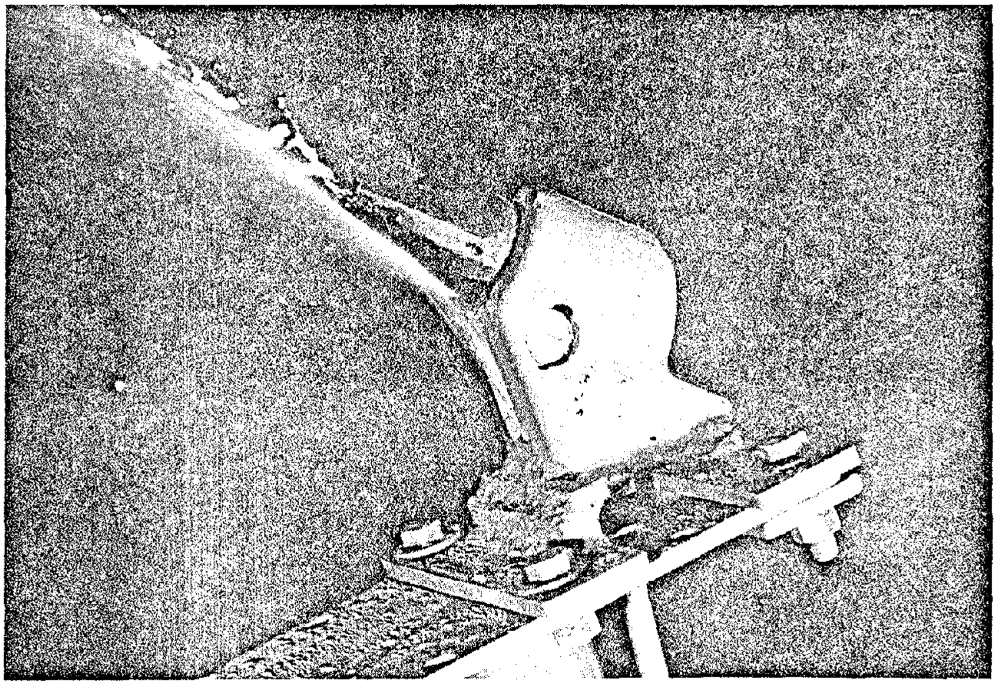
Figure 6. Two Sizes of Nozzles Used on Test Machine. Large Ones (New and Used) are Lee Norse Part No. 011965. Small Ones are 3/8-Inch Setscrews Drilled Through and Fitted with Hand-made Cylindrical Strainers



2008P11

Figure 7. View of the Modified Prox Bit Block Showing Angle at Which the Water Jet Impinges on the Bit

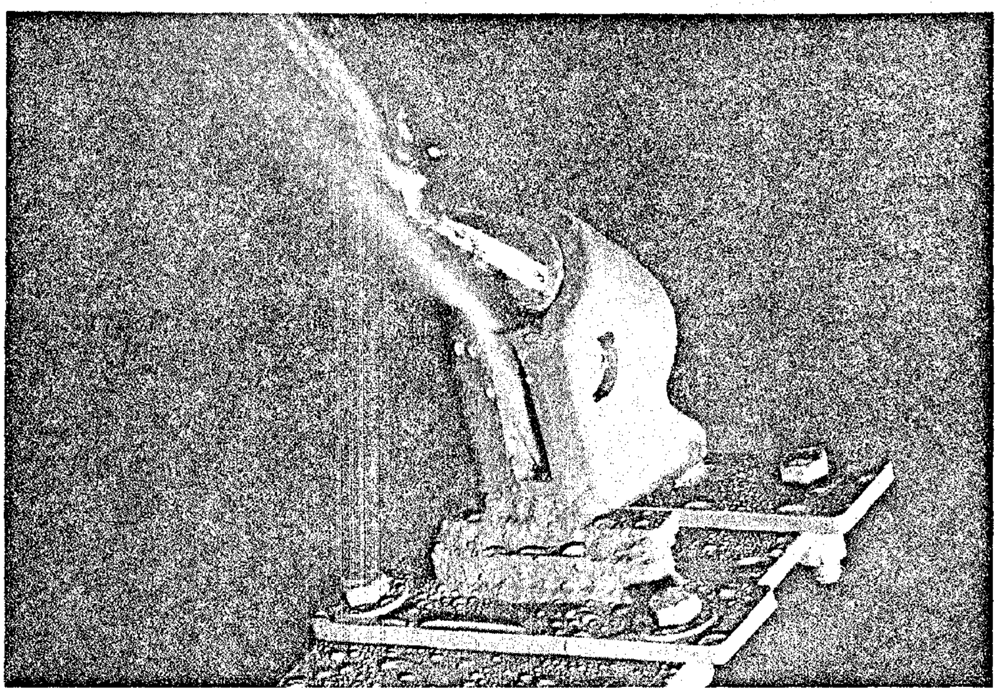


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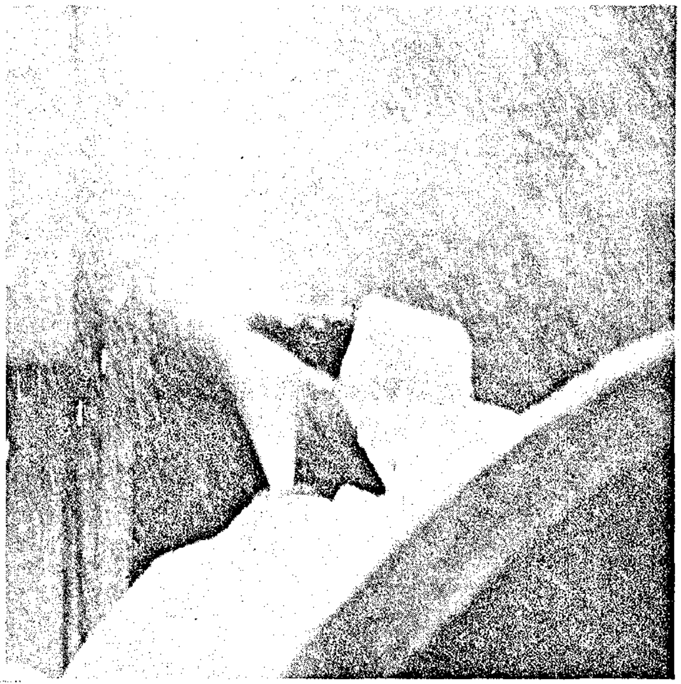
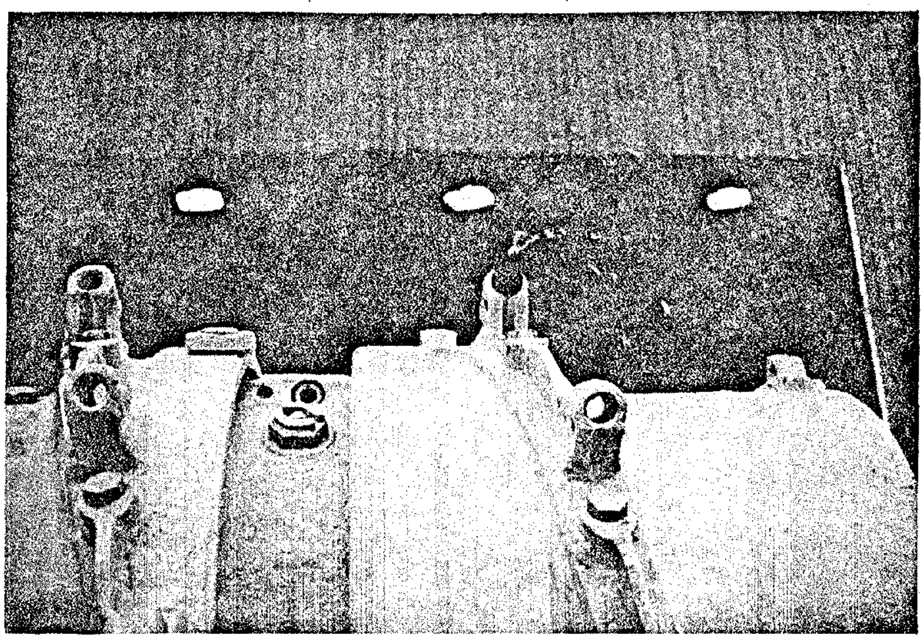
Figure 8. View of the Modified Prox Bit Block Showing the Location of the Jet Nozzle in the Block



2008P26

Figure 9. Prox Bit Block on Test Machine with Spray From 1-Inch Nozzle



2008P25

Figure 10. Bit Blocks on Top of Scroll, Left Outer Cutter at Right, Left Inner Cutter at Left

providing the passage which feeds the water to all the nozzles. The 11 bits on each of the inner cutters are laterally spaced 2-1/8 inch apart (i.e., the grooves cut in the face by each bit are 2-1/8 inch apart), and of these bits, 10 have 3/8-inch nozzles and nine also have the large 1-inch nozzles. The 13 bits on the two outer cutters are laterally spaced 2-1/4 inches apart, and of these, 12 have the 3/8-inch nozzles and 11 also have the 1-inch nozzles.

The two extensible end cutters are not piped with water. Each end cutter has 12 bits, but the width cut is only 7 to 8 inches, as there are several bits per row toward the end of the cutting head.

C. Wet-head Rotary Seals

Each of the four cutters is fed with water through a rotary 22-inch diameter seal set, a cross section of which is shown in Figure 11. The two sealing elements in each set were originally Parker polyurethane rings of 3/4-inch U-shape cross section. They were replaced by Fluorocarbon high density polyethylene rings prior to the last series of tests (Fall 1975). See Section VII.)

D. Fixed Spray Nozzles for Wet-head and Conventional Spray Machines

Both the wet-head machine and the conventional spray machine had fixed nozzles which were operated in all modes. Figure 12 shows two manifolds (eight nozzles) mounted on each side of the boom. In addition, four vertical sprays under the cutting boom were directed down at the gathering head and two sprays near the hinge of the boom directed into the chain conveyor. These 22 nozzles were of the design shown in Figure 13, similar to that of the large nozzles in the cutters and are referred to as "side sprays."

The two nozzles at the conveyor throat are not considered sufficient by U.S. Steel. On all machines at Robena, a Conflow nozzle is also located at this point. It is fed separately from the other nozzles by a long 1/4-inch hose running back to the operator's cab, which limits its flow rate to 2.5 to 3 gpm.

In addition to the side sprays, the conventional spray machines had the standard 20 fixed sprays located in line at the front end of the boom--10 along the top edge, and 10 along the bottom edge (six behind each outer cutter, and four behind each inner cutter). The top ones are inclined slightly upward and the bottom ones slightly downward (tangential to the bit tip trajectory), and the vertical distance between the two rows of sprays is 18 inches. The same large nozzles are used as on the cutters of the wet-head machine (part no. 0-011965, Figure 5).

The wet-head machine has the same nozzle positions at the front edge of the boom. These were plugged for the duration of the tests.

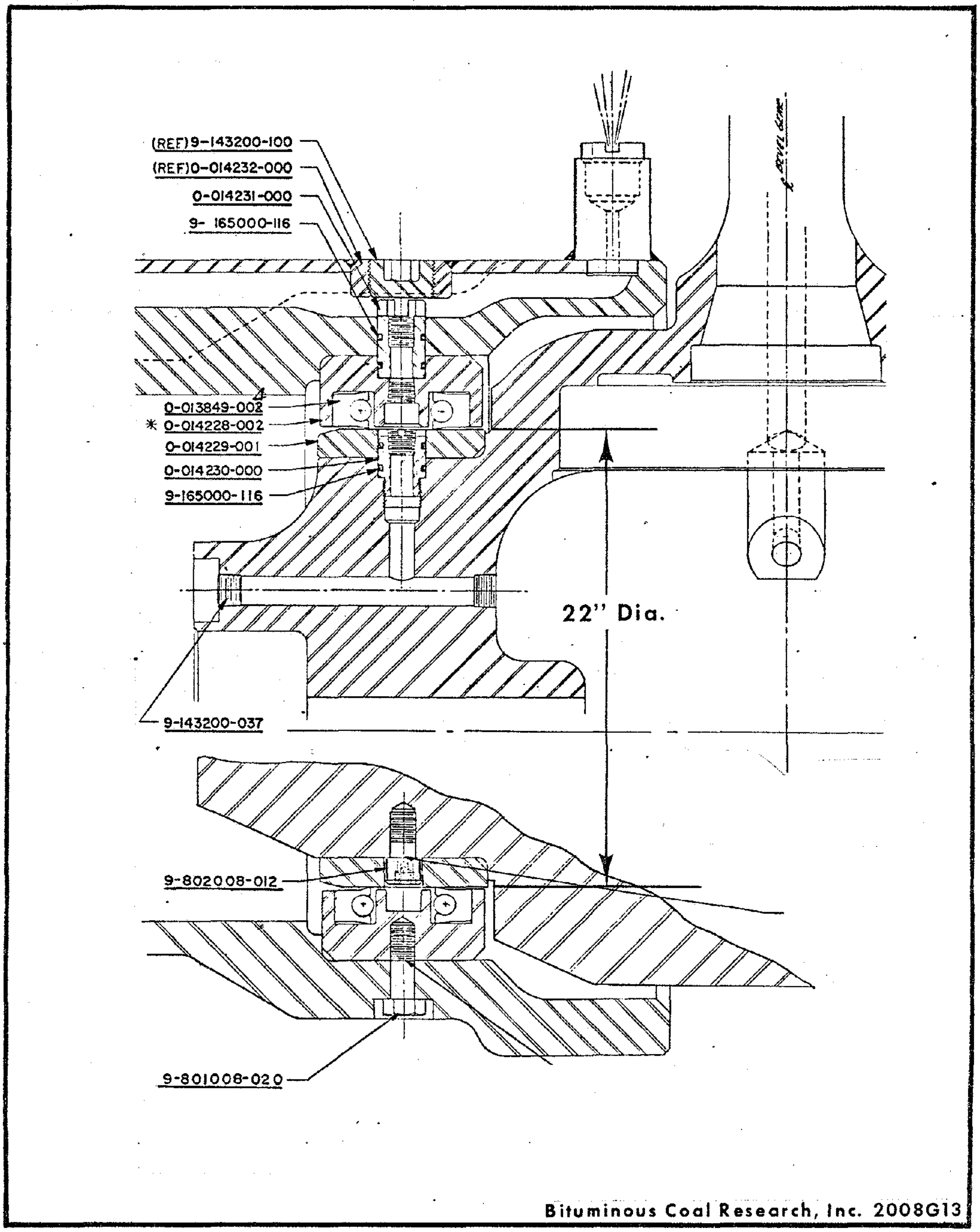
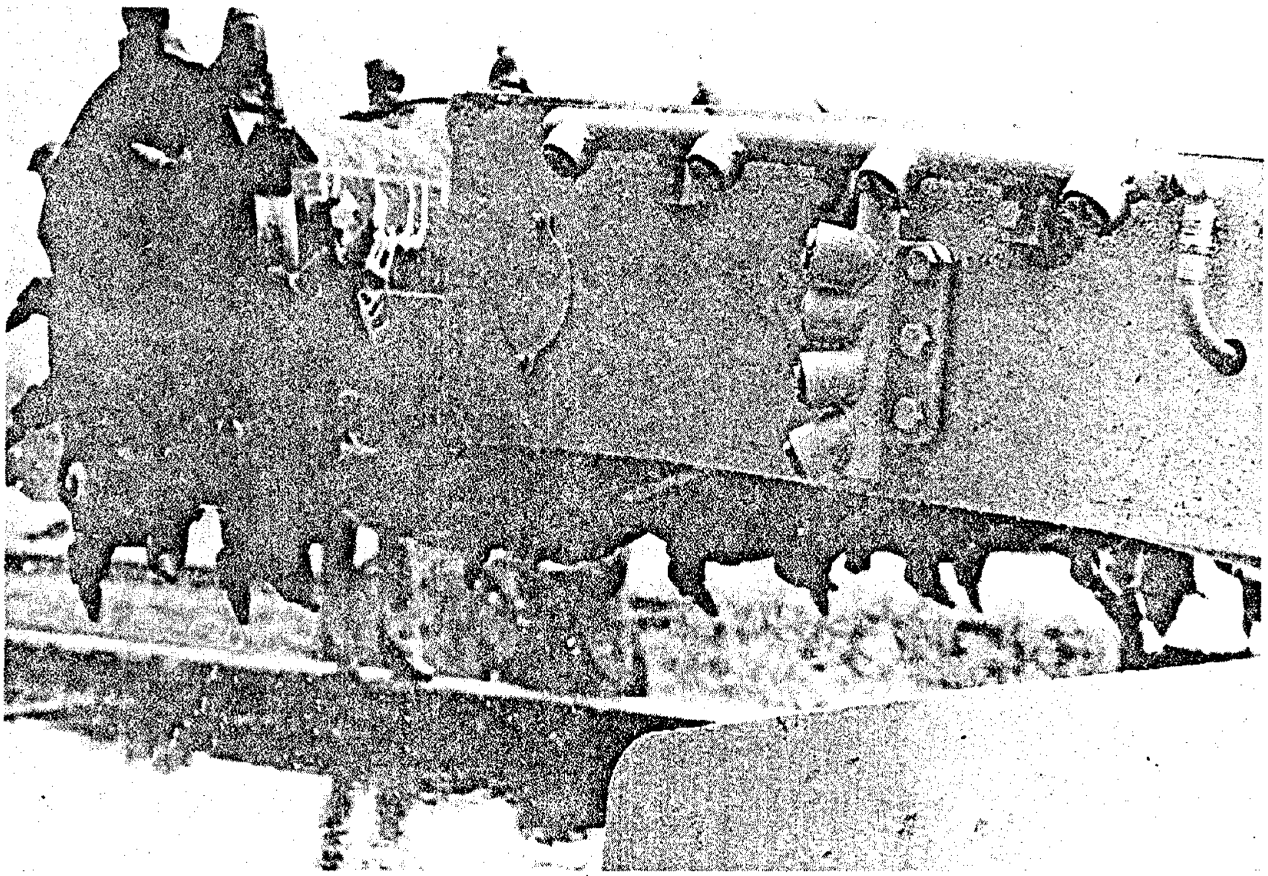


Figure 11. Cross Section of one Cutter with Rotating Seal



2008P32

Figure 12. Spray Manifold on Left Side of Boom, HH-105 Machine

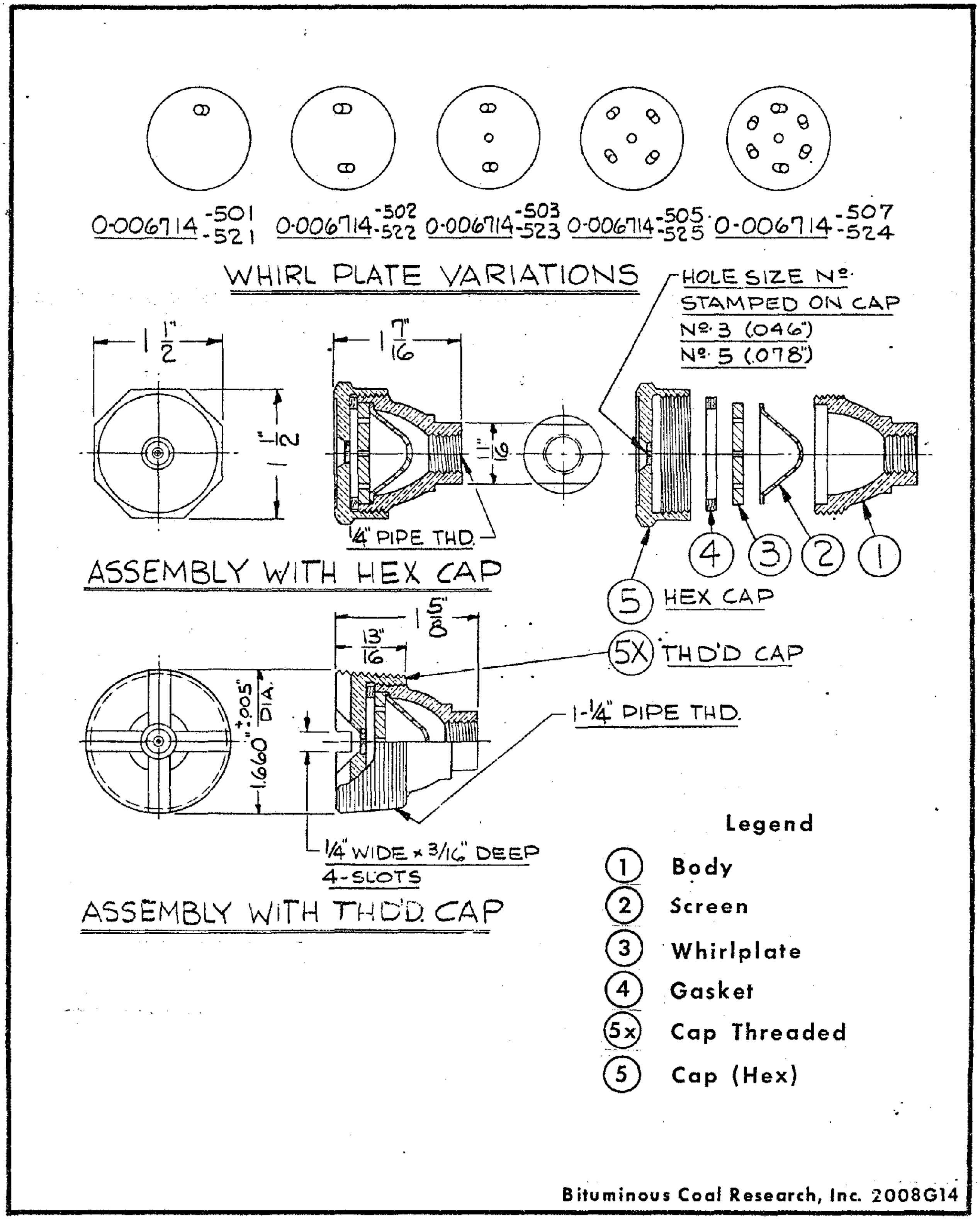


Figure 13. Nozzles Used for Fixed Side Sprays

E. Water Distribution on the Machines

The piping diagrams of the machines are shown in Figures 14 and 15 (tests of January and February 1973) and Figures 16 and 17 (tests of October and November 1975). A pressure regulator is normally installed on the Lee-Norse machines to protect the heat exchangers (oil coolers) and electric motor jackets from excessive water pressure. Since the line pressure at Robena did not exceed 250 psi, these regulators were later eliminated. All the machines were equipped with booster pumps, mostly to regain the loss of pressure through the motor jackets and head passages and piping. The diagrams indicate when the pumps were used. In practice, it is less troublesome to split the water flow and properly size the water passages when possible than to use a pump. (Only a portion of the spray water is needed for cooling purposes.) Originally all machines were provided with a cartridge filter on the machine at the trailing hose connection. For the tests of October-November 1975 this had been replaced by a larger capacity filter off the machine at the upstream end of the trailing hose.

F. Initial Underground Tests, Summer 1972

The HH-105 test machine was demonstrated at the Lee-Norse plant on June 14, 1972, and shipped to Robena mine immediately afterwards. Because of various delays, it was not transported to the section until late August. In the meantime, dust sampling was started to obtain base data with a conventional fixed spray machine, the U.S. Steel machine already operating in the section.

As soon as the test wet-head machine was ready, it was put in operation, using the 3/8-inch nozzles at the base of the bit blocks. However, difficulties occurred immediately. The nozzles plugged so fast that continuing operation was not possible. In addition, it appeared that some seals might be leaking.

Close examination of the head, coupled with detail checks of water flows and pressures, revealed several things. Much of the nozzle plugging was due to loose pieces of the vinyl coating on the inner passageways. The available pressure at the nozzles was too low, particularly on the outer cutters, indicating a large pressure drop in the feed to these cutters. Some restrictions were also found in the water channels of some of the cutters and in some individual bit blocks.

It was finally decided to remove the miner head from the mine and ship it back to the factory, where the following corrections were made: (1) a length of 1/4-inch water hose in each gear case was replaced by 3/8-inch hose and the fittings were drilled out; (2) each spray nozzle location on the cutters, both in the block and ahead of the block was drilled straight through to the water channel to reduce the possibility of plugging and facilitate cleaning up (see Figure 3) and, when necessary, the bit block was burned off and replaced; (3) where the water channel on top of the cutter scroll was restricted, the blocks were burned off and the casting cut out to proper depth; (4) a 100-mesh cartridge filter was added in the boom

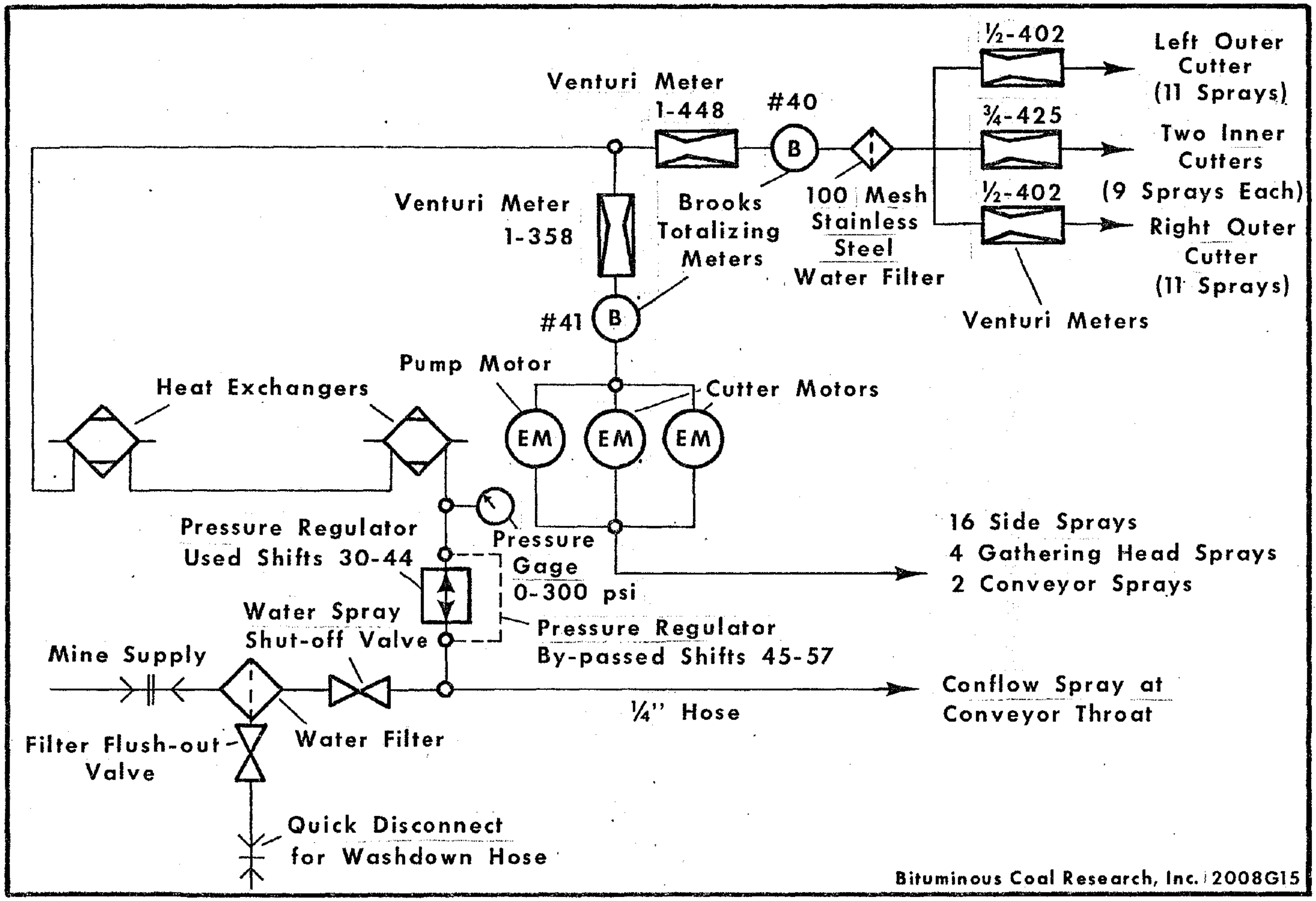


Figure 14. Schematic Spray Water Piping Diagram, BCR Machine, Jan-Feb, 1973

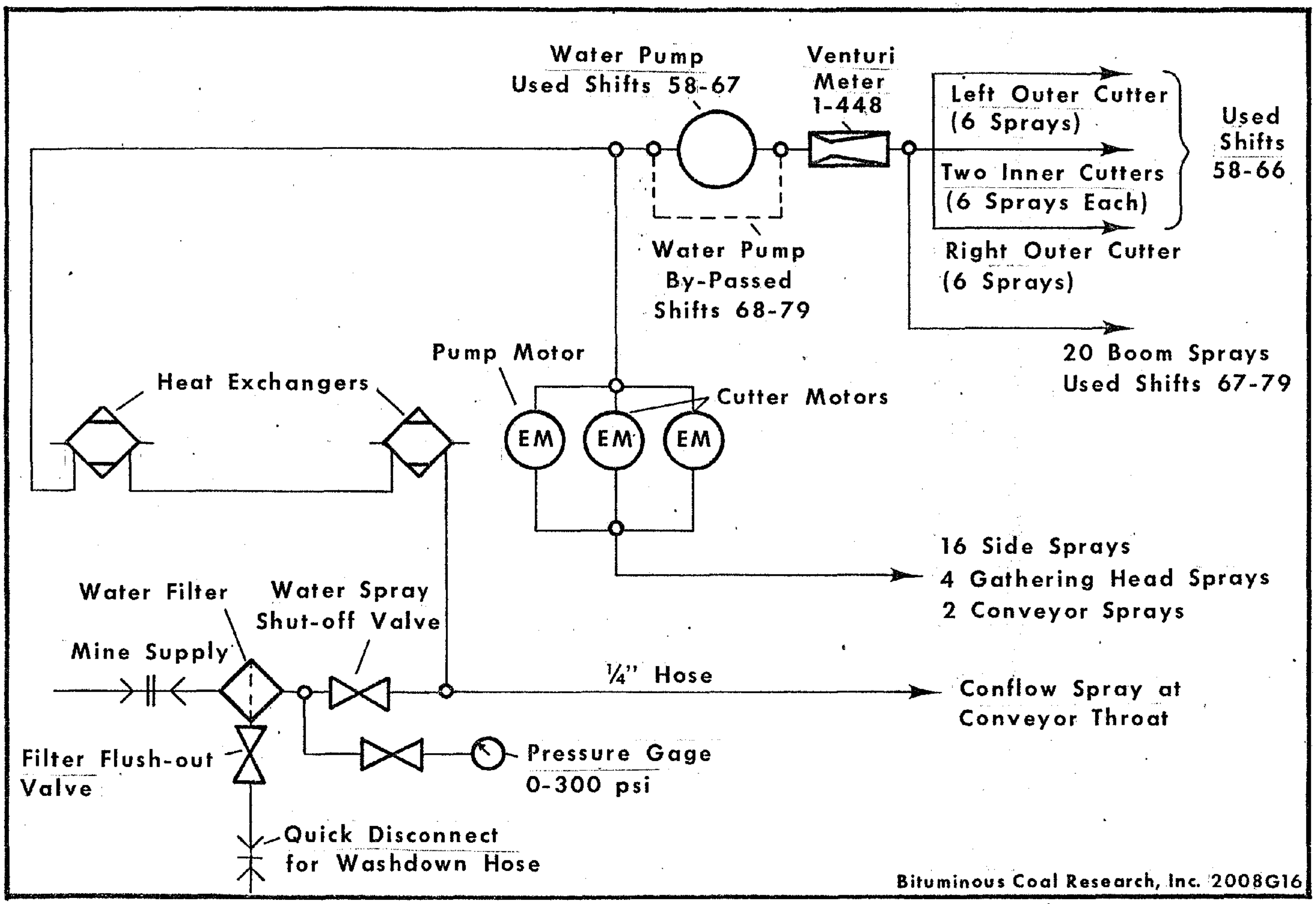


Figure 15. Schematic Spray Water Piping Diagram, USS Machine, Jan-Feb, 1973

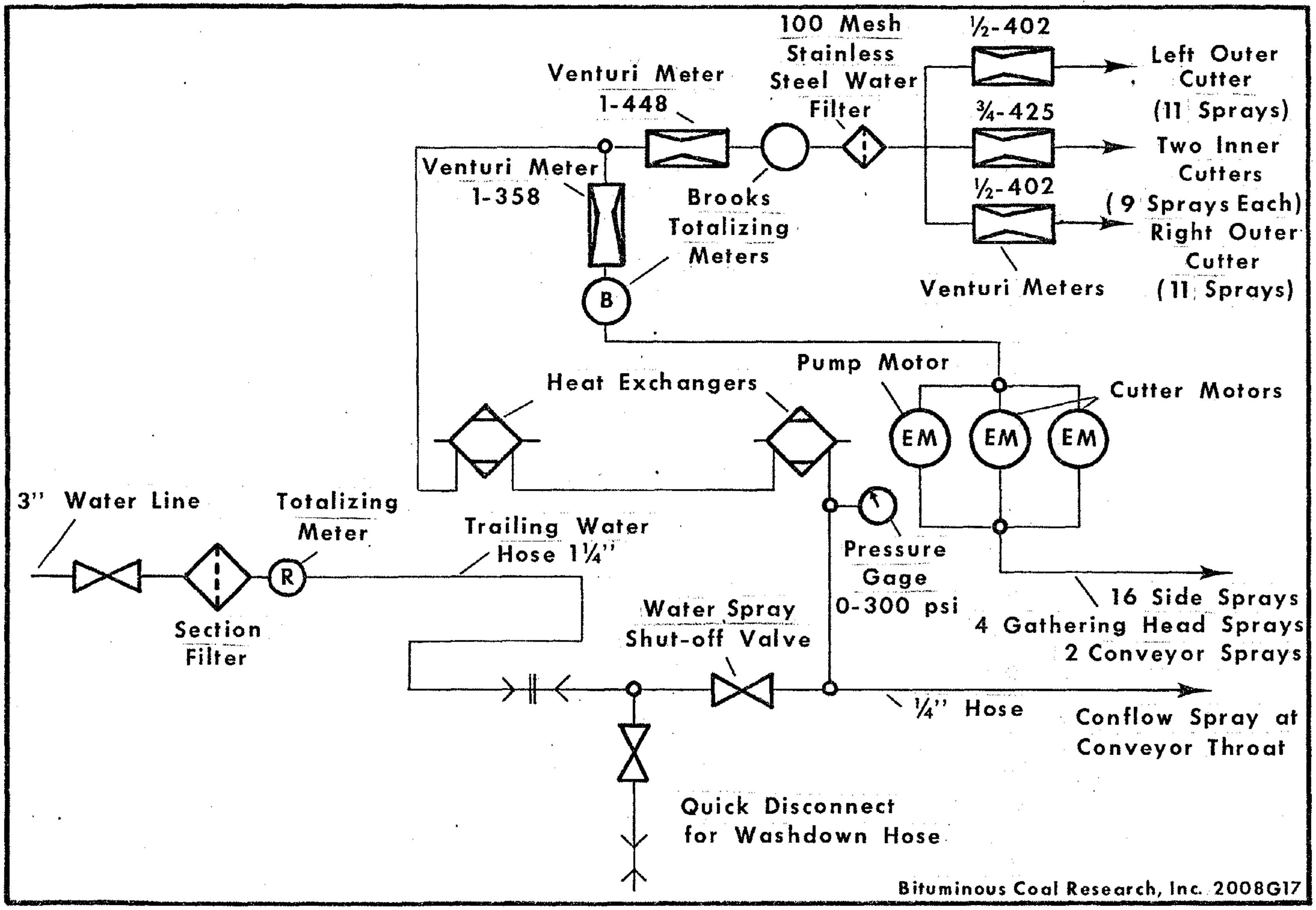


Figure 16. Schematic Spray Water Piping Diagram, BCR Machine, Oct-Nov, 1975

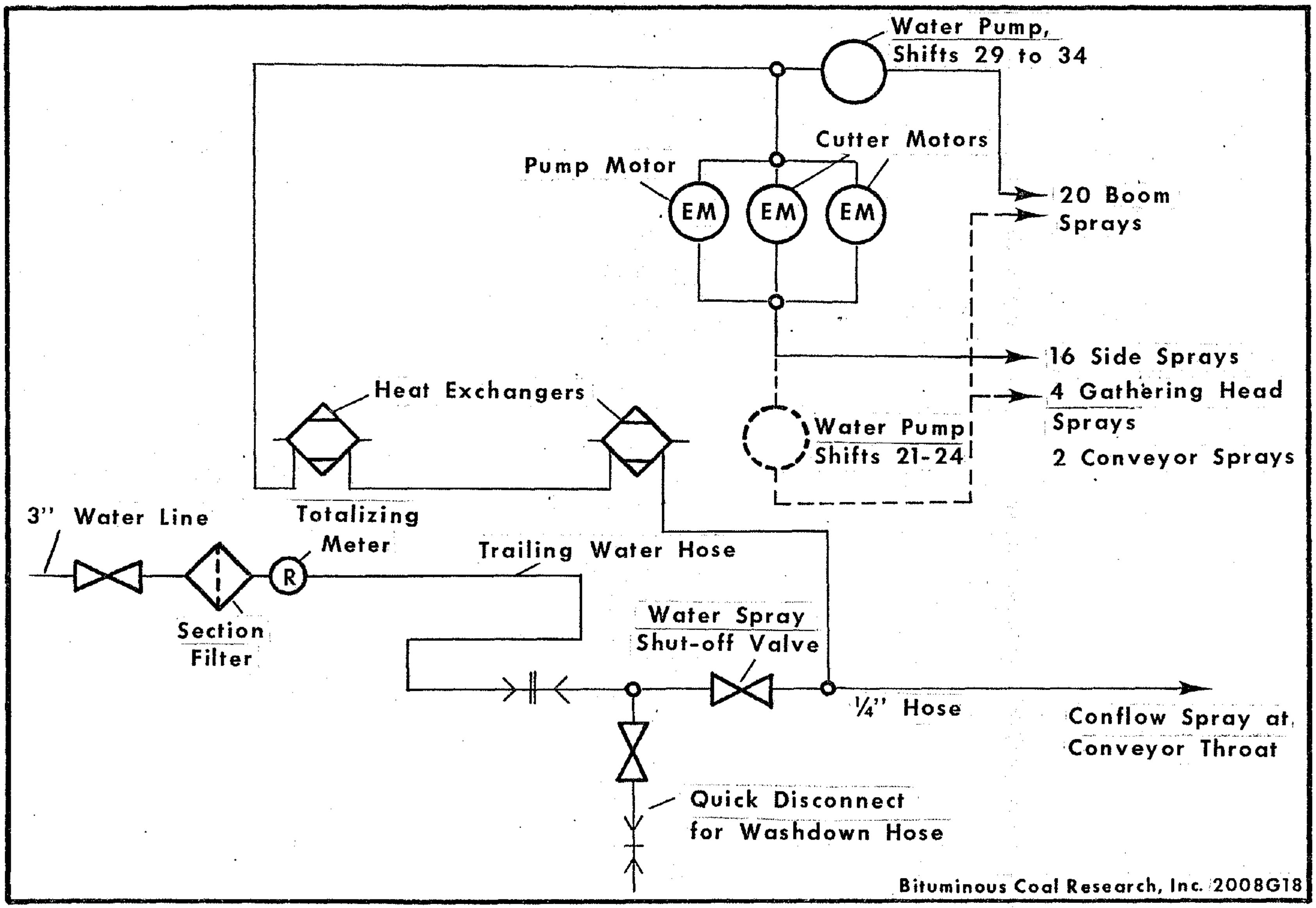


Figure 17. Schematic Spray Water Piping Diagram, USS Machine, Oct-Nov, 1975

of the machine (see Figure 16) and small strainers fabricated to fit behind each 3/8-inch nozzle; (5) three venturi tubes were added in the boom to monitor the flow to each cutter (see Figure 16).

The four sets of water seals were also examined. They did not appear damaged, but since leakage had been observed in the mine, they were replaced before reassembling the head.

Pressure drop tests after the work was completed indicated negligible pressure drops in the water channel on the cutters themselves, a drop of less than 40 psi at 6 gpm for each of the outer cutter feed passages (from the venturi in the boom well to the cutter inlet just downstream of the seal), and a drop of less than 30 psi at 8 gpm for the combined feed to the two inner cutters. Thus, one could feed 16 to 18 gpm through the head with a pressure at the nozzles no less than 30 psi below that available at the distribution manifold at the boom (i.e., at the newly installed filter).

The machine was thoroughly flushed at the factory after completion of the above work. Nothing was done to the anti-corrosion vinyl coating. A positive solvent which would remove it without mechanical help was not available, and it was feared that if only a partial softening of the coating were obtained, more plugging of nozzles would result from its gradual peeling off.

V. UNDERGROUND TESTS OF JANUARY-FEBRUARY 1973

The head was shipped back to Robena mine in mid-December, 1972; however, the panel in which the initial tests (August and September 1972) had been conducted encountered rock and had to be retreated. As dust measurements would not be practical in the return of a pillar line, a new advancing panel was started January 15, 1973 with the reassembled test machine. The assembly of the U.S. Steel machine to which it was to be compared, a new HH-105 just received at the mine, was not completed until the end of the month. The two machines were essentially identical except for the head. This new U.S. Steel machine had a wet-head also, with the same 1-inch nozzles in front of the bit blocks, but at only approximately every other bit block location. Thus, it had six nozzles in each cutter instead of the 11-9-9-11 on the test machine. It had the same type of water seals but did not benefit from the corrections made to the head of the test machine. (See Section IV.) The piping arrangements of the machines were shown in Figures 14 and 15.

The first problem encountered with the test wet-head machine was the plugging of the 3/8-inch nozzles. It had not been possible to flush the system properly in the mine, as had been intended. Not only were the strainers in back of the nozzles too small for the amount of foreign material present in the water, but they were also too difficult to remove and clean. After three shifts it was decided to switch to the 1-inch nozzles which have a much larger strainer area.

The second problem continuously faced during this period was leakage of the rotary water seals. After the first ten shifts of the series, there was always at least one seal leaking enough to prevent adequate flow of water to one of the cutters. The failures were not complete; that is, a seal leaking for some period of time would re-seat itself later. Several corrective measures were tried, but the problem grew worse.

After this experience, the U.S. Steel machine, also a wet-head as indicated above, was put into operation. During the fourth shift, seal leakage started to appear. After nine shifts the water through the head had to be disconnected, and the machine was operated with the conventional fixed boom sprays.

All of the measurements obtained during these tests were presented in Technical Letter Report No. 21 (BCR Report L-518) dated April 5, 1973. They have now been superseded by the measurements obtained in October-November 1975.

Following the very poor experience with seals, it was concluded that seals which would last at least for the number of shifts needed for a meaningful series of tests were necessary.

VI. DIFFICULTIES WITH ROTARY WATER SEALS

Review of Seal Tests

As indicated in the previous section, seal leakage greatly hampered obtaining full-shift respirable dust measurements with the wet-head machine. The difficulty was in establishing the process of seal failure and pinpointing the initial cause. Removing the seals requires complete dismantling of the head, hardly an operation to be performed at the face. Furthermore, the seals had already been changed when the head was at the factory, and nothing particularly wrong had been observed on the removed seals, even though some leakage had occurred previously. Thus, taking the head apart would not necessarily reveal the problem. In addition, the failures were in a sense a reversible process, in that a seal leaking at one time would sometimes re-seat itself. It was found that sometimes a seal could be made to stop leaking by applying water to it backwards through the head. Unfortunately, the seals are not constantly under pressure. Every time cutting is stopped, the water must be turned off and it drains out of the head and seals. When the machine is started again, water pressure builds up only gradually.

Several problems could be suspected, such as not enough water pressure to open up the lips of the seal, particles of dirt lodged under the lips, seal twisting in the groove in the ON-OFF operation and not always recovering its proper position, greater eccentricity developing in the head than the resilience of the seal lip could accommodate, set taken by the seal material while the machine is idle, and even some damage to the seal during installation (it is not possible to observe the seals while the cutters are slipped in place; and, with such heavy parts, one cannot "feel" if a seal is being pinched or twisted). The following efforts were made to determine which, if any, of these hypotheses were true.

After the return of the head to the factory, at the end of February 1973, it was powered and water was fed to the cutters. Seven of the eight sealing rings were leaking. Where they were leaking was noted and careful measurements were made. After dismantling, much coal and dirt was found around the seal rings, but this could have been the result of seal failure as well as its cause. No definite conclusions could be drawn. However, the chrome plating on the sliding surface of the stationary inner rings had been worn through at several places, and some of the sealing rings may have turned within their outer retaining grooves instead of remaining stationary.

Several approaches were initiated in attempting to solve this frustrating seal problem. New seal rings with thinner lips were ordered from Parker, in the hope that flexibility would be gained in following the variations in gap width along the periphery of the cutter. Also ordered was a set of Precision metal piston-type rings, and fabrication of retaining rings for this type of seal was started. Since a piston ring may adapt itself better to gap variations, and has inherently very little friction when not under pressure, it does not generate destructive heat in the absence of water. Because of the quick wear observed on the chrome plating, two inner rings were ordered with ceramic-type coatings.

Fabrication also began on a rig to test the seals at the plant. It made use of the head of the test machine, with cutter shaft in place but without cutters. Instead of inserting the seal set to be tested in a cutter where it couldn't be seen, a smaller holder was made for the outer part of the seal, which could be attached to the end of the shaft in place of one of the outer cutters. Through a small 1/2-inch rotary seal located on the centerline of the holder, water could be piped into the seal, then out through the boom passageway and the electric motor for cooling. (The water was fed in opposite direction to normal flow in order to apply the full city water pressure to the seal.)

The testing of a Parker ring with a first type of ceramic coating showed that the two materials were not compatible, resulting in shredding of the seal.

The piston-type rings presented two problems. In the first place, the outer surface of the piston ring did not seal well enough against the inner surface of the outer retaining ring (this is a static seal, both rings rotate together). The gap around the circumference was only of the order of a mil in places, but due to the large diameter, the water leakage was too great. To eliminate that leakage a small groove was cut around the periphery of the piston ring and an O-ring was installed.

The second problem was that of initial sealing. This type seal depends on the water pressure to hold the side of the piston ring against the wall of the groove of the inner retaining ring, these two elements forming the two mating surfaces of the rotating seal. Again because of the large diameter of the seal relative to its cross section, the initial leakage around the piston ring was large and the pressure buildup was not sufficient to move it over in the groove. Even after mechanically holding the piston ring against its mating surface and lapping the surfaces together, it was not possible to reduce the leakage sufficiently, and further experimenting with that type of seal was abandoned.

Several of the failed seals had been sent to the Parker testing laboratory for evaluation. The report which finally came back in August 1973 was that polyurethane used for all seals supplied to Lee-Norse to date had been a poor choice for this application. Its coefficient of friction is too high, water is a poor lubricant, the heat dissipation is poor, and it is easily damaged by a rise in temperature. Parker recommended that a type of nitrile be used instead.

This new material was tested as soon as rings could be molded, and the performance was much better than with polyurethane. The chrome surface became polished rather than wearing through. The seal was tested for some

20 hours at 120 psi without leakage. One problem for installation, though, was that the seals were too limp to stay unsupported in the grooves. Possible modifications in composition and cross-section as well as stiffening at the heel of the ring were discussed with Parker. The first set of seals made following this discussion did not meet dimensional specifications. The second set had enough body and ran rather smoothly as long as the water pressure was low, but started to warm up quickly when the pressure reached 100 psi.

In the meantime, early in 1973, BCR had proposed to the Bureau a separate research program on rotary water seals suitable for wet-heads. Contract No. H0232055 was awarded to BCR on May 24, 1973. After a survey to determine which commercially available seals might be used in this application, and after design and assembly of a test rig, actual seal testing started at the BCR laboratory late in 1973. The reader is directed to the final report for this contract for the details of the testing procedure and the results of the tests. This report, "Testing and evaluation of rotary water seals for wet-head continuous mining machine," final report on Contract H0232055, dated March 1975, is available from U.S. Comm. NTIS PB 244-283/AS.

The third set of nitrile seals fabricated by Parker was tested both at the Lee-Norse plant and at BCR, with the same results. One seal of the pair performed well, while the other failed, because it rotated in the outer retaining ring rather than remaining stationary, resulting in heating, distortion, and swelling. Seal testing continued at BCR only, where, as a first attempt to prevent the unwanted movement of the rings, they were glued in place in the holder. This seemed to accomplish what it was intended to do; the rings were prevented from turning and twisting, and only the inner lip of the seal was in contact with the chromed mating surface. However, a complete water seal between the ring and the groove was not achieved.

Early in 1973 Lee-Norse Co. had been in contact with the Fluorocarbon Co., whose seal appeared interesting, although they had never made anything as large as 22 inches. One of their seals was included among the 8-inch seals to be tested by BCR; and its performance was sufficiently better than others that 22-inch seals were ordered in the spring of 1974, and Lee-Norse designed and fabricated the necessary seal holder.

The 22-inch Fluorocarbon seals were tested in the fall of 1974, and out-performed all other seals tested to that point. Testing was stopped after 320 hours of actual running time and the seals, although worn very thin, were not leaking yet. This is not to say that the life obtained was anywhere near sufficient for practical commercial use in a mining machine, but it looked like a good prospect for completing the proposed wet-head tests, barring any excessive reduction in useful life because of the mining environment as compared to the laboratory environment.

Seals were ordered in early 1975 to equip the test machine, and Lee-Norse started fabrication of additional seal holders at the same time. This seal was the same U-shape cross section as the polyurethane seal. It is only about 1/2-inch square in cross-section, made up of a high density polyethylene jacket over a stainless steel double-layer V-shaped spring. The inner ring mating surface is the same as that for the polyurethane seal, but with a deeper bevel on the outside edge to facilitate assembly.

VII. FINAL SERIES OF UNDERGROUND TESTS
October-November 1975

Following reassembly at the Lee-Norse plant with Fluorocarbon seals, the boom of the HH-105 test machine was shipped to Robena mine on August 12, 1975. It was lowered into the mine on September 16, assembled to the body of the machine, and the machine was moved to the section chosen for the tests during the weekend of October 4.

The water circuits were checked, nozzles and meters installed, and a few problems resolved before the machine was ready to operate. All water flow rates were checked, and on October 15 dust sampling began.

By November 21, dust sampling was terminated after the desired number of sampling shifts had been obtained, with no trouble from seal leakage.

In comparison with the first tests with the wet-head machine, considerable progress had been made. The seals were no longer leaking. The water passages were large enough so that there was always adequate water pressure and quantity behind the nozzles. The need for a multilevel water filtration system having been fully recognized, there was no nozzle plugging problem from entrained particulates.

These tests also benefited from BCR's having conducted other comparable tests with wet-head machines since the tests at Robena in early 1973. These tests were conducted under the two Bureau contracts referred to in Section I of this report, as well as under Contract H0230031 "Design, fabrication and testing of a system to demonstrate the effectiveness of respirable dust control on longwall shearers by use of water piped through the shearer drum," and Contract H0230029 "Dust control on auger head mining machines using the wet auger system."

A. Test Plan

The dust sampling procedure was simplified from that of 1973 by eliminating the more cumbersome samplers. Because it was known that stoppings, curtains, and line brattices are well maintained at Robena, fewer samplers were placed on the clean air side. They were concentrated, instead, on the return side of the brattice where the effect of the machine cutting head would be the most pronounced. Two packages of five samplers each were used to measure both respirable dust and total airborne dust. (The test procedure is detailed in Appendixes A and B.)

Measurements were made not only on a shift basis, but also on a "cut" basis, that is, data were recorded for each place where the machine was moved during each shift. Data included number of mine cars loaded from the cut, gallons of water used, water flow rates, etc. Unfortunately "cut" respirable dust samples cannot be obtained with the personal or MRE samplers because the dust weights resulting from only one cut are too small. But it could be done for total airborne dust samples, which are much heavier.

Also, more successful than previously was the matching of water flow rates between the wet-head and the conventional spray machines. In order to determine that one mode of operation produces less dust than another, one must also show that it uses less water, or at least no more water. Otherwise, a decrease in dust production could always be attributed to an increase in water consumption.

B. Test Site

The tests were conducted in No. 2 Panel Right, off No. 1 Flat Left. This panel has five entries 16- to 18-feet wide driven on 85-foot centers, with crosscuts every 85 feet. Entries No. 1 and 5 are return entries, and permanent stoppings are built as soon as possible. The track is in the middle entry, No. 3. The continuous mining machine is served by two shuttle cars dumping directly into mine cars. A double-boom roof-bolting machine is used. The normal procedure is to work two places at the same time, the bolter and the miner alternating positions. The air is split between the two machines, one split being directed to each return. The machines progress from right to left, entry 5 to entry 1, until a crosscut is completed across the five entries, then back from 1 to 5 with the next crosscut. Two places worked at the same time when progressing from right to left to complete crosscut 8 would be, for example, 3 straight between 7 and 8 crosscuts, and 8 crosscut between 2 and 3 straight. At the start of the tests the section had advanced to crosscut 7, and crosscut 11 was reached by the end.

Seam height varied from 6-1/2 to 7 feet, and the seam was dry.

Figure 18 indicates which areas of the section were mined for each mode of operation.

C. Chronology of Tests

The wet-head machine was operated and dust samples collected for 19 shifts between October 15 and October 29. From October 30 to November 11, dust samples were collected during 14 shifts of operation of the conventional spray machine. Finally, 12 more shifts were sampled with the wet-head machine in operation, from November 14 to November 21.

1. Shifts 1 to 14

Dust sampling was started with the wet-head machine, rather than with the conventional spray machine, in order to avoid unnecessary sampling in case of premature failure of the wet-head seals. Again, knowing only that the new Fluorocarbon seals had had satisfactory life in a laboratory set-up, but not what their life would be in actual mining conditions, it was decided to make full use of every working hour of the test machine and conduct dust sampling during both operating shifts. Sampling two shifts a day instead of one, however, has serious drawbacks: mechanical problems are likely to void more sampling shifts before they can be corrected, and more shifts go by before any difficulty in testing procedure shows up and can be remedied.

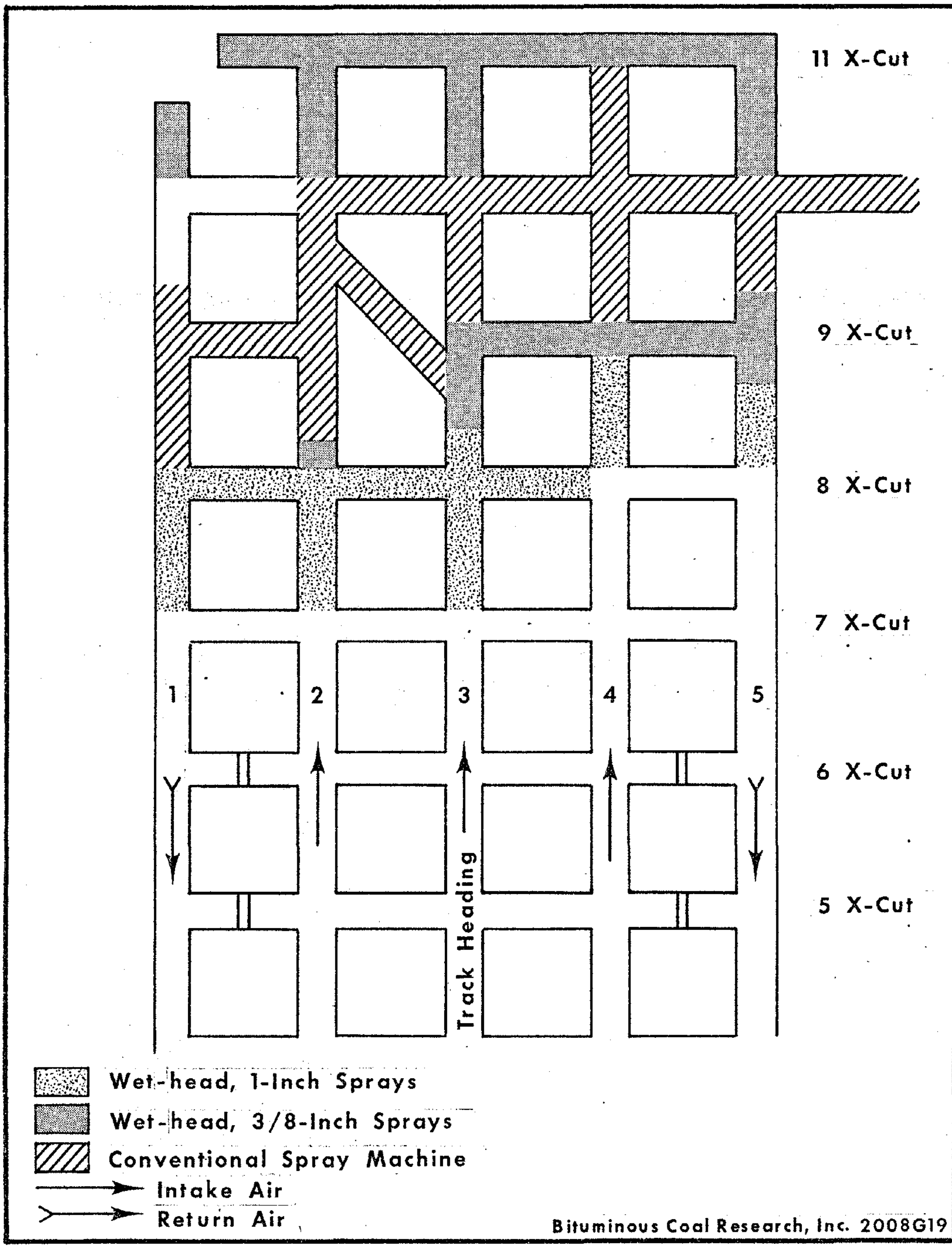


Figure 18. Areas Mined with Wet-head and Conventional Spray Machines

During these first 14 shifts, the spray nozzles used on the cutters were the standard Lee-Norse part no. 0-011965-100 1-inch nozzles (No. 3 orifice, 1-hole whirlplate, Figure 4). There are 40 such nozzles on the cutting head, one in front of almost every bit block, the main exception being the bits on the extensible end cutters (the last 8 inches of cutting width on each side of the machine). (See Section IV.) There was no problem of nozzles plugging from either internal or external causes. A few nozzles lost their carbide orifice plate insert, probably from impact against a sharp lump. Abrasion of the rather unprotected nozzle heads was severe, but without effect on the operation of the nozzle. (See Figure 6.)

2. <u>Shifts 15 to 20</u>

For this series of shifts, still with the wet-head machine, the 3/8-inch setscrew nozzles at the base of each bit block were used instead of the 1-inch nozzles in front of the bit blocks. The setscrews, orifice 1/32-inch, had all been fitted with a small handmade wire mesh strainer. (See Figure 6.) Although the strainer seemed to prevent plugging from the inside, a considerable improvement over previous tests, there was still some stoppage because of outside material packing up in the 3/16 hex wrench cavity of the setscrew. Setscrews with 1/16-inch orifices were tried, and these did not suffer from the packing problem. However, use of this size orifice in all setscrews was not possible because it would have resulted in too large a water flow and too low a pressure at the nozzle. The tests with the wet-head machine were then interrupted.

3. <u>Shifts 21 to 34</u>

Dust sampling for six to eight shifts with the conventional spray machine had been planned. However, it had not been possible to check the exact condition and water capacity of its spray system prior to Shift 21. It was found then that the total water usage of the machine was less than estimated and less than that of the wet-head, and also that not enough of the water was directed at the head. It was imperative that this condition be remedied, so that, if a marked dust control improvement was to be found with the wet-head machine, it could not be attributed simply to the use of larger quantities of water. Furthermore, there was a feeling at the time that perhaps the conventional spray machine was cutting coal at a faster rate than the wet-head machine, thus aggravating the problem.

During shifts 21 to 24, the machine was used just as it had been operating prior to the tests with the wet-head machine. The total water flow while cutting was 22 to 22-1/2 gpm, while at least 26 gpm was desired.

Several changes were made, and the final arrangement used for shifts 29 to 34 was that shown in Figure 17, Section IV.

Of the 20 fixed front boom sprays just behind the cutters, the top 10 had the original Lee-Norse No. 3 1-inch nozzles (part 0-011965-100). Because of excessive wear at the bottom front edge of the boom, the bottom water channel had been rebuilt and provided with recesses in which the nozzles would be protected. In order to fit into these recesses, the 10 bottom nozzles had been changed to Spraying Systems VeeJet H 1/4 VV 11008 flat spray nozzles, and for lack of depth these nozzles did not have any strainers. At the time of the tests, many of these nozzles had become very difficult to remove and it was not possible to clean them up as often as would have been desirable.

The conventional spray machine differed from the wet-head machine in two aspects. All Lee-Norse machines at the mine now have pin-on bit blocks instead of the Prox blocks used on the wet-head machine. This was already discussed in Section IV. The conventional spray machine has also been raised several inches, which gives it more ground clearance and a better ability than the wet-head machine to follow the rolls in the mine bottom.

4. Shifts 35 to 46

These 12 sampling shifts were again with the wet-head machine with the 3/8-inch nozzles at the base of the blocks, but this time the orifices had been redrilled with a No. 58 bit, giving a diameter approximately half way between the 1/32- and the 1/16-inch orifices tried during Shifts 15 to 20. This time all nozzles remained open with only minimum occasional cleaning, and the water flow obtained through the cutters was just about the same as that with the 1-inch nozzles.

These nozzles were intended to project a solid stream of water on the bit itself. However, because of the way the setscrews were drilled, in a number of cases the jet was missing the bit. Also, because this is a straight jet rather than a cone of droplets as produced by the 1-inch nozzles, the end rings of bits at both ends of the cutting head, which are not covered by individual nozzles, did not benefit from a fallout of water from adjacent bits as they had with the 1-inch nozzles. Thus, more dust may have been released from the ends of the cutting head than had been during Shifts 1 to 14.

D. Field Test Data

The equipment and procedures used for dust sampling are described in Appendix A. The procedures followed underground in the tests at Robena are detailed in Appendix B.

The data collected during the shifts of underground dust sampling are tabulated in Appendix C, as follows: Tables C-1, 2, and 3 give the operating data for each shift, and Tables C-4, 5, and 6 similar data for every cut of every shift. Tables C-7, 8, and 9 give for each shift the weight of dust collected by each of the eleven respirable dust samplers and each of the four total airborne dust samplers. Tables C-1, 4, and 7 are for the first 19 shifts with the wet-head machine; Tables C-2, 5, and 8 for Shifts 21 to 34 with the conventional spray machine, and Tables C-3, 6, and 9 for the last series, Shifts 35 to 46, with the wet-head machine. Also in Appendix C and preceding the tables are explanatory notes which define in detail how the data listed in Tables C-1 to C-9 were obtained.

E. Critical Examination of Field Test Data

1. Shift Production

No decision was made ahead of time as to what level of production was to be considered "valid" for the purpose of this study. Rather, the shifts were grouped by tonnage after the tests and the distribution was examined. For half the shifts the production was above 300 tons, and for the other half below that tonnage. Three shifts were notably lower than the others: No. 26, 28, and 36 at 156, 138, and 156 tons, respectively, and were not included in the evaluation. Production during the remaining 42 shifts ranged between 192 and 420 tons, with 31 of these between 240 and 360 tons. The distribution was about the same for each series of tests.

2. Respirable Dust Measurements

All the personal samplers were used in pairs. (See Appendix A for configuration of packages.) The agreement between the filter weights in each pair has been very good. Considering only the personal samplers in return air (the others were in relatively dust-free air most of the time), out of 90 pairs (45 shifts) the difference between the two filter weights was 0.1 mg or less for 69 pairs, and 0.2 mg or less for 81 pairs. There was also surprisingly good agreement between the top and bottom package behind the brattice; i.e., between the two pairs of personal samplers and between the two MRE's. In 23 of the 45 shifts the difference in filter weights for the two MRE's was 0.2 mg or less, and in 35 it was 0.5 mg or less. Of the 10 remaining shifts, two were errors (Shifts 13 and 32) and in four cases the pairs of personal samplers also showed a similar difference between top and bottom (Shifts 12, 29, 42, and 44). This leaves only four shifts: Shifts 4 and 11 where there was also disagreement among the personal samplers, Shift 24 where the weights were 5.3 and 5.9 mg, and Shift 9.

This record indicates at the same time (1) that the sampling instruments as used in these tests were very dependable and (2) that most of the time the average dust concentration behind the line brattice was the same at the 2-foot and 5-foot elevations.

3. Total Airborne Dust Measurements

Total dust was measured with four samplers behind the brattice, two in each package. For one sample one Unico cassette was used for the whole shift, but for the other the cassette was changed between each place, so that 2, 3, or 4 cassettes were used in succession with the same pump. The sum of the weights of dust on these successive cassettes (SC) matched the weight obtained from the single full-shift cassette or total gross sample (TG) fairly well. This is logical, but nevertheless quite remarkable considering the extreme variation of weight from one cut to the next, and the fact that much dust accumulates in the inlet of the cassette and could easily be lost in handling. Again, considering the large weight changes from cut to cut, there was reasonable agreement between the top and bottom packages.

4. Location of Dust Sampling Packages

In order to evaluate dust control at the head of the machine, it was necessary to locate the sampling packages downwind of the machine. Several difficulties existed. If the packages were too close to the machine, the water mist would reach the samplers and might fill up the cyclones. The paste forming on the face of the cyclones might block the sampler inlets. This could be avoided only by close watch of the samplers, and cleaning up the front when necessary. By going too far downwind, on the other hand, one risks contamination by rock dust from the trickle duster. This can occur particularly when curtains are changed or doors opened, and may go unnoticed. Close visual examination of the filters and ashing of the samples were used to try to detect such cases (see following paragraph). This difficulty is aggravated when the line brattice is very short or where there is no line at all, as when starting up from an intersection, and is too frequent to be able to simply avoid shifts which include such cuts. As a rule, samplers were kept at least 10 feet away from the machine.

5. Samples Contaminated with Rock Dust

Rock dust in samples could come from several sources. It could be from eddies forming around the trickle duster bringing the rock dust back upstream. It could happen when the machine starts in a place freshly rock dusted. It could be dropping off a line brattice being torn down. Since limestone is much denser than coal, it does not take much to raise the weight of a filter. Its presence in the air is in no way related to the effectiveness of the dust control measures at the cutting head, so that test results could be completely altered.

A first means of detection is visual observation, particularly of MRE filters. For equal weight a contaminated filter is lighter in color, greyer, and also more uniform, bland. A second more quantitative method is to ash the sample. The method, ashing at 400 C for 16 hours, was that developed on another contract to determine the combustible content of small samples of mine dust. The method was not found practical for samples smaller than 10 mg, thus only full-shift gross samples (TG) could be large enough to be ashed. The results and more details on the method are given in Appendix A. A third means is to compare the weights of adjacent MRE and personal filters. It was found that when rock dust was present, the weight ratio of MRE to personal filters tended to be high.

Using these various criteria in addition to the observations of the sampling crew, it was determined that the return samples behind the brattice (No. 300 packages) for Shifts 11, 12, 24, and 26 should be voided, and that the samples of Shifts 1, 3, 9, and 32 could be questioned.

6. Water Measurements

The same totalizing water meter was used for all sampled shifts except 37 and 38. This meter had been checked in the laboratory to make sure that its accuracy was uniform over the range to be used. Actually, two meters had been installed in parallel in the line just downstream of the section filter at the feed end of the trailing hose, the second one as a back-up for the first one but normally blocked off by a plate (solid disc) in one of the unions. (It is preferred not to use valves because they could be left open; or partially open.) The second meter was used for Shifts 37 and 38 after pressure drop problems which occurred during Shift 36 were finally traced to the meter. It was later found that pieces of coal had lodged in the internals of the meter in spite of the upstream strainer. (This indicates the need for a strainer on each side of a meter, and not just upstream.) The readings from the second meter were corrected to those of the first, following the calibration curves obtained in the laboratory.

In the case of the test machine, which had two additional meters mounted on it, the ratios of the readings of the three meters were checked after every shift, to detect malfunctions or failures or errors as soon as possible. These ratios stayed constant within ± 1 percent for a given mode of operation as long as no abnormal conditions occurred.

As was indicated, a number of venturi tubes had been mounted on the test machine, one each in series with each of the two water meters, and three in the boom for each of the three separate feeds to the cutters. These had been installed prior to the 1973 tests, but did not provide the hoped-for benefits because of a lack of a suitable differential gage. Venturi tubes are convenient because they are small, rugged, inexpensive, and cause little pressure drop. Their disadvantage lies with the need of a gage to read the differential pressure. Such gages are expensive, large, not very rugged, and affected by vibrations or pulsations. The pressure ports are easily plugged, and the sensing lines difficult to purge. The small rugged gage used in the 1975 tests proved to be what was needed. It certainly was not very accurate, but was sufficient to see that the water flows to the three cutters were normal. Several times broken or lost nozzles were detected. Seal leakage could have been detected also, and it was a satisfactory back-up system if one of the water meters had failed (as had happened in previous tests).

7. Air Measurements

Air measurements remain one of the weak points of the underground tests. Conditions near the face are simply not appropriate for acceptable measurement of air quantities. The total volume of intake air and the total volume of return air were measured every shift between No. 5 and No. 6 crosscuts. The figures usually matched within 10 percent.

The quantity of air flowing past the 300 sampling packages is of particular concern, because if both the concentration of dust and the quantity of air are known, the quantity of dust being entrained past the sampling station can be calculated. The air velocity behind the brattice is usually within the uniform linear range of the vane anemometer. However, a correct estimate of the cross-sectional area is difficult, and conditions for stable and uniform flow do not exist. A difference between two successive anemometer readings is not unusual. A 6-inch uncertainty on the width of the space behind the line brattice can represent a 20-percent difference in cross section. Thus, one must accept the possibility of large errors in the calculated air or dust quantities.

8. Sampling Time

The sampling times listed in the tables for each sampling position are the actual lengths of time during which the respective dust samplers were turned on. For the pumps equipped with a counter, such as the MRE and the BC, the sampling time is what the counter should read (or its equivalent in liters) if the pump has functioned properly. This is checked after each shift, and agreement within 5 percent has been easily maintained. This sampling time was not used to calculate any dust concentration, because such concentration is useful only as an average exposure factor and not as a measure of the rate of dust production by the machine. (Actually the exposure is defined only on a full-shift basis, so that the quantity chosen could just as well have been the weight of dust collected on the filter.) In the present case the actual sampling time is immaterial as long as the samplers are turned on any time dust which has been generated by the machine is present. For convenience, the samplers are not turned off during the shift, but if a substantial source of dust were present while the machine was not working, it would be necessary to turn the samplers off, since their purpose here is to evaluate the machine and not other sources of dust.

9. Operating Crew

The crew operating the machine for any particular shift is indicated in the tables. The crews were rotated between the two operating shifts every two weeks. The operating practices of the two crews differed, as reflected most immediately in the cutting rate; that is, the tons per minute produced by the machine (production divided by the elapsed time registered on the counter on the machine). This does not necessarily mean that one operator was mining coal faster; it could just as well mean that the other operator was starting the cutters turning earlier, before actually moving into the face. Of course a higher cutting rate also results in a lower gallons-of-water per ton. Average cutting rate and shift production were calculated for each crew and each machine with the following results (excluding only "low tonnage" shifts).

	Crew A	Crew B
Wet-head Machine		
No. of Shifts	16	14
Cutting Rate, tons/min	2.66	3.20
Shift Production, tons	312	289
Conventional Spray Machine		
No. of Shifts	7	5
Cutting Rate, tons/min	2.79	4.03
Shift Production, tons	315	286

Each group of tests (see Section F) included approximately the same number of shifts with each crew, which should reduce the possible influence of crew procedure on the overall test results. The dust data were also examined "by crew," as shown later in Section H.

10. Mechanical Differences Between the Wet-head Machine and the Conventional Spray Machine

It was noted earlier that in this last series of tests the two machines were not identical. It is, of course, not possible to know if these differences have any influence on the dust generation. From the figures given above, it appears that there is a difference in cutting rate, since both operators achieve a higher figure with the conventional spray machine. It may be noted that this increased rate did not seem to have any effect on the shift production.

F. Effectiveness of Wet-head as Determined from Full-shift Dust Samples

All the data obtained during the October-November 1975 tests at Robena mine are given in Tables C-1 to 9 in Appendix C, as previously indicated. From the 45 shifts available, several groups were retained for analysis, according to the chronology previously given, and the criteria for validity discussed in the preceding paragraphs. These groups are: (1) Shifts 1 to 14, the first shifts of operation of the wet-head machine with the large 1-inch nozzles in front of the bit block; (2) Shifts 21 to 24, the first shifts sampled with the conventional spray machine, fixed nozzles on the boom, nozzles as well maintained as practical, but otherwise with distribution of water as existed at the time (as noted earlier, this resulted in a total water flow below that of the test machine); (3) Shifts 29 to 34, still conventional spray machine but repiped in order to increase the total amount of water to the machine and to direct a larger portion of it to the front boom sprays; (4) Shifts 35 to 46, wet-head machine with 3/8-inch nozzles at the base of the bit block.

Within these four groups of shifts, the only shifts not included in the analysis were those indicated earlier; that is, those where the production was notably lower than average, and those where the dust samples had been definitely contaminated by rock dust. Scrutinizing the dust samples further, a few appeared somewhat questionable, and the corresponding shifts were dropped resulting in (5) a group of six shifts for the wet-head machine with the 1-inch nozzles and (6) a group of five shifts for the conventional spray machine (retained only were shifts where all respirable dust samples behind the brattice were available; i.e., two MRE and four personal samples). One must remember, however, that variations in dust weight from shift to shift are large, and one risks erroneous conclusions when considering too few shifts. Further, as indicated previously, the machine operator does affect the data obtained, and it is desirable to have both crews equally represented in any grouping of shifts. (As it turned out the further elimination of shifts did not really change the results obtained from the first grouping.)

Table 4 is a summary of test data given in detail in Tables 5 through 10. The variables judged most significant relative to the tests being conducted were averaged for each group of shifts in a given operating mode, for instance, shifts with the wet-head machine and 1-inch nozzles on the cutter head. For evaluation of airborne dust generated, the data obtained from the samplers located downwind of the machine behind the brattice were used (a discussion of the samplers located on the machine follows later).

The tables indicate that the lowest dust in the return was found for the wet-head machine with 1-inch nozzles (Shifts 1-14), and the highest for the conventional spray machine operating "as is" (Shifts 21-24). They also show a significant reduction in dust just from an increase and redistribution of the spray water on the conventional spray machine (Shifts 29-34). That increase in water brought the flow rate on the conventional spray machine to that of the wet-head machine; but, because of the higher cutting rate, the rate in terms of gal/ton still remained below that of the wet-head machine. It is not possible to say whether another small water rate increase would have further reduced the dust with the conventional spray machine, or whether the high dust level found for the first three shifts was typical (three shifts are not enough to indicate a trend). However, if one examines separately the 11 shifts included in the wet-head group (1 to 14), only Shifts 9 and 10 have all respirable dust samples approaching the average of the six "best" conventional spray shifts (29 to 34), and in no shift is the total airborne dust level above half of the average of the best conventional spray shifts. Thus it seems reasonable to conclude that the wet-head provides a substantial dust reduction.

Some other factors are somewhat "slanted" in favor of the conventional spray machine, re-enforcing the conclusion that the wet-head is effective. For instance, the average production during the shifts compared was slightly higher for the wet-head, which should have resulted in greater dust generation. In addition, the wet-head is not completely wet since the end cutters are not sprayed except from fallout from the outer cutters. Calculation of the dust weights by crew shows that they are lower for the B crew, the same which had a higher cutting rate. If dust weight and cutting rate are related, then the conventional spray machine is again favored since it has a higher cutting rate than the wet-head machine. The airflows behind the brattice seem to have covered the same range for both machines. The average airflow per cut was just about the same; within both cases some cuts showed less than 10,000 cfm, and others more than 20,000 cfm.

TABLE 4. SUMMARY OF TEST DATA FOR WET-HEAD (BCR) AND CONVENTIONAL SPRAY (USS) MACHINES

Machine	BCR	USS	USS	BCR	BCR	USS
Cutter nozzles	1-inch	none	none	3/8 inch	1-inch	none
Shift series	1-14	21-24	29-34	35-46	5-8, 10, 14	29-34
Shifts omitted	[1]	[2]	[3]	[4]	[5]	[6]
Number of shifts A crew	6	1	3	6	4	3
B crew	5	2	3	5	2	2
Average per shift						
Production, tons	315	302	299	288	306	310
Cutting time, minutes	112	90	87	99	114	93
Cutting rate, tons per minute	2.8	3.3	3.4	2.9	2.7	3.3
Water rate, gallons per minute	24.2	22.1	25.2	26.6	24.2	25.1
gallons per ton	8.6	6.6	7.3	9.2	9.0	7.5
Dust samples from 300H and 300L return packages: number of samples averaged and average weight (standard deviation), mg						
M number	19	6	10	22	12	10
average weight, (standard deviation)	1.98(.6)	3.28(.9)	2.50(.8)	2.03(.5)	1.80(.6)	2.50(.8)
P number	43	12	24	44	24	20
average weight, (standard deviation)	0.68(.2)	1.67(.6)	1.02(.4)	0.92(.3)	0.62(.2)	1.09(.4)
TG number	21	6	12	22	12	10
average weight, (standard deviation)	20.0(11)	59.8(22)	44.7(27)	23.6(11)	18.8(11)	48.9(27)
SC number	21	6	10	22	12	8
average weight, (standard deviation)	18.7(10)	62.9(26)	41.3(28)	24.8(12)	17.2(11)	46.4(29)

[1] First series with test machine and large nozzles. Shifts omitted from average: 2 (power failure) 11 and 12 (rock dust contamination).

[2] First sampling of USS machine "as is", spray water 22 gpm. Shifts omitted: 24 (rock dust contamination).

[3] USS machine after adjustment of spray water piping.

[4] Test machine with small nozzles. Shifts omitted: 36 (low production).

[5] Same as [1], but excluding any shift questionable at all: 1, 3 and 9 (possible rock dust contamination) 4 and 13 (sample weights).

[6] Same as [3], but excluding shift 32 (possible rock dust contamination).

TABLE 5. OPERATING DATA FOR WET-HEAD MACHINE
SHIFTS 1 TO 14: 1-IN. NOZZLES

Shift Number	01	03	04	05	06	07	08	09	10	13	14
Date (1975)	10-15	10-16	10-16	10-17	10-17	10-20	10-20	10-21	10-21	10-23	10-23
Crew	A	A	B	A	B	B	A	B	A	B	A
Production, tons	336	390	324	324	198	294	300	360	420	216	300
Number of cuts	4	4	3	3	2	3	4	4	5	2	3
Cutting time, minutes	123	144	81	132	63	102	111	132	153	66	123
Cutting rate, tons/min	2.7	2.7	4.0	2.4	3.1	2.9	2.7	2.7	2.7	3.3	3.4
Water consumption during shift, gallons											
Total to machine	3027	3338	2130	3217	1657	2292	2563	3059	3942	1549	2917
Per ton of coal	9.0	8.6	6.6	9.9	8.4	7.8	8.5	8.5	9.4	7.2	9.7
Through cutters	1768	1942	1250	1895	991	1369	1511	1859	2396	915	1710
Through side sprays	945	1054	650	979	502	677	784	904	1120	477	900
Average water flow during shift, gpm (calculated from shift consumption and cutting time)											
Total to machine	24.6	23.2	26.3	24.4	26.3	22.5	23.1	23.2	25.8	23.5	23.7
Through cutters	14.4	13.5	15.4	14.4	15.7	13.4	13.6	14.1	15.7	13.9	13.9
Through side sprays	7.7	7.3	8.0	7.4	8.0	6.6	7.1	6.9	7.3	7.2	7.3
Water flow rate spot checks, gpm (1 min. readings while cutting)											
Total to machine	24.0	24.9	26.4	24.8	25.8	25.8	NA	25.2	26.5	25.3	25.0
Through cutters	14.2	14.6	14.8	15.0	15.1	15.1	15.6	15.5	15.9	15.2	14.8
Through side sprays	7.5	7.8	7.8	7.7	7.9	7.9	7.0	7.6	7.6	7.8	7.7
Water pressure at operator's cab, psi	160	165	165	160	170	160	165	170	165	170	165
Airflow, 1000 cfm											
Total section intake	NA	NA	NA	38	49	40	39	34	40	35	46
Total section return	NA	NA	NA	42	48	35	41	38	47	39	43

TABLE 6. OPERATING DATA FOR CONVENTIONAL SPRAY MACHINE
SHIFTS 29 TO 34

Shift Number	29	30	31	32	33	34
Date (1975)	11-11	11-11	11-12	11-12	11-13	11-13
Crew	A	B	A	B	A	B
Production, tons	258	258	300	246	408	324
Number of cuts	3	3	3	3	4	3
Cutting time, minutes	93	66	102	54	132	72
Cutting rate, tons/min	2.8	3.9	2.9	4.6	3.1	4.5
Water consumption during shift, gallons						
Total to machine	2342	1629	2456	1408	3433	1820
Per ton of coal	9.1	6.3	8.2	5.7	8.4	5.6
Through cutters	--	--	--	--	--	--
Through side sprays	--	--	--	--	--	--
Average water flow during shift, gpm (calculated from shift consumption and cutting time)						
Total to machine	25.2	24.7	24.1	26.1	26.0	25.3
Through cutters	--	--	--	--	--	--
Through side sprays	--	--	--	--	--	--
Water flow rate spot checks, gpm (1 min readings while cutting)						
Total to machine	28.1	26.8	27.3	26.7	27.1	27.8
Through cutters	--	--	--	--	--	--
Through side sprays	--	--	--	--	--	--
Water pressure at operator's cab, psi	140	165	150	150	130	130
Airflow, 1000 cfm						
Total section intake	41	44	42	35	44	45
Total section return	44	46	42	43	44	42

TABLE 7. OPERATING DATA FOR WET-HEAD MACHINE
SHIFTS 35 TO 46: 3/8-IN. NOZZLES

Shift Number	35	37	38	39	40	41	42	43	44	45	46
Date (1975)	11-14	11-17	11-17	11-18	11-18	11-19	11-19	11-20	11-20	11-21	11-21
Crew	A	B	A	B	A	B	A	B	A	B	A
Production, tons	276	330	192	318	384	228	330	312	258	276	264
Number of cuts	3	3	3	3	4	2	3	3	3	3	4
Cutting time, minutes	102	96	75	108	120	72	135	93	102	93	96
Cutting rate, tons/min	2.7	3.4	2.6	2.9	3.2	3.2	2.4	3.4	2.5	3.0	2.7
Water consumption during shift, gallons											
Total to machine	2640	2620	2142	2805	3467	1831	3460	2380	2672	2504	2546
Per ton of coal	9.6	8.2	11.6	8.8	9.0	8.0	10.5	7.6	10.4	9.1	9.6
Through cutters	1597	1515	1239	1741	2146	1138	2106	1486	1667	1604	1585
Through side sprays	748	693	550	804	922	522	977	646	725	676	697
Average water flow during shift, gpm (calculated from shift consumption and cutting time)											
Total to machine	25.9	28.3	29.6	26.0	28.9	25.4	25.6	25.6	26.2	26.9	26.5
Through cutters	15.7	15.8	16.5	16.1	17.9	15.8	15.6	16.0	16.3	17.2	16.5
Through side sprays	7.3	7.2	7.3	7.4	7.7	7.2	7.2	6.9	7.1	7.3	7.3
Water flow rate spot checks, gpm (1 min readings while cutting)											
Total to machine	25.0	27.8	28.4	26.1	26.3	25.6	26.0	26.3	26.3	25.9	25.6
Through cutters	15.4	16.4	17.6	16.4	16.3	16.2	16.1	16.8	16.5	16.8	16.2
Through side sprays	7.2	7.3	7.6	7.3	7.0	7.4	7.3	7.3	7.2	7.2	7.1
Water pressure at operator's cab, psi	165	180	185	175	140	165	170	170	170	170	160
Airflow, 1000 cfm											
Total section intake	43	37	38	45	38	35	37	36	37	42	44
Total section return	43	41	49	46	44	40	42	41	42	42	40

TABLE 8. WEIGHT OF DUST (mg) COLLECTED AT EACH SAMPLING LOCATION, WET-HEAD MACHINE
SHIFTS 1 TO 14: 1-IN. NOZZLES

Shift Number	01	03	04	05	06	07	08	09	10	13	14
Intake to section (Sampling Package No. 100)											
Sampling time, min	341	366	352	377	334	372	376	378	374	354	353
Dust weight, mg											
LP	0.1	NA	0.1	0.1	NA	0.1	0.1	0.1	0.0	0.0	NA
RP	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.0	0.0	0.0
Mining machine (Sampling Package No. 200)											
Sampling time, min	355	357	344	366	276	365	276	371	366	340	342
Dust weight, mg											
LP	0.2	0.3	0.3	0.1	NA	0.4	0.1	0.7	0.3	0.2	0.1
RP	NA	0.2	0.2	0.1	0.2	0.4	0.1	0.9	0.4	0.1	0.0
M	0.7	0.7	0.3	0.2	0.3	0.7	0.3	1.9	0.7	0.7	0.4
Return behind brattice, top (Sampling Package No. 300H)											
Sampling time, min	352	357	340	362	272	361	280	364	349	339	338
Dust weight, mg											
LP	0.7	0.5	0.8	0.5	0.4	0.8	0.4	0.8	0.9	0.5	0.6
RP	0.8	0.6	1.2	0.5	0.4	0.8	0.5	0.8	1.1	0.5	0.6
M	2.9	2.1	2.0	1.6	1.3	1.8	1.4	3.5	2.9	1.5	1.7
TG	NA	41.6	12.6	7.4	8.2	28.2	21.3	25.5	27.3	11.1	8.4
SC	NA	29.1	15.1	7.2	8.0	25.6	16.6	25.9	24.1	11.6	7.9
Return behind brattice, bottom (Sampling Package No. 300L)											
Sampling time, min	352	357	340	362	272	361	280	364	349	339	338
Dust weight, mg											
LP	0.6	0.6	1.1	0.4	0.4	0.7	0.5	1.0	1.1	0.5	0.6
RP	NA	0.6	1.1	0.5	0.5	0.7	0.5	1.1	0.9	0.6	0.6
M	2.7	2.3	1.1	1.7	1.1	1.7	1.6	2.6	2.9	2.7*	1.9
TG	15.3	34.7	11.0	8.7	10.7	22.8	40.0	20.6	28.6	23.3	13.7
SC	16.2	39.8	11.0	5.6	11.4	19.5	41.2	19.0	27.6	19.9	11.1

* Filter appears contaminated

TABLE 9. WEIGHT OF DUST (mg) COLLECTED AT EACH SAMPLING LOCATION, CONVENTIONAL SPRAY MACHINE SHIFTS 29 TO 34

Shift Number		29	30	31	32	33	34
Intake to section (Sampling Package No. 100)							
Sampling time, min		361	334	367	285	379	287
Dust weight, mg							
	LP	0.2	0.1	0.1	0.1	0.1	0.1
	RP	0.2	0.1	0.1	0.1	0.1	0.1
Mining machine (Sampling Package No. 200)							
Sampling time, min		358	319	364	275	375	275
Dust weight, mg							
	LP	0.2	0.3	0.3	0.3	0.5	0.3
	RP	0.3	0.4	0.3	0.3	0.5	0.4
	M	0.5	1.0	0.7	NA	0.8	0.9
Return behind brattice, top (Sampling Package No. 300H)							
Sampling time, min		358	317	361	262	367	258
Dust weight, mg							
	LP	0.5	0.8	1.0	0.7	1.7	1.2
	RP	0.6	0.8	1.1	0.7	1.8	1.2
	M	1.3	1.6	2.4	NA	3.9	2.7
	TG	14.5	26.5	70.4	20.3	63.5	24.4
	SC	17.3	32.1	NA	18.1	72.9	28.3
Return behind brattice, bottom (Sampling Package No. 300L)							
Sampling time, min		358	317	361	262	367	258
Dust weight, mg							
	LP	0.7	0.7	1.0	0.6	1.6	1.5
	RP	0.8	0.7	1.0	0.6	1.7	1.5
	M	2.0	1.9	2.5	NA	3.5	3.2
	TG	33.9	27.5	90.8	26.6	86.3	51.6
	SC	39.0	26.3	NA	23.5	104.2	51.4

TABLE 10. WEIGHT OF DUST (mg) COLLECTED AT EACH SAMPLING LOCATION, WET-HEAD MACHINE
SHIFTS 35 TO 46: 3/8-IN. NOZZLES

Shift Number		35	37	38	39	40	41	42	43	44	45	46
Intake to section (Sampling Package No. 100)												
Sampling time, min		384	366	338	368	355	318	370	358	308	379	325
Dust weight, mg												
	LP	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.0	0.1	0.1
	RP	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	NA
Mining machine (Sampling Package No. 200)												
Sampling time, min		386	365	329	366	351	316	357	355	282	374	317
Dust weight, mg												
	LP	0.5	0.8	0.4	0.8	0.4	0.4	0.5	0.4	0.2	0.4	0.2
	RP	0.5	0.7	0.4	0.8	0.4	0.3	0.5	0.4	0.1	0.4	0.2
	M	1.0	1.7	0.8	1.9	0.9	0.6	1.0	1.2	0.2	NA	0.7
Return behind brattice, top (Sampling Package No. 300H)												
Sampling time, min		376	363	316	362	343	314	339	355	272	369	307
Dust weight, mg												
	LP	0.8	0.4	0.3	1.4	1.2	0.7	1.4	1.0	0.7	0.9	0.9
	RP	0.8	0.7	0.3	1.2	1.3	0.8	1.2	0.9	0.8	NA	0.8
	M	1.9	1.5	0.7	2.5	2.2	1.5	3.0	2.5	1.6	2.2	1.9
	TG	13.7	10.3	4.4	36.6	20.9	18.8	20.5	31.0	23.4	18.7	19.7
	SC	13.6	12.0	4.2	31.9	22.3	21.8	19.0	34.4	35.9	14.5	20.8
Return behind brattice, bottom (Sampling Package No. 300L)												
Sampling time, min		376	363	316	362	343	314	339	355	272	369	307
Dust weight, mg												
	LP	0.9	0.8	0.3	1.2	1.3	0.8	1.1	1.3	0.9	0.9	0.9
	RP	0.9	0.8	0.4	1.2	1.2	0.9	1.2	1.3	1.1	1.1	0.8
	M	2.4	1.8	1.0	2.1	2.6	1.8	2.4	2.7	2.2	2.3	1.9
	TG	19.0	15.8	8.1	38.5	36.3	31.5	24.6	46.8	31.8	27.4	22.7
	SC	18.8	14.3	7.4	38.0	32.1	34.0	23.8	51.7	31.8	40.8	22.8

G. Effectiveness of Wet-head as Determined from Single-cut Total Airborne Dust Samples

As indicated previously, only the total airborne dust could be measured separately for each cut. The dust weights obtained, two samples per cut (one from the high 300 package, the other from the low), are listed at the bottom of Tables C-4, -5, and -6 in Appendix C.

For each of the same groups of shifts discussed previously; i.e., 1-14, 29-34, and 35-46, the number of cuts for which the weight of airborne dust (average of high and low samples) fell within increments of weights are shown in Table 11. The cuts where rock dust contamination occurred are not included. From these three groups of shifts data were obtained for totals of 37 cuts for the wet-head machine with 1-inch sprays, 36 for the same machine with 3/8-inch sprays, but only 17 for the conventional spray machine. This smaller number for the conventional machine should be kept in mind when looking at the numbers in Table 11.

These same data are shown in graph form in Figure 19, but using the percentage of cuts rather than the number within each group, which fall within a weight range. This graph shows clearly the large gain in airborne dust control of the wet-head machine over the conventional spray machine, particularly with the large 1-inch nozzles. For the wet-head machine with the large nozzles, the gross dust weight was less than 10 mg for 92 percent of the cuts, while for the conventional spray machine this was the case for only 41 percent of the cuts. In 24 percent of the cuts, the conventional machine produced a dust weight above 20 mg, topping at 38 mg, while the wet-head never exceeded 20 mg with either kind of nozzle. The median dust weight was 5.3 mg for the wet-head with large nozzles, and 12.3 mg for the conventional machine, or well above twice as much.

No clear correlation could be found between dust weight and other variables such as tonnage, air velocity, distance to the face, etc., which could explain the relatively large differences in dust weight which occurred from cut to cut. On the other hand, as noted previously, there was generally good agreement between the weight of the single gross sample (TG) collected for the full shift, and the sum (SC) of the samples collected during each of the successive cuts, and also between the weights of the top and bottom samples in a given cut. This at least implies that the large weight differences found between cuts are real, and not due to sampler malfunctioning.

TABLE 11. NUMBER OF CUTS FOR WHICH TOTAL AIRBORNE DUST IN RETURN IS WITHIN GIVEN WEIGHT RANGE

	Wet-head 1-inch Nozzles (Shifts 1-14)	Wet-head 3/8-inch Nozzles (Shifts 35-46)	Conventional Sprays (Shifts 29-34)
Number of cuts for following dust weight increments, mg			
0 to 5.0	18	11	3
5.1 to 10.0	16	14	4
10.1 to 15.0	1	6	6
15.1 to 20.0	2	5	0
20.1 to 25.0	0	0	1
25.1 to 30.0	0	0	1
30.1 to 35.1	0	0	1
35.1 to 40.0	0	0	1
Total number of cuts	37	36	17
Median dust weight, mg	5.3	7.2	12.3
Average production per cut, tons	94	92	91

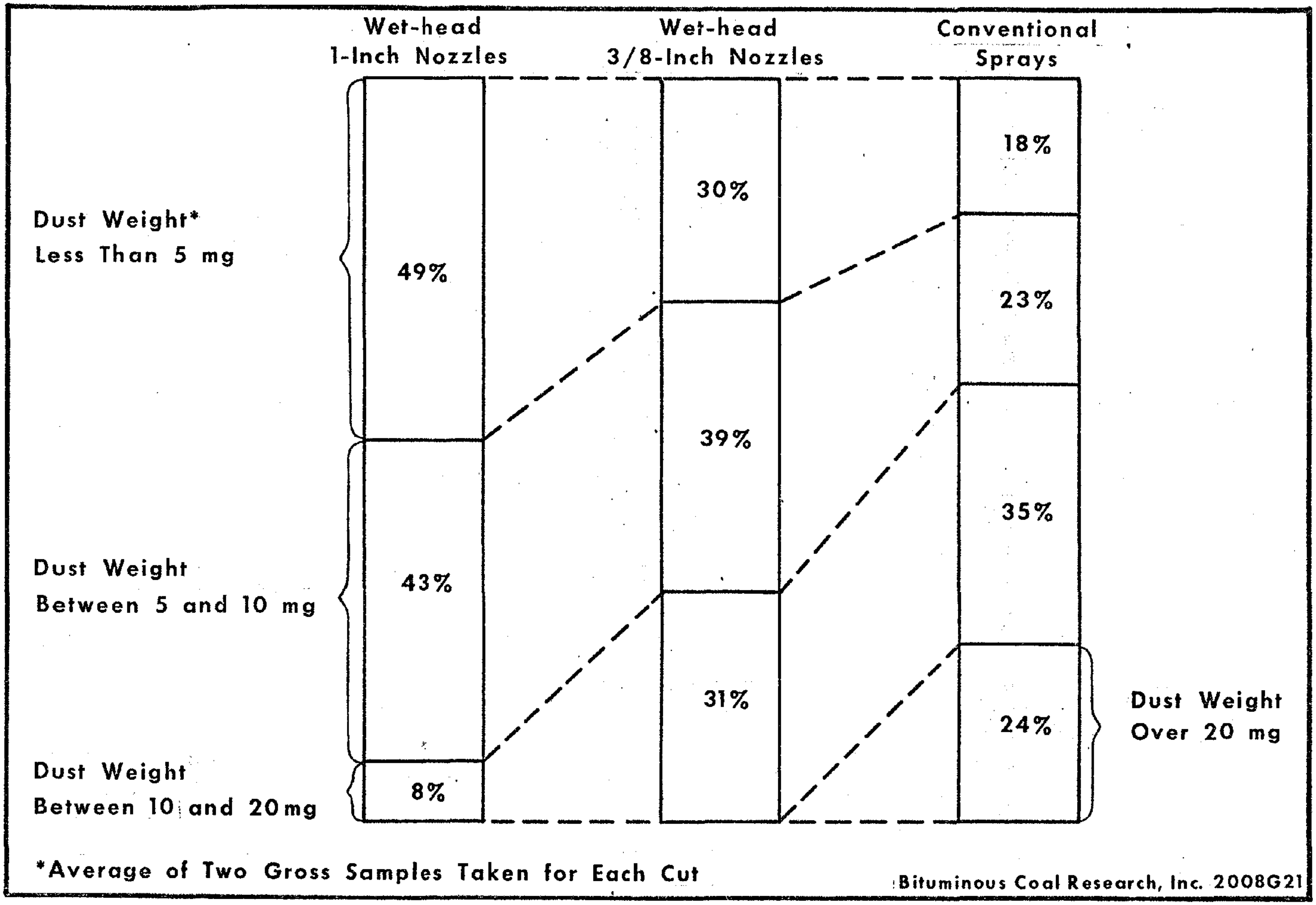


Figure 19. Distribution of Cuts by Weight of Total Airborne Dust in Return Behind Brattice - Percentage of Cuts in Each Weight Range

H. Dust Conditions at Mining Machine and Effect of Operating Crew on Test Data

As indicated earlier, exhaust ventilation is used at the face at Robena; air volumes are large and the line brattice is usually well installed. Thus, the sampling package located on the continuous mining machine most of the time sampled air uncontaminated by dust produced at the face.

On only seven occasions did this package record noticeable dust. For Shifts 9, 15, 17, 21, 37, 39, and 43 the weight of the MRE sample was higher than 1 mg, and the weights of the personal samples were also higher than usual. This always occurred with the same operating crew (crew B), and perhaps is related to their particular procedure. This is one of the indications that the operating crew may make a difference on test results.

To further delineate bias introduced by the sampling crew a number of variables from Table 4 were calculated separately for each crew, and for the three most significant series of shifts already chosen for Table 4, namely series 1-14 (wet-head machine with 1-in. nozzles), series 29-34 (conventional spray machine) and series 35-46 (wet-head machine with 3/8-in. nozzles). Results of this calculation are shown in Table 12.

As previously indicated, it may be seen that crew B had a higher cutting rate than crew A, or, equivalently, that crew A kept the cutter head in motion for relatively longer periods.

The return dust weights appear somewhat higher for crew A than for crew B. However, for the groups of shifts selected, the crews did not achieve exactly the same tonnage per shift for each machine (as they did overall for the full duration of the tests). If the dust weights are corrected for this difference to a nominal 300-ton production, about average for the shifts considered, the difference between the two crews practically disappears.

Besides cutting time (or cutting rate), the only variable which remains significantly different between the two crews is the rate of water usage per ton of coal, which thus does not appear to have a direct effect on dust present in the return (within the conditions of the tests).

The average respirable dust weights at the mining machine package are also shown in Table 12. The difference between crews is very marked here, crew B averaging around 75 percent more dust than crew A. (This is the same crew which was noted earlier as having MRE readings above 1 mg.)

The respirable dust level at the machine seems to have increased also as the tests progressed, although the differences between groups of tests were much less than the difference between crews. In order to keep those observations in perspective, however, it should be pointed out again that the dust levels at the machine were always low, as should be expected when using a well-maintained exhaust ventilation system. The differences considered may appear relatively significant percentage wise, but in actual weight they are small. (Note also that the standard deviations for the machine samples are rather high.)

TABLE 12. EFFECT OF OPERATING CREW ON TEST DATA

Shift Series	1 - 14		29 - 34		35 - 46	
Crew	A	B	A	B	A	B
No. of Shifts	6	5	3	3	6	5
Average per shift						
production, tons	345	278	322	276	284	293
cutting rate, tons/min	2.6	3.1	2.9	4.3	2.7	3.2
water rate, gpm	24.2	24.1	25.2	25.3	26.9	26.3
gal/ton	9.2	7.7	8.5	5.9	9.9	8.3
Dust Samples from 300H and 300L Return Packages:						
Average Weight (Standard Deviation), mg:						
M	2.14(.6)	1.71(.5)	2.60(1.0)	2.35(.7)	1.98(.6)	2.09(.4)
P	0.64(.2)	0.73(.3)	1.11(.5)	0.92(.4)	0.90(.3)	0.96(.3)
TG	22.4 (13)	17.4 (7)	59.9 (30)	29.5 (11)	20.4 (9)	27.5 (11)
Average Weight "Corrected to 300 Tons," mg:						
M	1.86	1.85	2.42	2.55	2.09	2.14
P	0.56	0.78	1.03	1.00	0.95	0.98
TG	19.5	18.8	55.8	32.1	21.5	28.2
Dust Samples from Mining Machine Package:						
Average Weight (Standard Deviation), mg:						
M	0.50(.2)	0.78(.6)	0.67(.2)	0.95(.1)	0.77(.3)	1.35(.6)
P	0.18(.1)	0.36(.3)	0.35(.1)	0.33(.0)	0.36(.1)	0.54(.2)
Average Weight "Corrected to 300 Tons," mg:						
	0.43	0.84	0.62	1.03	0.81	1.38
	0.16	0.39	0.33	0.36	0.38	0.55

VIII. CONCLUSIONS

The latest series of underground tests with a Lee-Norse Hard Head 105 continuous mining machine has proved that dust generation at the face is better controlled by water sprays located near each bit on the cutters than it is by fixed sprays on the boom behind the cutters. The reduction in respirable dust measured behind the brattice in the return air from the machine was of the order of 25 percent, and, in total airborne dust, 60 to 70 percent. Respirable dust readings in front of the operator's cab were relatively low throughout the tests, as would be expected since exhaust face ventilation is used at Robena, with large volumes of air and a well-installed line brattice. Any change in dust level at that location was more related to the crew operating the machine at the time than to anything else.

The large reduction in total airborne dust in return air is of great significance, because it indicates a possible similar reduction in the amount of float dust accumulating in the returns and consequent improved conditions with respect to explosion hazard.

The improvement in dust control also results in better visibility. The operator can see the face and the bits, which should facilitate the operation of the machine. He does not get wetted by the sprays, as had been feared. There was no evidence, either, of excess water running back under the machine and softening the bottom. Thus, phasing the head; i.e., interrupting water feed to the nozzles when they face the rear of the machine, does not appear to be necessary.

It should be noted that the substantial reduction in dust level was obtained with a cutting head which was about 80 percent wet-head, hence some further improvement should be gained if all the bits on the cutters were sprayed, particularly at the ends of the head.

There had been some concern at the beginning of this study that nozzles located so close to the coal face would constantly become plugged with coal. This is not the case. There is wear on the nozzles, and probably they should be better protected than they were on the test machine, but there is less wear and tear than there is on the fixed nozzles located at the bottom front edge of the boom. Furthermore, the nozzles on the head are more accessible and easier to change than the fixed nozzles on the boom.

Because of the adjacent sprays, the plumb bob bits stayed clean and rotated freely in their supports. There was even wear of the tip, not the flattening on one side so common on standard heads.

Various problems encountered in this project, as well as in other projects dealing with dust control at the face, point out the importance of proper engineering practices if any kind of water spray is to be effective at all. This cannot be over-emphasized.

The first problem faced was that of dirty spray water, resulting in plugging of the nozzles. There should be a filter of sufficient capacity in the section. This does not preclude individual strainers in each nozzle, usually provided by the manufacturer, but often neglected. A wet-head, in particular, will have many nozzles, each with a rather small orifice, and one small particle can plug it. An additional filter(s) somewhere in the boom before the distribution manifold will not only increase the time between clean-up of the nozzle strainers, but also protect the water seals of the cutters. Not only are there times when the trailing hose or other parts of the piping will be damaged, causing dirt to enter the system, but also some scale and rust particles eventually come loose from the cooling circuits of the motors or the channels through the machine frame.

A second important item is to have all water channels of sufficient capacity. It is almost an exercise in futility to pipe a cutter head for water, and then to provide for no more than a few gallons capacity. A new machine should have the capacity for no less than 20 gpm through the cutters with a minimum of pressure drop.

Third, corrosion is often a problem. Not only does rust contribute to plugging of nozzles (and filters eventually), but the corroded channels gradually reduce water flow. Holes drilled through frame members or channels cast in a part should be avoided, as well as channels made up of welded plates. Slag from welding or inaccuracy of fabrication contribute to smaller cross sections than designed. If used at all, such channels should be straight and have access plugs for clean-up. Many trade-offs are inevitable when designing a mining machine, but the water system must not be compromised.

Another item commonly neglected is the trailing water hose. Anything less than 1-1/4-inch ID is too small, and inevitable repairs should not be made with smaller diameter fittings or couplings which reduce the water flow.

Finally, one must come back to the question discussed at length earlier, that of the head rotary water seal. No wet-head can work without a durable seal, and therein lies the problem. The Fluorocarbon seal used in the last series of tests was the best found so far which fitted the space available in the HH-105 machine, but it is still far from the dependable system which is needed. Development work should continue in three directions: material for seal (Fluorocarbon's high-density polyethylene was a step in the right direction), smaller diameter (a 22-inch diameter causes too large a peripheral speed and a difficult problem of heat dissipation), and ease of replacement.

IX. INVENTIONS

There do not appear to be any patentable results or inventions from the work performed under this contract.

APPENDIX A

DUST SAMPLING EQUIPMENT AND ANALYTICAL PROCEDURES

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APPENDIX A

DUST SAMPLING EQUIPMENT AND ANALYTICAL PROCEDURES

I. SAMPLERS AND SAMPLING PACKAGES

Equipment utilized for dust sampling included:

1. MRE Gravimetric Dust Sampler Type 113A with 4-channel elutriator plate calibrated to 2.5 lpm.

2. MSA Model G personal sampler pump, fitted with SKC pulsation dampener and SKC voltage regulator and calibrated to 2.0 lpm.

3. Willson Casella Type BC personal sampler pump with integral pulsation dampener and counter, calibrated to 2.0 lpm.

4. Millipore reusable 37 mm filter cassette with stainless steel support screen (MSA parts No. 625412 and 456224) mounted on top of 10 mm nylon cyclone with stainless steel coupler (part No. 625412).

5. Unico reusable 37 mm filter cassette (National Mine Service part No. P8130-0022) with same stainless steel support screen as above, used without cyclone for collection of total airborne dust sample.

The samplers were grouped in packages as follows:

1. No. 100, or intake, package shown in Figure A-1 and consisting of two BC pumps and two Millipore cassettes with cyclones.

2. No. 200, or machine, or J, package shown in Figure A-2. This same type of package was used on the machine for contracts H0232060 and 61, and consists of one MRE and two MSA pumps with Millipore cassettes and cyclones.

3. No. 300, or return, package shown in Figures A-3 and A-4. This package contained one MRE and two MSA pumps with Millipore cassettes and cyclones for sampling of respirable dust. It also contained two additional MSA pumps to sample total airborne dust with Unico cassettes without cyclones. This package was placed in the return with the front face shown in Figure A-3 upstream; i.e., with the openings of the cyclones and of the Unico cassettes facing into the general direction of the airflow. The MRE was thus perpendicular to the direction of the air; i.e., the flow was from left to right as seen in Figure A-4.

II. FILTER MATERIALS AND WEIGHING PROCEDURE

A. Analytical Balance

Mettler automatic weighing system consisting of electronic analytical balance HE20, control unit BE20, and digital display BA28.

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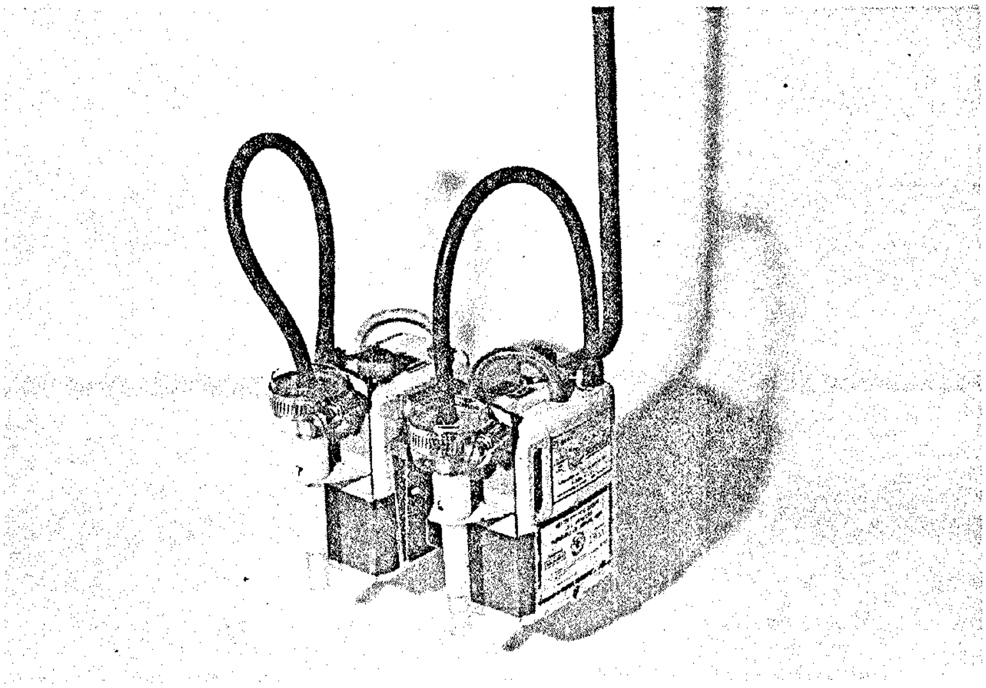

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Figure A-1. Intake Sampler Package No. 100

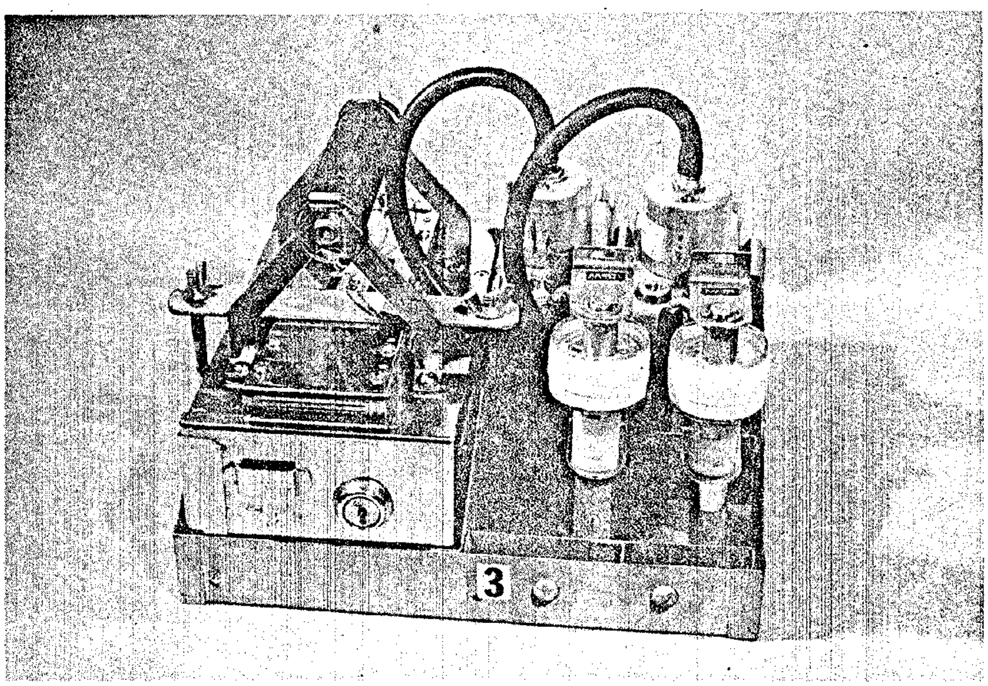

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Figure A-2. "J" Type or Mining Machine Sampler Package No. 200

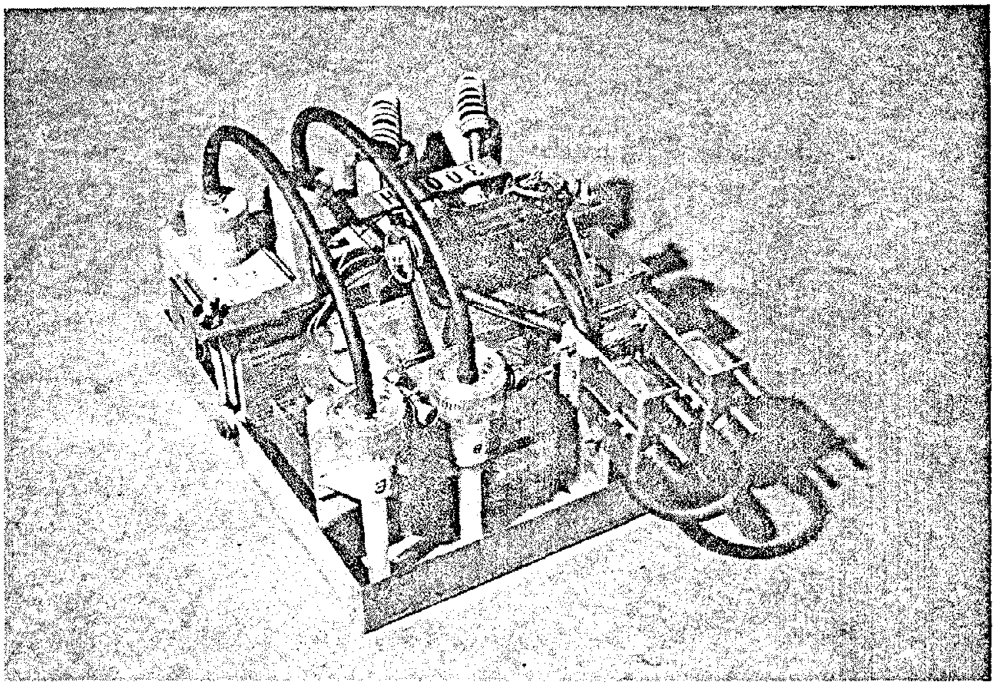

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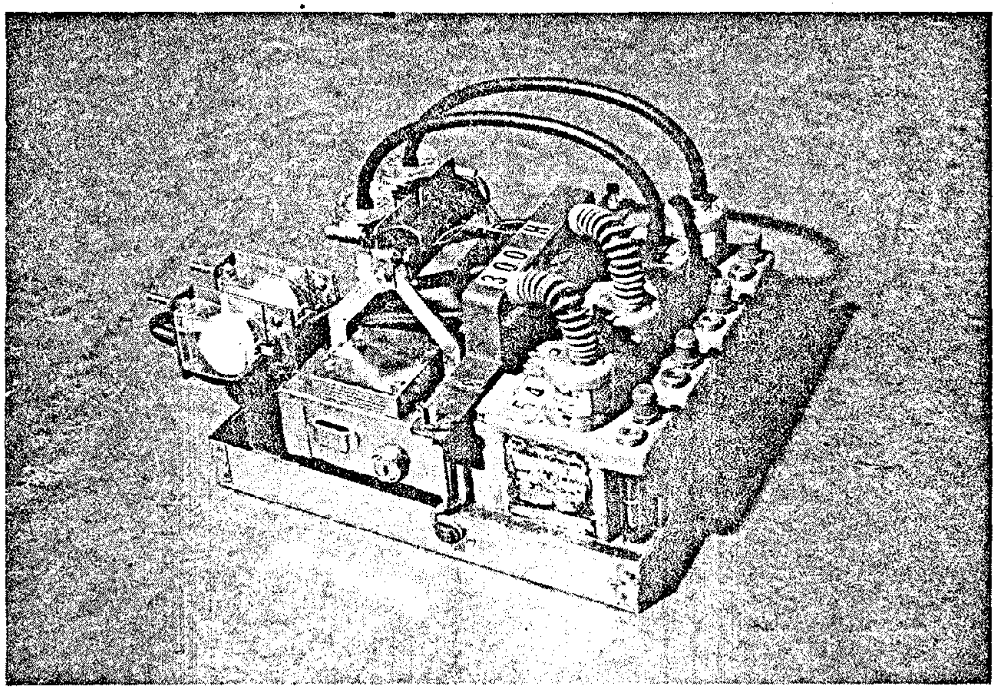
Figure A-3. Return Sampler Package No. 300, Upstream View



2008P20

Figure A-4. Return Sampler Package No. 300, Side View

B. Filter Material

Gelman Instrument Co. Vinyl Metricel, a polyvinylchloride membrane filter (VM-1), 5.0μ pore size, 37 mm diameter for Millipore and Unico cassettes, 55 mm diameter for MRE sampler.

C. Weighing Procedure

1. Weighing Before Use: All filters are first dried in a vacuum desiccator for one hour at room temperature and a vacuum of approximately 28 inches of mercury. Air is then admitted slowly to the desiccator through a gas-drying column packed with Drierite. The filters are removed from the desiccator one at a time, weighed, and the weights recorded to the nearest 0.01 milligram on the corresponding shift data sheet.

The MRE filters and the personal sampler filters are weighed alone (without cassette). After weighing, the MRE filters are returned to the Petri dish, and the personal filters are returned to the Millipore cassette in which they were desiccated. The cassette is pressed closed tight, and finally all the cassettes are checked for leaks. (The use of a self-sealing cellulose band around the cassette was abandoned when it was found that the band would become loose again under high humidity, thus could not be depended upon to protect against leaks.)

For the Unico cassettes, intended for total airborne samples, the inner capsule is weighed whole with filter and support screen. After weighing, the inner capsule is inserted in the outer envelope. This inner capsule was the reason for choosing the Unico cassette for gross samples. These samples are sometimes large, the particles do not adhere to the filter material and remain loose in the capsule, thus it is more practical to weigh the whole capsule.

2. Weighing After Use: After use the filters are brought back to the laboratory for postweighing.

The filter cassettes or Petri dishes are carefully opened and the filters are subjected to vacuum desiccation in the same manner as described above for the preweighing process. Care is taken to bring the contents of the desiccator to equilibrium slowly, so as not to disturb the dust on the filters. The filters are examined and contamination or suspected leakage noted.

The filter preweight (tare weight) is subtracted from the postweight value to determine the weight of dust retained, to the nearest 0.01 milligram.

After all filters are weighed, they are stored for future reference.

III. PREPARATION AND HANDLING OF SAMPLERS AND FILTERS BEFORE AND AFTER EACH SHIFT

A. Assembly of Samplers Prior to Working Shift

1. Personal Sampler

   a. Inspect cyclone for scoring.
   b. Assemble dry cyclone and install in sampling package.
   c. Remove plugs from filter cassette and install cassette.
   d. Remove pump from charger, check battery voltage, and install in package.
   e. Record pump number, cyclone number, filter number, and counter reading, if appropriate, on pump schedule sheet.
   f. Check that hoses are not pinched, twisted, or routed improperly.
   g. Check starting of pump momentarily.

2. MRE Sampler

   a. Line up samplers with corresponding filters.
   b. Remove blanking plates and install filters.
   c. Check counter and zero if necessary.
   d. Remove battery from charger and check voltage.
   e. Insert battery into sampler, close each sampler, and install in package.
   f. Record sampler and filter numbers on pump sheet.
   g. Check starting of pump momentarily.

3. Total Airborne Dust Sampler

   a. Remove pump from charger and check battery voltage.
   b. Install filter cassette in Unico holder.
   c. Record pump and filter numbers on pump sheet.
   d. Check that hoses are not pinched, twisted, or routed improperly.
   e. Check starting of pump momentarily.

B. Handling Samplers After Shift

1. Personal Sampler

   a. Remove filter cassettes from packages.
   b. Cap filter cassettes with colored plugs in reverse order than received.
   c. Clean cyclones and connecting hoses with water and Sparkleen in ultrasonic bath.
   d. Rinse cyclones and connecting hoses with unfiltered alcohol.
   e. Place cyclones and hoses to dry on drying rack.
   f. Record counter reading on pump sheet if appropriate.
   g. Clean pumps and packages.

2. MRE Samplers

   a. Line up all samplers and corresponding Petri dishes.
   b. Clean off back of MRE with brush, and open.
   c. Remove filter and place in Petri dish.
   d. Put blanking plate in filter holder compartment but do not close.
   e. Record number of liters of air on pump sheet and turn counter back to zero.
   f. Remove batteries and place on charger.
   g. Clean outside of sampler with compressed air.
   h. Clean elutriator plates with compressed air.

3. Total Airborne Dust Samplers

   a. Clean off outside of filter holder with brush.
   b. Remove filter cassette and plug both inlet and outlet.
   c. Check that all cassettes are properly identified on pump sheet.

IV. CALIBRATION OF SAMPLERS

The procedures outlined in "Bureau of Mines Information Circular 8503," February 1971, by staff, Pittsburgh Field Health Group, Chapter VIII, pp. 27 through 30, are used for the calibration of the sampling equipment. The only modifications to the IC 8503 guidelines are as follows:

A. MRE Gravimetric Sampler

1. To adapt MRE to test stand, a rubber hose configuration was set up to reproduce filter and elutriator resistance. This system was supplied by the Pittsburgh Field Health Group.

2. Motor speed is checked at three voltage levels: 6.5, 6.0, and 5.7 volts; and instrument is run at 6.0 volts for approximately one hour.

3. Elutriator and filter holder are checked for leakage as explained in instruction leaflet 3104/AT for Gravimetric Dust Sampler Type 113A.

B. MSA Type G Personal Sampler with SKC Pulsation Dampener and SKC Voltage Regulator

1. The test rig was changed to cut down on length of rubber hose from cyclone to pump, in order to match conditions under which the sampler is used in the sampling package.

2. Instrument is run for approximately 15 minutes at 6.4 volts.

C. Willson Casella Type BC Personal Sampler with Integral Pulsation Dampener

Same calibration procedures as for MSA sampler.

V. ASHING OF AIRBORNE DUST SAMPLES

In order to determine whether samples were contaminated by rock dust, an ashing procedure developed to determine the incombustible content of deposited mine dust was extended to airborne dust samples. In this procedure 0.5 g duplicate samples are ashed in a muffle furnace at 400 C for 16 hours (overnight). A total of 12 crucibles on a rack can be placed in the furnace at the same time. The samples are placed in the crucibles and dried. The crucibles are then weighed prior to and after ashing.

The difficulty with airborne dust samples is the size of the sample. It was found by trial and error that for the purpose of this test, which is more qualitative than quantitative, it was possible to go down to 10 mg of material in the crucible without usually incurring too large an error. Nevertheless, such a small amount in a method developed for much larger quantities causes it to be very susceptible to loss of material or contamination in the furnace, or even weighing errors.

To conserve material, it had been hoped to ash the filter together with the dust. However, the filter material used in the samplers does not have a constant ash content and weight correction was not possible. Thus, it was necessary to brush the dust off the filter and the cassette into the crucible, generally losing 3 to 7 mg of material in the transfer. (A little might be gained by cleaning the filter in an ultrasonic bath, using a liquid which could evaporate without a residue. This was tried on a few filters; however, the possible gain did not seem to warrant further effort along this line.)

The only samples usually large enough were the total shift samples (TG) and only these samples were ashed. Results are shown in Table A-1.

In addition to the incombustible content calculated from the weight loss during ashing at 400 C, Table A-1 gives an incombustible content "after further ashing at 900 C." Ashing of samples containing limestone is done at as low a temperature as 400 C to avoid decomposing the limestone and losing carbon dioxide. Inversely, if a sample which has been ashed at 400 C is returned to the furnace for further ashing at 900 C, and if it then shows an additional weight loss, this is an indication that the incombustible material probably was limestone.

It may be noted in the table that samples which had a very high incombustible content at 400 C had a somewhat lower one at 900 C (Shifts 12, 26). However, a large decrease in incombustible content may be simply due to incomplete ashing to start, or more likely to loss of material in the successive handling, heating, and cooling operations. A gain in incombustible content is probably due to contamination. One must remember the very small weights involved (starting with 10 mg means only 1 mg left after the first ashing if the incombustible is 10 percent), and refined techniques would be necessary to get more consistent results. This was beyond the scope of this project.

It must be stated again that this procedure was not intended as an accurate determination of the incombustible content of airborne dust samples, but only as one of several simple means used to detect samples which may have been contaminated with rock dust.

TABLE A-1. INCOMBUSTIBLE CONTENT OF TOTAL AIRBORNE DUST SAMPLES DETERMINED BY SUCCESSIVE ASHING AT 400 C FOR 16 HOURS AND AT 900 C FOR 4 HOURS

Shift Number	7	8	9	10	12	18	19	21	22	23
TG Sample from 300H Package										
Weight in Cassette as Collected, mg	28.2	21.3	25.4	27.3	28.9	16.9	24.9	46.3	56.8	29.8
After Transfer to Crucible, mg	23.9	16.8	18.3	22.2	21.8	9.7	20.2	40.4	51.6	23.1
Incombustible Content,										
Ashing at 400 C, percent	12	19	24	7	32	18	7	9	NA	NA
After Further Ashing at 900 C, percent	12	19	21	10	25	10	10	9	8	14
TG Sample from 300L Package										
Weight in Cassette as Collected, mg	22.8	40.0	20.6	28.6	31.7	34.2	43.2	90.9	76.8	58.5
After Transfer to Crucible, mg	17.6	35.6	17.1	22.4	24.3	25.2	39.4	82.1	71.7	48.6
Incombustible Content,										
Ashing at 400 C, percent	11	11	16	4	37	8	6	8	9	NA
After Further Ashing at 900 C, percent	13	11	17	8	29	6	7	8	7.5	16
Shifts Where Rock Dust Contamination Occurred (x) or was Suspected (?)			?		x					

TABLE A-1. INCOMBUSTIBLE CONTENT OF TOTAL AIRBORNE DUST SAMPLES DETERMINED BY SUCCESSIVE ASHING AT 400 C FOR 16 HOURS AND AT 900 C FOR 4 HOURS (Continued)

Shift Number	24	25	26	27	28	29	30	31	32	33
TG Sample from 300H Package										
Weight in Cassette as Collected, mg	49.8	39.6	20.5	17.2	18.2	14.5	26.5	70.4	20.3	63.5
After Transfer to Crucible, mg	42.9	34.6	16.1	11.9	12.9	11.3	22.7	62.1	15.5	53.0
Incombustible Content,										
Ashing at 400 C, percent	43	6	33	18	NA	NA	12	11	19	9
After Further Ashing at 900 C, percent	NA	7	20	13	5	11	10	8	19	10
TG Sample from 300L Package										
Weight in Cassette as Collected, mg	66.8	NA	23.0	38.2	23.1	33.9	27.5	90.8	26.6	86.3
After Transfer to Crucible, mg	55.0	58.4	17.0	25.8	19.6	27.5	23.2	85.4	21.7	81.0
Incombustible Content,										
Ashing at 400 C, percent	39	8	45	15	NA	NA	13	10	17	8
After Further Ashing at 900 C, percent	NA	8	27	13	12	15	6	7	15	8
Shifts Where Rock Dust Contamination Occurred (x) or was Suspected (?)	x		x						?	

TABLE A-1. INCOMBUSTIBLE CONTENT OF TOTAL AIRBORNE DUST SAMPLES DETERMINED BY SUCCESSIVE ASHING AT 400 C FOR 16 HOURS AND AT 900 C FOR 4 HOURS (Concluded)

Shift Number	34	39	40	41	42	43	44	45	46
TG Sample from 300H Package									
Weight in Cassette as Collected, mg	24.4	36.6	20.9	18.8	20.5	31.0	23.4	18.7	19.7
After Transfer to Crucible, mg	20.0	31.5	14.2	15.1	16.8	26.9	18.0	13.7	15.9
Incombustible Content,									
Ashing at 400 C, percent	9	13	24	9	16	13	13	9	6
After Further Ashing at 900 C, Percent	4	10	6	9	11	11	10	5	4
TG Sample from 300L Package									
Weight in Cassette as Collected, mg	51.6	38.5	36.3	31.5	24.6	46.8	31.8	27.3	22.6
After Transfer to Crucible, mg	46.3	33.0	30.5	24.3	19.6	40.7	25.6	22.9	18.3
Incombustible Content,									
Ashing at 400 C, percent	10	15	22	15	11	11	10	8	7
After Further Ashing at 900 C, percent	6	11	9	8	7	8	9	9	4
Shifts Where Rock Dust Contamination Occurred (x) or was Suspected (?)									

APPENDIX B

TEST PROCEDURES - ROBENA MINE

October 15 to November 21, 1975

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APPENDIX B

. TEST PROCEDURES - ROBENA MINE

Overall the test procedures were similar to those of the late 1972--early 1973 tests at Robena, and of the late 1973 tests under Contracts H0232060 and H0232061. Basically, dust sampling is extended to the full operating shift whenever possible. During that same period of time the operation of the mining machine is monitored: production, operating time, air velocities, spray water rates and pressure, condition of spray nozzles, etc., including sketches of the places loaded out, indicating the relative positions of the machine, line brattice, check curtain, and dust samplers.

The same procedure is followed for various "modes" or arrangements of water sprays, i.e., for the wet-head machine with 1-inch nozzles or the base machine with fixed boom sprays. Within the constraints of an operating section, the variables which may be controlled are maintained at the desired value whenever possible.

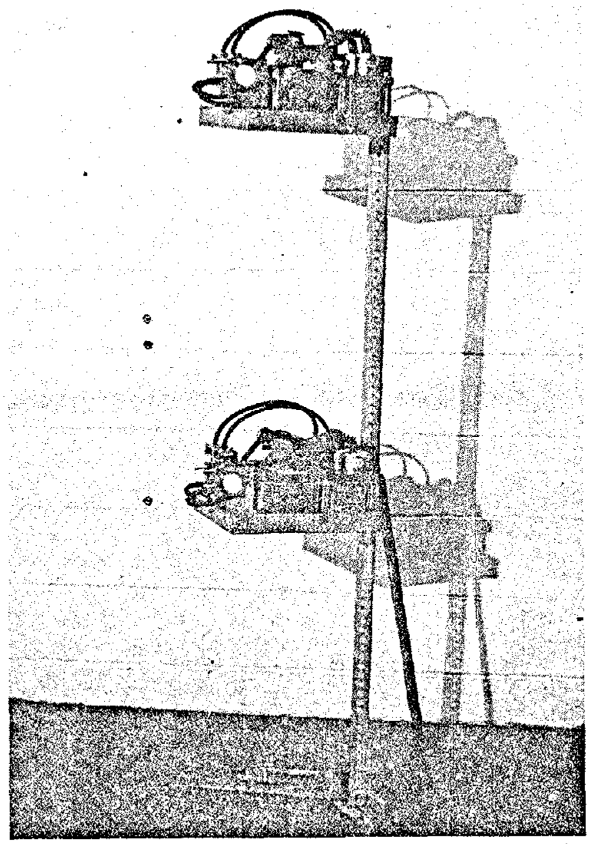
I. LOCATION OF DUST SAMPLING PACKAGES

1. An intake air package (No. 100) was hung in the No. 3 track heading, just inby the shuttle car loading ramp, and remained there for the duration of the shift.

2. A mining machine package (No. 200) was anchored on top of the methane monitor in front of the operator's cab, sampler inlets facing the rib.

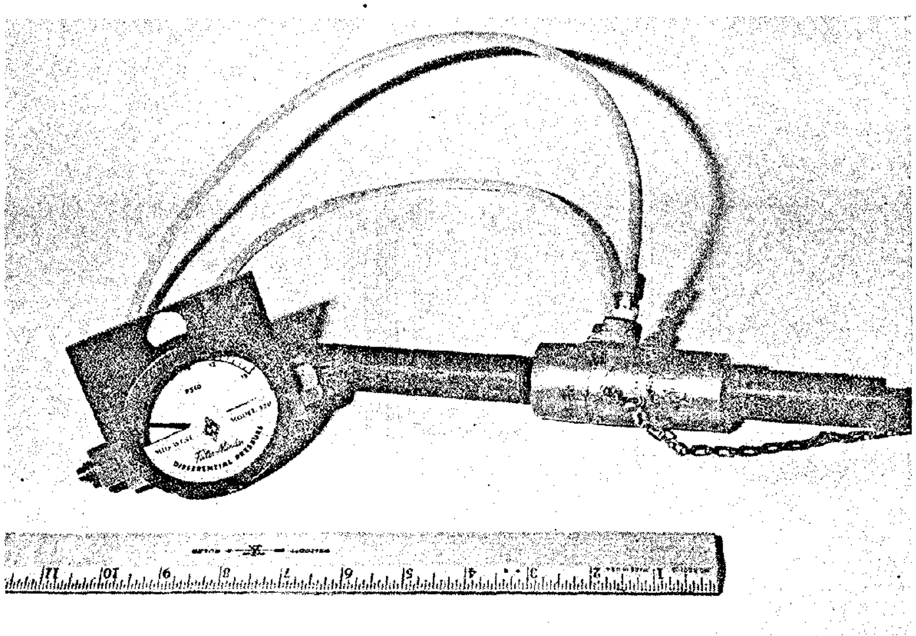
3. Knowing that curtains are well maintained and air plentiful at Robena, fewer samplers were placed on the intake side than had been done previously. Instead, those freed samplers were used on the downwind side of the machine, the most significant location to evaluate the effect of water sprays on dust. Two return packages (No. 300) were located behind and at the discharge end of the line brattice, just upwind of the trickle duster. They were mounted on a stand, as shown in Figure B-1, placing the sampler inlets at elevations of approximately 2-1/2 and 5 feet (seam height varied from 6-1/2 to 7 feet), with the stand at the downwind side of the packages. These packages were moved from cut to cut while the machine was moving to the new place.

4. As indicated above, most of the operating variables can be and are recorded separately for every place where the machine moves to during the shift. As conditions change quite a bit from place to place, it would be desirable to conduct dust sampling cut by cut also. Unfortunately the respirable dust samplers used do not produce a large enough sample in the time it takes to take a cut to make such measurements reliable. However, this is not the case if one removes the cyclone and collects the total air-borne dust or gross sample. Each of the two return packages was fitted with two gross samplers. Instead of taking full shift samples with both samplers, it was decided to change the cassette between places on one of them, thus obtaining separate gross samples for each cut, as well as one full-shift sample.



2008P19

Figure B-1. Stand Used to Position Two Return Sampler Packages Behind Brattice



2008P23

Figure B-2. Venturi Tube and Differential Pressure Gage

To summarize, respirable dust samples were collected at three places: section intake, mining machine, and return side of the brattice, and gross samples at only one of these three places, the return side of the brattice.

II. MONITORING OF WATER FLOWS

The locations of the various meters used to monitor the water flow to the spray nozzles on both the test and conventional machines were indicated in Figures 14 to 17 in Section IV. The meters used were as follows:

1. The total water supply to the machine in use was measured with a Rockwell Model 504 nutating disc high pressure (2000 psi) 1-inch totalizing meter located at the end of the section water line (feed end of the trailing hose). This meter has a nominal rating of 20 gpm, but checks at the laboratory indicated that it could easily handle the slightly larger capacity required. Two meters were actually piped in parallel, with one meter blocked off as a stand-by. The meter was read at the beginning and end of each shift, and during place moves, to obtain the water consumption both per shift and per cut. In addition, total flow rates were obtained at regular intervals by timing the meter with a stop watch.

2. On the test machine only, two Brooks-Brodie ER-93 HP oscillating piston high pressure (400 psi) 1-inch totalizing meters to measure separately the water to the cutters and the water to the side sprays. (The water to the Conflow nozzle on the conveyor is not included in either but was included in the total water supply above; it amounted to 2.5 to 3 gpm.) Again, these meters were used to determine both the water consumption during shift and cuts and the water flow rate with a stop watch. Both meters were installed under a protective hood on the left side of the machine.

3. Venturi tubes installed to monitor the cutters separately and to back-up the totalizing meters were Barco Series VI, as shown in Figure B-2 with the Mid-West Model 120 differential pressure gage used during the 1975 tests (range 0-15 psid). The same gage was connected to all venturi tubes in turn through a quick opening valve manifold. This assembly was located on the right side of the machine in front of the operator's cab.

III. MONITORING OF AIRFLOWS

All air quantities were obtained by traversing a measured cross-section with a 4-inch vane anemometer.

Total section ventilation was obtained for each shift by measurements made in each entry between No. 5 and No. 6 crosscuts. These measurements were made outby the last row of permanent stoppings and fairly consistent quantities of air were obtained from shift to shift. However, as in previous tests, the measurement of airflows in the face area proved to be difficult. In the face area, one is hampered by poor velocity distribution across any given cross section, low air velocities, small cross-sectional areas behind brattice lines which cannot be accurately estimated, and presence of operating machinery. For each cut anemometer traverses of return air were obtained in the vicinity of the sampling packages behind the brattice and further downstream in the crosscut ahead of the next entry (referred to as "downstream of the trickle duster"). On the intake side, some readings were obtained at the brattice opening near the face, or on the wide side of the brattice, before the machine moved in. Many times readings in the immediate face area were not possible, so some readings were taken outby the last open crosscut. An examination of the calculated air volumes shows that some of the measurements made are not compatible, a reflection on the difficulty of obtaining dependable air measurements in the face area.

APPENDIX C

FIELD DATA - ROBENA MINE

October 15 to November 21, 1975

Page

APPENDIX C

FIELD DATA - ROBENA MINE
October 15 to November 21, 1975

EXPLANATORY NOTES

Production, cutting time, and total amount of water used were obtained for each cut taken (places loaded out) as well as for the full shift.

The production, in tons of raw coal, was determined from the number of mine cars loaded. The production rate, tons per minute, was based on the shift production and cutting time. The cutting time was obtained from an elapsed time meter (hours and tenths) mounted on the miner and activated by the cutter motors.

Water consumption was obtained from three totalizing water meters, one at the feed end of the trailing hose (used for both machines) for the total water consumption and two on the machine (wet-head machine only) for the water to the cutters and side sprays. Several flow-rate spot checks while cutting (one-minute reading of totalizing meters) were made during each shift, preferably at least once for each cut. An average of these spot checks is reported for each shift. In addition, an average water flow during shift was calculated, based on the total water measured and the cutting time.

The water pressures indicated are spot checks while cutting and are read from a pressure gage mounted in the operator's cab downstream of the shutoff valve. The water pressure for the shift is an average of individual readings taken during each cut.

Each cut is located by both entry and crosscut. For example, "Entry No. 4-3, Crosscut No. 8" indicates that the machine was taking a cut in crosscut 8 moving from entry No. 4 toward entry No. 3. "Entry 3 ST, Crosscut 7-8" indicates that the machine was advancing in 3 straight, from crosscut 7 toward crosscut 8.

The airflow data were collected with Davis A-2 4-inch Biram-type anemometers. Normally two separate 1-minute traverses were made across the width and the height of the entry. The average of these two velocity readings was then corrected using the calibration curve for that anemometer, and the quantity of air was calculated using the corrected air velocity and cross-sectional area.

The airflows shown in Tables C-1, 2, and 3 are the total section ventilation for that shift. Air measurements were made once a shift in each entry between No. 5 and No. 6 crosscuts, which were outby the last row of permanent stoppings. Total section intake air is the total quantity of air measured in entries 2, 3, and 4. The total section return is the total quantity of air measured in entries 1 and 5.

Two additional airflows are given in Tables C-4, 5, and 6. The "Near 300 Package" air readings were taken at the discharge end of the line brattice in the vicinity of the 300 package. The "Downstream of Trickle Duster" air readings were taken further downstream in the crosscut or entry ahead of the next intersection.

The "Distance from Face to 300 Package" was measured at the beginning of each cut. The corner of the entry and crosscut (beginning of the narrow space behind the brattice where the packages would be normally located) was used as starting point for the estimation of that distance, even when it was not practically feasible to locate the package there (the package could not be placed closer than 10 to 15 feet from the machine without becoming excessively wet).

The "Time in Place" was measured from the start of mining in a particular heading or crosscut until the miner completed the cut and started moving to a new place.

Dust sample designation is as follows (Tables C-7, 8, and 9):

LP, RP	Personal samplers, Left and Right when looking into the cyclone inlets
M	MRE sampler
TG, SC	Two samplers (Unico cassettes) in each 300 package used without a cyclone to collect a total airborne dust sample. TG ("total gross") is a full shift sample (same as respirable dust samples). SC ("sum of cuts") is the sum of the weights of the individual gross samples collected in each cut of the shift (individual weights for each cut are shown at the bottom of Tables C-4, 5, and 6).

The dust samplers were operated for the full shift as much as possible. When this was not possible because of equipment breakdown, clean-up chores, or other unusual conditions, the recorded production, cutting time, water consumption, etc., correspond to the time of operation of the samplers.

Shift 2 is not listed in any of the tables; a general mine power failure at the beginning of the shift stopped all operations for the remainder of the shift.

TABLE C-1. OPERATING DATA FOR WET-HEAD MACHINE
SHIFTS 1 TO 14: 1-INCH NOZZLES
SHIFTS 15 TO 20: 3/8-INCH NOZZLES

Shift Number	01	03	04	05	06	07	08	09	10
Date (1975)	10-15	10-16	10-16	10-17	10-17	10-20	10-20	10-21	10-21
Crew	A	A	B	A	B	B	A	B	A
Production, tons	336	390	324	324	198	294	300	360	420
Number of cuts	4	4	3	3	2	3	4	4	5
Cutting time, minutes	123	144	81	132	63	102	111	132	153
Cutting rate, tons/min	2.7	2.7	4.0	2.4	3.1	2.9	2.7	2.7	2.7
Water consumption during shift, gallons									
Total to machine	3027	3338	2130	3217	1657	2292	2563	3059	3942
Per ton of coal	9.0	8.6	6.6	9.9	8.4	7.8	8.5	8.5	9.4
Through cutters	1768	1942	1250	1895	991	1369	1511	1859	2396
Through side sprays	945	1054	650	979	502	677	784	904	1120
Average water flow during shift, gpm (calculated from shift consumption and cutting time)									
Total to machine	24.6	23.2	26.3	24.4	26.3	22.5	23.1	23.2	25.8
Through cutters	14.4	13.5	15.4	14.4	15.7	13.4	13.6	14.1	15.7
Through side sprays	7.7	7.3	8.0	7.4	8.0	6.6	7.1	6.9	7.3
Water flow rate spot checks, gpm (1 min readings while cutting)									
Total to machine	24.0	24.9	26.4	24.8	25.8	25.8	NA	25.2	26.5
Through cutters	14.2	14.6	14.8	15.0	15.1	15.1	15.6	15.5	15.9
Through side sprays	7.5	7.8	7.8	7.7	7.9	7.9	7.0	7.6	7.6
Water pressure at operator's cab, psi	160	165	165	160	170	160	165	170	165
Airflow, 1000 cfm									
Total section intake	NA	NA	NA	38	49	40	39	34	40
Total section return	NA	NA	NA	42	48	35	41	38	47

TABLE C-1. OPERATING DATA FOR WET-HEAD MACHINE
SHIFTS 1 TO 14: 1-INCH NOZZLES
SHIFTS 15 TO 20: 3/8-INCH NOZZLES
(Continued)

Shift Number	11	12	13	14	15	16	17	18	19	20
Date (1975)	10-22	10-22	10-23	10-23	10-24	10-24	10-28	10-28	10-29	10-29
Crew	B	A	B	A	B	A	B	A	B	A
Production, tons	252	360	216	300	288	240	300	336	348	276
Number of cuts	3	4	2	3	3	2	2	3	4	2
Cutting time, minutes	84	144	66	123	87	99	84	120	102	93
Cutting rate, tons/min	3.0	2.5	3.3	3.4	3.3	2.4	3.6	2.8	3.4	3.0
Water consumption during shift, gallons										
Total to machine	2018	3536	1549	2917	1894	2203	1913	3164	2518	2396
Per ton of coal	8.0	9.8	7.2	9.7	6.6	9.2	6.4	9.4	7.2	8.2
Through cutters	1220	2020	915	1710	844	961	1049	1954	1572	1568
Through side sprays	592	982	477	900	785	877	613	884	708	701
Average water flow during shift, gpm (calculated from shift consumption and cutting time)										
Total to machine	24.0	24.6	23.5	23.7	21.8	22.3	22.8	26.4	24.7	25.8
Through cutters	14.5	14.0	13.9	13.9	9.7	9.7	12.5	16.3	15.4	16.9
Through side sprays	7.0	6.8	7.2	7.3	9.0	8.9	7.3	7.4	6.9	7.5
Water flow rate spot checks, gpm (1 min readings while cutting)										
Total to machine	25.3	24.4	25.3	25.0	21.1	20.9	25.0	26.4	25.4	26.2
Through cutters	15.6	15.2	15.2	14.8	9.3	9.1	14.6	16.4	16.0	16.9
Through side sprays	7.2	7.4	7.8	7.7	8.7	8.5	7.8	7.5	7.3	7.3
Water pressure at operator's cab, psi	175	165	170	165	185	185	180	165	160	160
Airflow, 1000 cfm										
Total section intake	40	48	35	46	37	43	44	47	46	45
Total section return	38	45	39	43	41	45	45	42	42	43

TABLE C-2. OPERATING DATA FOR CONVENTIONAL SPRAY MACHINE
SHIFTS 21 TO 34

Shift Number	21	22	23	24	25	26	27	28
Date (1975)	10-30	10-30	10-31	10-31	11-4	11-6	11-7	11-10
Crew	B	A	B	A	A	A	A	A
Production, tons	372	306	228	276	372	156	288	138
Number of cuts	4	3	2	3	4	2	3	2
Cutting time, minutes	102	108	60	90	138	72	129	48
Cutting rate, tons/min	3.6	2.8	3.8	3.1	2.7	2.2	2.2	2.9
Water consumption during shift, gallons								
Total to machine	2143	2654	1179	1900	3564	1845	3162	1265
Per ton of coal	5.8	8.7	5.2	6.9	9.6	11.8	11.0	9.2
Through cutters	--	--	--	--	--	--	--	--
Through side sprays	--	--	--	--	--	--	--	--
Average water flow during shift, gpm (calculated from shift consumption and cutting time)								
Total to machine	21.0	24.6	19.6	21.1	25.8	25.6	24.5	26.4
Through cutters	--	--	--	--	--	--	--	--
Through side sprays	--	--	--	--	--	--	--	--
Water flow rate spot checks, gpm (1 min readings while cutting)								
Total to machine	22.8	22.6	22.0	22.2	26.1	27.8	28.2	29.7
Through cutters	--	--	--	--	--	--	--	--
Through side sprays	--	--	--	--	--	--	--	--
Water pressure at operator's cab, psi	NA	160	170	180	150	190	175	155
Airflow, 1000 cfm								
Total section intake	33	44	41	45	44	40	39	40
Total section return	34	38	42	43	43	40	42	45

TABLE C-2. OPERATING DATA FOR CONVENTIONAL SPRAY MACHINE
SHIFTS 21 TO 34 (Continued)

Shift Number	29	30	31	32	33	34
Date (1975)	11-11	11-11	11-12	11-12	11-13	11-13
Crew	A	B	A	B	A	B
Production, tons	258	258	300	246	408	324
Number of cuts	3	3	3	3	4	3
Cutting time, minutes	93	66	102	54	132	72
Cutting rate, tons/min	2.8	3.9	2.9	4.6	3.1	4.5
Water consumption during shift, gallons						
Total to machine	2342	1629	2456	1408	3433	1820
Per ton of coal	9.1	6.3	8.2	5.7	8.4	5.6
Through cutters	--	--	--	--	--	--
Through side sprays	--	--	--	--	--	--
Average water flow during shift, gpm (calculated from shift consumption and cutting time)						
Total to machine	25.2	24.7	24.1	26.1	26.0	25.3
Through cutters	--	--	--	--	--	--
Through side sprays	--	--	--	--	--	--
Water flow rate spot checks, gpm (1 min readings while cutting)						
Total to machine	28.1	26.8	27.3	26.7	27.1	27.8
Through cutters	--	--	--	--	--	--
Through side sprays	--	--	--	--	--	--
Water pressure at operator's cab, psi	140	165	150	150	130	130
Airflow, 1000 cfm						
Total section intake	41	44	42	35	44	45
Total section return	44	46	42	43	44	42

TABLE C-3. OPERATING DATA FOR WET-HEAD MACHINE
SHIFTS 35 TO 46: 3/8-INCH NOZZLES

Shift Number	35	36	37	38	39	40	41	42	43	44	45	46
Date (1975)	11-14	11-14	11-17	11-17	11-18	11-18	11-19	11-19	11-20	11-20	11-21	11-21
Crew	A	B	B	A	B	A	B	A	B	A	B	A
Production, tons	276	156	330	192	318	384	228	330	312	258	276	264
Number of cuts	3	2	3	3	3	4	2	3	3	3	3	4
Cutting time, minutes	102	42	96	75	108	120	72	135	93	102	93	96
Cutting rate, tons/min	2.7	3.7	3.4	2.6	2.9	3.2	3.2	2.4	3.4	2.5	3.0	2.7
Water consumption during shift, gallons												
Total to machine	2640	*	2620	2142	2805	3467	1831	3460	2380	2672	2504	2546
Per ton of coal	9.6	*	8.2	11.6	8.8	9.0	8.0	10.5	7.6	10.4	9.1	9.6
Through cutters	1597	*	1515	1239	1741	2146	1138	2106	1486	1667	1604	1585
Through side sprays	748	*	693	550	804	922	522	977	646	725	676	697
Average water flow during shift, gpm (calculated from shift consumption and cutting time)												
Total to machine	25.9	*	28.3	29.6	26.0	28.9	25.4	25.6	25.6	26.2	26.9	26.5
Through cutters	15.7	*	15.8	16.5	16.1	17.9	15.8	15.6	16.0	16.3	17.2	16.5
Through side sprays	7.3	*	7.2	7.3	7.4	7.7	7.2	7.2	6.9	7.1	7.3	7.3
Water flow rate spot checks, gpm (1 min readings while cutting)												
Total to machine	25.0	26.2	27.8	28.4	26.1	26.3	25.6	26.0	26.3	26.3	25.9	25.6
Through cutters	15.4	14.0	16.4	17.6	16.4	16.3	16.2	16.1	16.8	16.5	16.8	16.2
Through side sprays	7.2	6.8	7.3	7.6	7.3	7.0	7.4	7.3	7.3	7.2	7.2	7.1
Water pressure at operator's cab, psi	165	150	180	185	175	140	165	170	170	170	170	160
Airflow, 1000 cfm												
Total section intake	43	37	37	38	45	38	35	37	36	37	42	44
Total section return	43	41	41	49	46	44	40	42	41	42	42	40

* Water system failure

TABLE C-4. OPERATING DATA PER CUT FOR WET-HEAD MACHINE, SHIFTS 1 TO 20

Shift Number	1				3				4		
Cut Number	1	2	3	4	1	2	3	4	1	2	3
Location of Cut											
Entry Number	4-3	3 ST	4-3	3 ST	3 ST	4-3	3 ST	4-3	3 ST	4-3	2 ST
Crosscut Number	8	7-8	8	7-8	7-8	8	7-8	8	7-8	8	7-8
Distance from Face to 300 Packages, ft	18	0	33	15	20	48	40	68	55	83†	0
Production, tons	114	102	84	36	80	124	102	90	132	84	120
Cutting Time, min	39	36	36	12	30	54	36	24	33	18	30
Time in Place, min	75	85	55	22	49	101	73	50	87	51	54
Water Consumption, gallons											
Total for cut	974	959	812	281	723	1115	832	667	779	572	780
Per ton of coal	8.5	9.4	9.7	7.8	9.0	9.0	8.2	7.4	5.9	6.8	6.5
Water Flow Rate Spot Checks, gpm											
Total to machine	24.4	24.5	23.4	23.7	25.5	24.4	25.4	24.6	26.4	NA	NA
Through cutters	13.7	14.4	14.3	14.4	14.5	14.2	15.3	14.3	14.9	15.2	14.6
Through side sprays	7.9	7.6	6.9	7.6	8.2	7.1	8.1	7.8	7.8	7.9	7.6
Water Pressure at Operator's Cab, psi	160	160	160	160	160	160	170	170	165	170	165
Airflow, 1000 cfm											
Near 300 Packages	13	19	12	17	15	10	16	10	14	13	10
Downstream of trickle duster	NA	NA	NA	NA	NA	NA	NA	NA	NA	17	NA
Gross Dust Sample Weight, mg											
300H	9.9	7.0	NA	1.1	12.7	4.1	11.1	1.3	10.4	2.1	2.7
300L	3.9	6.4	4.9	1.0	22.2	8.0	6.7	2.9	4.7	2.6	3.7

† This cut broke through

TABLE C-4. OPERATING DATA PER CUT FOR WET-HEAD MACHINE, SHIFTS 1 TO 20 (Continued)

Shift Number	5			6		7			8			
Cut Number	1	2	3	1	2	1	2	3	1	2	3	4
Location of Cut												
Entry Number	3-2	2 ST	3-2	2 ST	3-2	3-2	2 ST	3-2	2 ST	1 ST	2 ST	3 ST
Crosscut Number	8	7-8	8	7-8	8	8	7-8	8	7-8	7-8	7-8	8-9
Distance from Face to 300 Packages, ft	106	8	118	23	50	54	46	72	86	32	95	0
Production, tons	78	108	138	102	96	120	84	90	66	108	90	36
Cutting Time, min	33	39	60	33	30	27	39	36	21	48	33	9
Time in Place, min	59	86	107	88	79	74	87	69	32	79	46	25
Water Consumption, gallons												
Total for cut	858	959	1399	926	731	691	881	720	502	1090	719	252
Per ton of coal	11.0	8.9	10.1	9.1	9.1	5.8	10.5	8.0	7.6	10.1	8.0	7.0
Water Flow Rate Spot Checks, gpm												
Total to machine	26.6	24.6	24.0	NA	NA	26.3	25.6	25.6	NA	NA	NA	NA
Through cutters	16.4	14.9	14.4	14.6	NA	15.4	14.6	15.4	15.3	15.6	NA	15.6
Through side sprays	7.5	8.1	7.5	7.8	NA	8.0	7.8	7.9	5.4	7.4	NA	7.8
Water Pressure at Operator's Cab, psi	160	170	155	170	NA	160	160	160	150	170	NA	170
Airflow, 1000 cfm												
Near 300 Packages	10	12	10	13	10	10	12	10	9	20	15	15
Downstream of trickle duster	26	23	24	NA	NA	13	25	14	NA	23	NA	NA
Gross Dust Sample Weight, mg												
300H	NA	4.6	2.7	3.2	4.8	6.0	16.3	3.3	1.1	11.0	3.4	1.1
300L	NA	3.1	2.6	4.1	7.3	6.4	9.8	3.3	1.0	23.8	2.6	13.8

TABLE C-4. OPERATING DATA PER CUT FOR WET-HEAD MACHINE, SHIFTS 1 TO 20 (Continued)

Shift Number	9				10					11		
Cut Number	1	2	3	4	1	2	3	4	5	1	2	3
Location of Cut												
Entry Number	3 ST	1 ST	2-1	1 ST	1 ST	2-1	1 ST	2-1	1 ST	1 ST	2-1	4 ST
Crosscut Number	8-9	7-8	8	7-8	7-8	8	7-8	8	7-8	7-8	8	8-9
Distance from Face to 300 Packages, ft	6	47	24	66	76	42	86	51	95	102	76†	0
Production, tons	96	90	114	60	84	78	78	120	60	96	90	66
Cutting Time, min	33	33	48	18	21	36	33	42	21	33	18	24
Time in Place, min	56	63	97	31	44	55	60	74	24	69	100	63
Water Consumption, gallons												
Total for cut	768	744	1092	455	525	1001	840	1039	537	662	626	644
Per ton of coal	8.0	8.3	9.6	7.6	6.2	12.8	10.8	8.6	9.0	6.9	7.0	9.8
Water Flow Rate Spot Checks, gpm												
Total to machine	25.6	24.7	25.5	25.0	NA	26.6	NA	26.5	NA	25.4	25.3	25.2
Through cutters	15.4	15.4	16.2	14.9	15.4	15.5	15.7	17.0††	NA	15.6	15.8	15.4
Through side sprays	7.9	6.5	7.2	7.8	7.9	7.7	7.6	7.0	NA	7.2	7.3	7.2
Water Pressure at Operator's Cab, psi	170	170	170	170	160	170	NA	165	NA	175	175	NA
Airflow, 1000 cfm												
Near 300 Packages	17	18	8	14	14	7	15	7	14	14	6	15
Downstream of trickle duster	15	25	9	22	NA	NA	NA	NA	NA	22	10	25
Gross Dust Sample Weight, mg												
300H	6.5	9.8	5.1	4.6	2.9	8.3	7.3	NA	5.6#	5.9	1.7	30.3
300L	3.3	6.0	5.5	4.2	2.8	10.4	5.4	NA	9.0#	3.7	2.4	40.6

† This cut broke through
†† Two broken nozzles in cutters

Includes cut No. 4

TABLE C-4. OPERATING DATA PER CUT FOR WET-HEAD MACHINE, SHIFTS 1 TO 20 (Continued)

Shift Number	12				13		14			15		
Cut Number	1	2	3	4	1	2	1	2	3	1	2	3
Location of Cut												
Entry Number	4 ST	5 ST	4 ST	5 ST	4 ST	5 ST	4 ST	5 ST	4 ST	5 ST	4-5	5-4
Crosscut Number	8-9	8-9	8-9	8-9	8-9	8-9	8-9	8-9	8-9	8-9	9	9
Distance from Face to 300 Packages, ft	8	24	29	42	50	60	73	80	92	100	107	126
Production, tons	96	96	72	96	108	108	72	120	108	90	102	96
Cutting Time, min	48	33	39	24	36	30	33	51	39	18	39	30
Time in Place, min	82	62	65	48	81	105	62	94	67	57	74	63
Water Consumption, gallons												
Total for cut	1203	694	933	706	904	644	802	1159	956	507	758	629
Per ton of coal	12.5	7.2	13.0	7.4	8.4	6.0	11.1	9.7	8.8	5.6	7.4	6.6
Water Flow Rate Spot Checks, gpm												
Total to machine	24.4	NA	NA	NA	25.4	25.3	25.0	NA	25.0	21.8	NA	20.8
Through cutters	15.6	15.0	15.6	14.6	15.5	15.1	14.6	14.8	14.9	9.3	8.8	9.8
Through side sprays	7.4	7.3	7.5	7.2	7.9	7.6	7.9	7.5	7.7	8.6	8.9	8.7
Water Pressure at Operator's Cab, psi	165	135	165	170	170	170	160	170	170	NA	190	180
Airflow, 1000 cfm												
Near 300 Packages	12	20	11	15	11	14	11	14	12	13	10	13
Downstream of trickle duster	NA	NA	NA	NA	16	17	NA	NA	NA	17	13	16
Gross Dust Sample Weight, mg												
300H	6.6	14.1	5.4	4.1	3.8	7.8	1.4	4.6	1.9	3.6	2.9	3.8
300L	7.1	9.5	6.0	7.6	10.1	9.8	1.7	5.2	4.2	4.5	6.8	4.1

TABLE C-4. OPERATING DATA PER CUT FOR WET-HEAD MACHINE, SHIFTS 1 TO 20 (Concluded)

Shift Number	16		17		18			19				20	
Cut Number	1	2	1	2	1	2	3	1	2	3	4	1	2
Location of Cut													
Entry Number	4-5	5-4	5 ST	3 ST	4-3	3 ST	4-3	3 ST	4-3	3 ST	4-3	2 ST	3-2+
Crosscut Number	9	9	9-10	8-9	9	8-9	9	8-9	9	8-9	9	8-9	9
Distance from Face to 300 Packages, ft	122	141	111	20	18	40	29	60	38	68	54	6	0
Production, tons	144	96	162	138	108	108	120	48	120	96	84	116	144
Cutting Time, min	60	42	48	30	39	45	36	12	36	30	24	45	48
Time in Place, min	103	130	88	81	71	73	105	25	83	63	52	100	87
Water Consumption, gallons													
Total for cut	1248	956	1104	727	971	1161	1033	388	769	722	639	1118	1277
Per ton of coal	8.7	10.0	6.8	5.3	9.0	10.7	8.6	8.1	6.4	7.5	7.6	9.6	8.9
Water Flow Rate Spot Checks, gpm													
Total to machine	20.9	NA	25.2	24.9	26.2	26.4	26.5	25.6	25.2	25.3	25.6	26.4	26.1
Through cutters	8.7	9.5	14.6	14.7	15.8	16.4	17.1	16.9	16.4	14.9	16.5	17.0	16.8
Through side sprays	8.6	8.4	7.6	7.8	7.6	7.2	7.6	7.7	7.4	7.2	7.1	7.4	7.2
Water Pressure at Operator's Cab, psi	190	180	180	180	165	165	170	160	160	160	160	170	150
Airflow, 1000 cfm													
Near 300 Packages	11	15	14	16	23	11	17	13	14	12	11	30	13
Downstream of trickle duster	NA	NA	19	28	17	27	16	21	18	20	17	35	22
Gross Dust Sample Weight, mg													
300H	2.8	3.2	7.2	11.6	5.2	8.8	7.1	2.6	9.1	4.0	8.1	2.8	9.7
300L	3.9	5.4	11.0	13.6	6.2	21.5	7.2	6.5	14.5	9.1	10.8	4.0	13.4

+ Slant crosscut

TABLE C-5. OPERATING DATA PER CUT FOR CONVENTIONAL SPRAY MACHINE
SHIFTS 21-34

Shift Number	21				22			23		24		
Cut Number	1	2	3	4	1	2	3	1	2	1	2	3
Location of Cut												
Entry Number	2 ST	3-2+	2 ST	3-2+	2 ST	3-2+	2 ST	2 ST	3-2+	1 ST	2-1	1 ST
Crosscut Number	8-9	9	8-9	9	8-9	9	8-9	9-10	9	8-9	9	8-9
Distance from Face to 300 Packages, ft	26	10	35	30	57	52	73	93	74†	33	0	42
Production, tons	60	108	108	96	96	102	108	120	108	60	120	96
Cutting Time, min	18	30	30	24	30	36	42	30	30	12	42	36
Time in Place, min	32	72	54	53	57	78	86	82	53	29	66	101
Water Consumption, gallons												
Total for cut	331	700	629	483	757	948	949	618	561	308	877	715
Per ton of coal	5.5	6.5	5.8	5.0	7.9	9.3	8.8	5.2	5.2	5.1	7.3	7.4
Water Flow Rate Spot Checks, gpm												
Total to machine	22.7	22.0	23.0	22.9	21.8	22.2	23.8	22.4	21.3	NA	22.4	22.0
Through cutters	--	--	--	--	--	--	--	--	--	--	--	--
Through side sprays	--	--	--	--	--	--	--	--	--	--	--	--
Water Pressure at Operator's Cab, psi	NA	NA	NA	NA	180	165	155	180	160	NA	NA	180
Airflow, 1000 cfm												
Near 300 Package	14	13	17	9	15	9	14	12	10	14	10	12
Downstream of trickle duster	18	19	11	12	27	18	24	24	11	26	16	36
Gross Dust Sample Weight, mg												
300H	20.3	15.9	16.3	6.5	7.3	30.9	18.1	17.1	16.2	3.3	35.3	9.5
300L	18.8	15.9	24.3	3.5	18.6	40.3	53.6	30.9	23.2	5.4	43.6	15.5

† This cut broke through
\+ Slant crosscut

TABLE C-5. OPERATING DATA PER CUT FOR CONVENTIONAL SPRAY MACHINE
SHIFTS 21-34 (Continued)

Shift Number	25				26		27			28	
Cut Number	1	2	3	4	1	2	1	2	3	1	2
Location of Cut											
Entry Number	2 ST	1 ST	2 ST	1 ST	3 ST	2-3	2-3	3 ST	2-3	4 ST	3-4
Crosscut Number	9-10	9-10	9-10	9-10	9-10	10	10	9-10	10	9-10	10
Distance from Face to 300 Packages, ft	20	31	33	50	0	18	33	43	49	35	40
Production, tons	60	96	132	84	96	60	90	102	96	96	42
Cutting Time, min	24	36	42	36	42	30	66	36	27	30	18
Time in Place, min	45	91	71	64	67	50	103	67	61	62	47
Water Consumption, gallons											
Total for cut	687	944	1059	818	1041	804	1635	885	642	792	474
Per ton of coal	11.4	9.8	8.0	9.7	10.8	13.4	18.2	8.7	6.7	8.2	11.3
Water Flow Rate Spot Checks, gpm											
Total to machine	26.6	26.0	26.0	26.0	27.5	27.9	28.7	28.7	28.6	29.4	30.2
Through cutters	--	--	--	--	--	--	--	--	--	--	--
Through side sprays	--	--	--	--	--	--	--	--	--	--	--
Water Pressure at Operator's Cab, psi	150	150	150	150	190	NA	170	175	175	155	155
Airflow, 1000 cfm											
Near 300 Package	12	16	11	16	14	17	14	9	13	13	11
Downstream of trickle duster	13	20	15	24	14	28	26	24	28	15	22
Gross Dust Sample Weight, mg											
300H	7.4	16.9	5.8	14.2	14.3	7.8	10.0	8.0	3.5	17.5	0.6
300L	6.3	29.4	17.2	19.8	22.8	2.8	8.5	20.7	4.6	27.4	2.3

TABLE C-5. OPERATING DATA PER CUT FOR CONVENTIONAL SPRAY MACHINE SHIFTS 21-34 (Continued)

Shift Number	29			30			31		
Cut Number	1	2	3	1	2	3	1	2	3
Location of Cut									
Entry Number	3-4	3-4	3 ST	5 ST	4-5	5 ST	4-5	5 ST	4-5
Crosscut Number	10	10	10-11	9-10	10	9-10	10	9-10	10
Distance from Face to 300 Packages, ft	72	87†	0	48	28	58	38	68	48
Production, tons	84	72	102	60	114	84	114	90	96
Cutting Time, min	30	24	39	18	24	24	48	24	30
Time in Place, min	45	37	104	41	58	75	92	47	58
Water Consumption, gallons									
Total for cut	767	615	960	477	595	557	1067	660	729
Per ton of coal	9.1	8.5	9.4	8.0	5.2	6.6	9.4	7.3	7.6
Water Flow Rate Spot Checks, gpm									
Total to machine	28.8	27.4	27.4	27.5	26.8	26.8	27.5	26.9	27.4
Through cutters	--	--	--	--	--	--	--	--	--
Through side sprays	--	--	--	--	--	--	--	--	--
Water Pressure at Operator's Cab, psi	135	NA	150	170	165	165	150	150	150
Airflow, 1000 cfm									
Near 300 Package	11	10	15	15	16	16	15	16	16
Downstream of trickle duster	21	19	27	20	22	21	21	18	24
Gross Dust Sample Weight, mg									
300H	2.4	1.2	13.7	11.5	14.6	6.0	25.4	NA	NA
300L	6.8	4.0	28.2	9.3	10.7	6.3	33.3	NA	NA

† This cut broke through

TABLE C-5. OPERATING DATA PER CUT FOR CONVENTIONAL SPRAY MACHINE SHIFTS 21-34 (Concluded)

Shift Number	32			33				34		
Cut Number	1	2	3	1	2	3	4	1	2	3
Location of Cut										
Entry Number	5 ST	4-5	4-5	4 ST	*	4 ST	*	4 ST	*	4 ST
Crosscut Number	9-10	10	10	10-11	10	10-11	10	10-11	10	10-11
Distance from Face to 300 Packages, ft	78	62	77†	20	0	33	16	51	33	69
Production, tons	102	102	42	90	102	84	84	114	102	102
Cutting Time, min	18	24	12	36	30	36	30	24	21	27
Time in Place, min	83	70	17	60	46	67	80	67	56	67
Water Consumption, gallons										
Total for cut	557	588	264	991	760	936	745	678	503	640
Per ton of coal	5.5	5.8	6.3	11.0	7.5	11.2	8.9	5.9	4.9	6.3
Water Flow Rate Spot Checks, gpm										
Total to machine	26.7	26.7	NA	26.2	27.0	27.6	27.5	27.2	27.7	28.1
Through cutters	--	--	--	--	--	--	--	--	--	--
Through side sprays	--	--	--	--	--	--	--	--	--	--
Water Pressure at Operator's Cab, psi	145	150	NA	130	130	130	130	130	130	140
Airflow, 1000 cfm										
Near 300 Package	15	16	12	11	16	9	12	10	11	11
Downstream of trickle duster	17	20	NA	10	23	14	19	12	13	12
Gross Dust Sample Weight, mg										
300H	5.4	9.0	3.7	16.7	23.3	6.0	26.9	11.0	10.6	6.7
300L	9.0	9.1	5.4	13.2	33.8	8.7	48.4	16.9	16.7	17.8

† This cut broke through
* Crosscut from No. 5 entry to old workings

TABLE C-6. OPERATING DATA PER CUT FOR WET-HEAD MACHINE
SHIFTS 35-46

Shift Number	35			36		37			38		
Cut Number	1	2	3	1	2	1	2	3	1	2	3
Location of Cut											
Entry Number	4-5	5 ST	4-5	4-5	5 ST	4-5	5 ST	4-5	5 ST	4-5	5 ST
Crosscut Number	11	10-11	11	11	10-11	11	10-11	11	10-11	11	10-11
Distance from Face to 300 Packages, ft	97	26	108	116	38	127	53	139	63	151	69†
Production, tons	102	114	60	60	96	96	138	96	42	96	54
Cutting time, min	36	48	18	18	32	24	42	30	18	36	21
Time in Place, min	106	81	39	145	106	62	131	58	39	77	39
Water Consumption, gallons											
Total for cut	1038	1191	411	**	**	720	1156	748	528	956	658
Per ton of coal	10.2	10.4	6.8	**	**	7.5	8.4	7.8	12.6	10.0	12.2
Water flow rate spot checks, gpm											
Total to machine	25.0	24.7	25.6	24.5	26.8	27.3	28.4	27.9	27.7	29.0	28.8
Through cutters	15.5	14.8	15.8	14.7	13.3	16.3	16.9	16.3	NA	17.5	17.8
Through side sprays	7.2	7.2	7.0	7.1	6.4	7.3	7.5	7.3	NA	7.6	7.7
Water Pressure at Operator's Cab, psi	170	170	160	**	**	180	180	185	NA	NA	NA
Airflow, 1000 cfm											
Near 300 Package	10	14	10	9	12	9	12	12	10	9	13
Downstream of trickle duster	10	20	11	12	16	10	18	15	21	16	17
Gross Dust Sample Weight, mg											
300H	4.8	7.4	1.5	2.1	8.0	2.7	7.2	2.1	0.8	1.4	1.2
300L	7.4	9.4	2.0	3.3	9.1	3.1	8.8	2.3	1.9	1.9	2.2

† This cut broke through

** Failure of water system

TABLE C-6. OPERATING DATA PER CUT FOR WET-HEAD MACHINE
SHIFTS 35-46 (Continued)

Shift Number	39			40				41		42		
Cut Number	1	2	3	1	2	3	4	1	2	1	2	3
Location of Cut												
Entry Number	3 ST	4-3	3 ST	4-3	3 ST	4-3	3 ST	4-3	2 ST	2 ST	3-2	2 ST
Crosscut Number	10-11	11	10-11	11	10-11	11	10-11	11	10-11	10-11	11	10-11
Distance from Face to 300 Packages, ft	40	27	52	42	67	46	87	63†	0	15	85	38
Production, tons	96	114	108	36	150	78	120	126	102	96	114	120
Cutting time, min	36	36	36	12	36	36	36	33	39	54	42	39
Time in Place, min	59	64	63	23	84	102	70	79	100	83	79	61
Water Consumption, gallons												
Total for cut	930	908	968	371	1061	990	1045	840	991	1427	1108	925
Per ton of coal	9.7	8.0	9.0	10.3	7.1	12.7	8.7	6.7	9.7	14.9	9.7	7.7
Water Flow Rate Spot Checks, gpm												
Total to machine	25.9	25.8	26.4	NA	26.5	25.4	27.0	25.5	25.8	25.6	26.4	NA
Through cutters	16.3	16.1	16.6	NA	16.1	16.2	16.8	15.9	16.4	14.6	16.2	16.3
Through side sprays	7.2	7.3	7.3	NA	6.8	7.0	7.3	7.5	7.4	7.4	7.3	6.5
Water Pressure at Operator's Cab, psi	170	180	170	NA	130	130	160	160	170	170	170	170
Airflow, 1000 cfm												
Near 300 Package	14	16	14	13	13	13	13	15	18	19	12	19
Downstream of trickle duster	22	18	20	18	22	17	21	18	28	27	17	32
Gross Dust Sample Weight, mg												
300H	9.6	15.8	6.6	2.9	5.9	8.8	4.8	9.8	11.9	9.5	4.3	5.2
300L	14.3	15.4	8.3	3.5	8.1	13.6	7.0	14.6	19.3	9.8	4.6	9.4

† This cut broke through

TABLE C-6. OPERATING DATA PER CUT FOR WET-HEAD MACHINE SHIFTS 35-46 (Concluded)

Shift Number	43			44			45			46			
Cut Number	1	2	3	1	2	3	1	2	3	1	2	3	4
Location of Cut													
Entry Number	3-2	2 ST	3-2	2 ST	3-2	1 ST	1 ST	2-1	1 ST	1 ST	2-1	2-1	2-1
Crosscut Number	11	10-11	11	10-11	11	10-11	10-11	11	10-11	10-11	11	11	11
Distance from Face to 300 Packages, ft	27	55	44	70	60	36	46	98	63	66	34	43	52
Production, tons	102	114	96	60	84	114	102	114	60	30	72	78	84
Cutting Time, min	27	36	30	24	33	45	30	42	21	12	30	27	27
Time in Place, min	59	88	60	40	80	70	116	84	54	22	49	43	43
Water Consumption, gallons													
Total for cut	719	896	765	698	816	1158	840	1130	533	303	781	747	716
Per ton of coal	7.0	7.9	8.0	11.6	9.7	10.2	8.2	9.9	8.9	10.1	10.8	9.6	8.5
Water Flow Rate Spot Checks, gpm													
Total to machine	25.9	26.9	26.0	26.4	26.8	26.1	25.7	26.2	26.2	NA	26.0	24.9	25.5
Through cutters	15.9	17.4	16.4	16.2	NA	16.8	16.3	16.9	17.6	16.0	15.7	16.3	16.8
Through side sprays	7.3	7.4	7.2	7.1	NA	7.3	7.2	7.2	7.1	7.2	7.1	7.0	7.2
Water Pressure at Operator's Cab, psi	170	170	170	170	150	180	170	170	165	NA	140	170	170
Airflow, 1000 cfm													
Near 300 Package	14	13	14	13	13	18	15	12	15	NA	15	16	14
Downstream of trickle duster	18	32	17	28	15	27	30	15	24	23	14	15	14
Gross Dust Sample Weight, mg													
300H	10.8	9.2	14.4	3.0	14.9	18.0	8.4	3.0	3.1	2.2	6.7	6.4	5.5
300L	17.0	15.8	18.9	4.9	10.5	16.4	23.5	9.2	8.1	2.4	6.0	8.2	6.2

TABLE C-7. WEIGHT OF DUST (mg) COLLECTED AT EACH SAMPLING LOCATION, WET-HEAD MACHINE
SHIFTS 1 TO 14: 1-INCH NOZZLES
SHIFTS 15 TO 20: 3/8-INCH NOZZLES

Shift Number	01	03	04	05	06	07	08	09	10
Intake to section (Sampling Package No. 100)									
Sampling time, min	341	366	352	377	334	372	376	378	374
Dust weight, mg									
LP	0.1	NA	0.1	0.1	NA	0.1	0.1	0.1	0.0
RP	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.0
Mining machine (Sampling Package No. 200)									
Sampling time, min	355	357	344	366	276	365	276	371	366
Dust weight, mg									
LP	0.2	0.3	0.3	0.1	NA	0.4	0.1	0.7	0.3
RP	NA	0.2	0.2	0.1	0.2	0.4	0.1	0.9	0.4
M	0.7	0.7	0.3	0.2	0.3	0.7	0.3	1.9	0.7
Return behind brattice, top (Sampling Package No. 300H)									
Sampling time, min	352	357	340	362	272	361	280	364	349
Dust weight, mg									
LP	0.7	0.5	0.8	0.5	0.4	0.8	0.5	0.8	0.9
RP	0.8	0.6	1.2	0.5	0.4	0.8	0.5	0.8	1.1
M	2.9	2.1	2.0	1.6	1.3	1.8	1.4	3.5	2.9
TG	NA	41.6	12.6	7.4	8.2	28.2	21.3	25.5	27.3
SC	NA	29.1	15.1	7.2	8.0	25.6	16.6	25.9	24.1
Return behind brattice, bottom (Sampling Package No. 300L)									
Sampling time, min	352	357	340	362	272	361	280	364	349
Dust weight, mg									
LP	0.6	0.6	1.1	0.4	0.4	0.7	0.5	1.0	1.1
RP	NA	0.6	1.1	0.5	0.5	0.7	0.5	1.1	0.9
M	2.7	2.3	1.1	1.7	1.1	1.7	1.6	2.6	2.9
TG	15.3	34.7	11.0	8.7	10.7	22.8	40.0	20.6	28.6
SC	16.2	39.8	11.0	5.6	11.4	19.5	41.2	19.0	27.6

TABLE C-7. WEIGHT OF DUST (mg) COLLECTED AT EACH SAMPLING LOCATION, WET-HEAD MACHINE
SHIFTS 1 TO 14: 1-INCH NOZZLES
SHIFTS 15 TO 20: 3/8-INCH NOZZLES
(Continued)

Shift Number		11	12	13	14	15	16	17	18	19	20
Intake to section (Sampling Package No. 100)											
Sampling time, min		380	374	354	353	336	328	362	321	356	322
Dust weight, mg											
	LP	0.0	0.1	0.0	NA	0.0	0.0	0.2	0.1	0.1	0.1
	RP	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.1
Mining machine (Sampling Package No. 200)											
Sampling time, min		374	359	340	342	331	302	355	306	350	295
Dust weight, mg											
	LP	0.2	0.2	0.2	0.1	0.5	0.3	0.6	0.3	0.3	0.4
	RP	0.3	0.3	0.1	0.0	0.5	0.2	0.6	0.3	0.5	0.4
	M	0.4	0.5	0.7	0.4	1.2	0.8	1.3	0.4	0.8	0.5
Return behind brattice, top (Sampling Package No. 300H)											
Sampling time, min		371	346	339	338	324	300	354	275	343	257
Dust weight, mg											
	LP	3.4	1.3	0.5	0.6	0.7	0.5	0.7	1.0	0.9	0.7
	RP	3.6	1.3	0.5	0.6	0.7	0.4	0.8	1.1	0.9	0.7
	M	8.2	5.1	1.5	1.7	2.6	1.6	2.4	2.7	2.4	1.4
	TG	37.7	28.9	11.1	8.4	11.7	5.7	16.6	16.9	25.0	16.8
	SC	37.9	30.2	11.6	7.9	10.4	6.0	18.8	21.1	23.8	12.5
Return behind brattice, bottom (Sampling Package No. 300L)											
Sampling time, min		371	346	339	338	324	300	354	275	343	257
Dust weight, mg											
	LP	2.7	1.4	0.5	0.6	0.8	0.6	0.8	0.9	0.9	0.7
	RP	2.0	1.6	0.6	0.6	0.8	0.6	0.8	1.0	0.9	0.7
	M	9.7	5.9	2.7*	1.9	2.7	1.8	2.0	2.5	2.3	1.6
	TG	51.2	31.7	23.3	13.7	15.3	8.2	25.8	34.2	43.2	25.8
	SC	46.7	30.2	19.9	11.1	15.5	9.4	24.6	34.9	40.8	17.4

* Filter appears contaminated

TABLE C-8. WEIGHT OF DUST (mg) COLLECTED AT EACH SAMPLING LOCATION, CONVENTIONAL SPRAY MACHINE
SHIFTS 21 TO 34

Shift Number		21	22	23	24	25	26	27	28
Intake to section (Sampling Package No. 100)									
Sampling time, min		340	337	359	239	383	359	370	376
Dust weight, mg									
	LP	0.2	0.1	0.1	0.0	0.0	0.1	0.1	0.1
	RP	0.2	0.1	0.1	0.1	0.0	0.0	0.1	0.1
Mining machine (Sampling Package No. 200)									
Sampling time, min		335	276	358	236	379	358	363	371
Dust weight, mg									
	LP	0.8	0.2	0.4	0.3	0.3	0.2	0.4	0.2
	RP	0.9	0.2	0.6	0.3	0.4	0.3	0.3	0.2
	M	1.4	0.4	0.9	0.9	NA	0.6	0.8	0.4
Return behind brattice, top (Sampling Package No. 300H)									
Sampling time, min		333	308	346	252	381	359	362	364
Dust weight, mg									
	LP	1.5	1.8	0.9	2.2	1.0	0.8	0.8	0.6
	RP	2.4	2.2	1.0	2.0	1.1	0.6	0.7	0.6
	M	3.9	3.6	2.2	5.9	3.4	3.7*	2.7	1.7
	TG	46.3	56.8	29.8	49.8	39.6	20.5	17.2	18.2
	SC	59.0	56.3	33.2	48.1	44.4	22.1	21.5	18.1
Return behind brattice, bottom (Sampling Package No. 300L)									
Sampling time, min		333	308	346	252	381	359	362	364
Dust weight, mg									
	LP	1.6	2.4	1.0	2.1	1.0	0.8	0.7	0.5
	RP	2.2	2.0	1.0	2.1	1.1	0.7	0.9	0.6
	M	4.0	3.9	2.1	5.3	3.6	4.1*	3.2	1.8
	TG	90.9	76.8	58.5	66.8	NA	23.0	38.2	23.1
	SC	62.5	112.4	54.1	64.4	72.8	25.5	33.4	29.6

* Filters do not appear that heavy

TABLE C-8. WEIGHT OF DUST (mg) COLLECTED AT EACH SAMPLING LOCATION, CONVENTIONAL SPRAY MACHINE SHIFTS 21 TO 34 (Continued)

Shift Number		29	30	31	32	33	34
Intake to section (Sampling Package No. 100)							
Sampling time, min		361	334	367	285	379	287
Dust weight, mg							
	LP	0.2	0.1	0.1	0.1	0.1	0.1
	RP	0.2	0.1	0.1	0.1	0.1	0.1
Mining machine (Sampling Package No. 200)							
Sampling time, min		358	319	364	275	375	275
Dust weight, mg							
	LP	0.2	0.3	0.3	0.3	0.5	0.3
	RP	0.3	0.4	0.3	0.3	0.5	0.4
	M	0.5	1.0	0.7	NA	0.8	0.9
Return behind brattice, top (Sampling Package No. 300H)							
Sampling time, min		358	317	361	262	367	258
Dust weight, mg							
	LP	0.5	0.8	1.0	0.7	1.7	1.2
	RP	0.6	0.8	1.1	0.7	1.8	1.2
	M	1.3	1.6	2.4	NA	3.9	2.7
	TG	14.5	26.5	70.4	20.3	63.5	24.4
	SC	17.3	32.1	NA	18.1	72.9	28.3
Return behind brattice, bottom (Sampling Package No. 300L)							
Sampling time, min		358	317	361	262	367	258
Dust weight, mg							
	LP	0.7	0.7	1.0	0.6	1.6	1.5
	RP	0.8	0.7	1.0	0.6	1.7	1.5
	M	2.0	1.9	2.5	NA	3.5	3.2
	TG	33.9	27.5	90.8	26.6	86.3	51.6
	SC	39.0	26.3	NA	23.5	104.2	51.4

TABLE C-9. WEIGHT OF DUST (mg) COLLECTED AT EACH SAMPLING LOCATION, WET-HEAD MACHINE
SHIFTS 35 TO 46

Shift Number	35	36	37	38	39	40	41	42	43	44	45	46
Intake to section (Sampling Package No. 100)												
Sampling time, min	384	336	366	338	368	355	318	370	358	308	379	325
Dust weight, mg												
LP	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.0	0.1	0.1
RP	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	NA
Mining machine (Sampling Package No. 200)												
Sampling time, min	386	324	365	329	366	351	316	357	355	282	374	317
Dust weight, mg												
LP	0.5	0.2	0.8	0.4	0.8	0.4	0.4	0.5	0.4	0.2	0.4	0.2
RP	0.5	0.2	0.7	0.4	0.8	0.4	0.3	0.5	0.4	0.1	0.4	0.2
M	1.0	0.4	1.7	0.8	1.9	0.9	0.6	1.0	1.2	0.2	NA	0.7
Return behind brattice, top (Sampling Package No. 300H)												
Sampling time, min	376	298	363	316	362	343	314	339	355	272	369	307
Dust weight, mg												
LP	0.8	0.7	0.4	0.3	1.4	1.2	0.7	1.4	1.0	0.7	0.9	0.9
RP	0.8	0.5	0.7	0.3	1.2	1.3	0.8	1.2	0.9	0.8	NA	0.8
M	1.9	0.9	1.5	0.7	2.5	2.2	1.5	3.0	2.5	1.6	2.2	1.9
TG	13.7	8.9	10.3	4.4	36.6	20.9	18.8	20.5	31.0	23.4	18.7	19.7
SC	13.6	10.1	12.0	4.2	31.9	22.3	21.8	19.0	34.4	35.9	14.5	20.8
Return behind brattice, bottom (Sampling Package No. 300L)												
Sampling time, min	376	298	363	316	362	343	314	339	355	272	369	307
Dust weight, mg												
LP	0.9	0.5	0.8	0.3	1.2	1.3	0.8	1.1	1.3	0.9	0.9	0.9
RP	0.9	0.6	0.8	0.4	1.2	1.2	0.9	1.2	1.3	1.1	1.1	0.8
M	2.4	1.0	1.8	1.0	2.1	2.6	1.8	2.4	2.7	2.2	2.3	1.9
TG	19.0	13.7	15.8	8.1	38.5	36.3	31.5	24.6	46.8	31.8	27.4	22.7
SC	18.8	12.4	14.3	7.4	38.0	32.1	34.0	23.8	51.7	31.8	40.8	22.8