APPLICATION OF WEATHERING PROTECTION AT THE FACE

Final Report

In Response To:

Contract No. H0272008

Prepared For:

U. S. Bureau of Mines
Section of Contracts
Building 20, Denver Federal Center
Denver, Colorado 80225

Attention: Contracting Officer
Contract No. H0272008

19 August 1980

MB-R-79/33, Rev. 5

PREPARED BY
MBA MBAssociates
...nger Canyon Road, San Ramon, California 94583

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16. Abstract

A machine was designed, built, and tested that sprayed a coal mine sealant on the roof immediately after exposure at the face.

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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF ILLUSTRATIONS

FORWORD

This report was prepared by MBAssociates, San Ramon, California under USBM Contract No. H0272008. The contract was initiated under the Coal Health and Safety Program. It was administered under the technical direction of Spokane Research Center with John C. Franklin acting as Technical Project Officer. David J. Askin was the Contract Administor for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period July 1977 to January 1980. This report was submitted by the author David C. McHuron on 25 March 1980.

ABSTRACT

The U. S. Bureau of Mines in their continuing research into sealants, selected MBAssociates to design, build, and test equipment and evaluate sealant as to its effectiveness is shale degradation.

There were 20,050 sq.ft. of coal mine roof sprayed with a mine sealant and as a result, it has been estimated that the sealant coated roof has from 50% to 95% less roof falls than that roof which was not coated with sealant.

INTRODUCTION

Many underground coal mines are composed of shale layered directly over the coal. This shale weathers severely immediately after exposure to the mine atmosphere.

[1]Investigations have shown that many shales separate into layers when emersed in water or when stored in a high relative humidity environment. Upon drying, or after removal from high humidity, the shales continue to separate. Condensation of the ventilating air causes underground coal mines to become wet during the warmer months. During the cooler months, the mines become dry from evaporation. This difference in mine atmosphere is responsible for the severe shale break-up experienced during the summer and the corresponding lessening of the break-up through the winter months.

Sealants for stopping or reducing shale degradation and sluffing have been used to some extent for many years. Various materials and methods have been utilized, including formed concrete lining, gunite, inorganic coating, and wide range of organic coatings. The U. S. Bureau of Mines, Spokane Research Center, has been researching sealants. It is under the auspices of this contract that this final report on the investigation and testing of equipment and sealant is presented.

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[1]Article by Jack E. Fraley and Robert E. Simpson in RETC PROCEEDING, 1974 Vol. 2, Page 1027.

FINAL REPORT

APPLICATION OF WEATHERING PROTECTION AT THE FACE

USBM Contract No. H027008

1.0 SUMMARY

The objective of the contract was to design and construct spray equipment to be mounted on a continuous miner for sealing the roof immediately after exposure. Also, selection of a sealant material then field evaluate the equipment.

The effort was divided into nine tasks, as follows:

- Sealant selection
- System design
- Phase I Report
- System fabrication
- Test Plan
- Simulated mine test
- Underground field test
- Equipment delivery
- Final Report

The result of the effort is the design, fabrication, and testing of equipment and the selection and testing of mine sealant. During May of 1979, 20,050 square feet of coal mine roof were sprayed using this equipment. Armco Steel's, Robin Hood Division, Mine #9, located at Twilight, West Virginia, was used as the test mine.

The average coverage[1] was 83.5 square feet per gallon of sealant at a total average cost[2] of $0.1345 per square foot with an average thickness[3] of 0.007 inch.

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[1]This average coverage value includes all sealant including that which was not used due to contamination (dirt, grease, etc.) split containers film and lumps, sealant that was washed out of the system at the end of the day, and missing (stolen?) sealant. See Appendix for calcuations.

[2]Includes miner's wages, shipping cost of the sealant and sealant cost. See Appendix for calculations.

[3]See Appendix for calculations.

2.0 SEALANT SELECTION

A meeting was set up between Spokane Research Center and MBA to discuss the Bureau's experience with Sealant materials and give reference to published articles, specific sealant manufacturers, and various contacts that could give additional information on mine sealants. The selection of mine sealant was based upon the following factors:

- MSHA approved or potentially MSHA approvable.
- Fire proof or self extinguishing.
- Minimum or no smoke when exposed to open flame.
- No toxic gas emissions when exposed to open flame.
- Less than 50,000 CPS.
- Water soluble for clean-up.
- Provide a moisture barrier.
- Adhesion to roof shale with varying degrees of dust and moisture.
- Suitable for airless spray.
- Impose no substantial risk of human toxicity.
- Cure temerpature range $40^{\circ}F$ to $90^{\circ}F$.
- Cure humidity range 30% to 85%.

Each sealant was then evaluated and the results recorded on a mine sealant evaluation sheet (Figure 1). After the sealant passed recorded on a sealant evaluation chart (Figure 2). The score for each sealant with respect to each evaluation parameters was rated on desirability and based entirely on the groups' minimum and maximum qualities. Any sealant that did not meet the minimum qualities, as called out in the contract, were not included in this evaluation.

The following list includes all the parameters used for sealant evaluation used for final selection:

FIGURE 1

MINE SEALANT EVALUATION SHEET

Sealant Name:

Description:

Curing Time In Minutes (.03 Thick):

Dry Steel Plt. at $70^{O}F$	____________
Dry Steel Plt. at $40^{O}F$	____________
Inorganic Specimen - Dry	____________
Inorganic Specimen - Wet	____________

Fire Test:

Apply Propane Torch to Cured Sealant For 30 Second and Rate

Flammable	____________
Self-Extinguishing	____________
Fire Proof	____________

Describe Smoke With Flame:

Describe Smoke Without Flame:

Self-Extinguishing Quality:

Time to Self-Extinguish: ____________

Odor:

Prior to Cure:

During Burning:

PH Value

EVALUATION PARAMETERS / SEALANTS		Dow XD7151	SCORE	Ocean 666	SCORE	Neoprene Latex 6977	SCORE	Acrylic Latex 6877	SCORE	Hydr-epoxy 156	SCORE	Hydr-epoxy 300	SCORE	Polysar XD674	SCORE	Hydro Seal	SCORE	Polysar XD674 w/soap	SCORE	Dow Latex XD8609 .01	SCORE	Dow Latex XD8260 .04	SCORE
DRYING TIME MINUTES	DRY SPEC.	1	0	8	0	5	0	1	0	60	5.0	45	4.0	3	0	4.5	1.0	8	1.0	3.5	0	12	2.0
	WET SPEC.	1	0	40	3.0	6	0	1	0	75	4.0	45	4.0	3	0	4.5	1.0	11	1.0	10	1.0	14	2.0
SMOKE		Mild w/o flame for 10 sec.	9.0	Light w/o flare for 30 sec.	4.0	Mild w/o flame for 5 sec.	8.0	Mild w/o flame for 5 sec.	8.0	Mild w/o flame for 15 sec.	8.0	Light w/flame Heavy w/o flame 15 sec.	7.0	Mild w/o flame for 10 sec.	5.0	Mild w/o flame for 60 sec.	7.0	Mild w/o flame for 40 sec.	4.0	Light for 5 sec.	10.0	Light w & w/o flame for 5 sec.	10.0
RHEOLOGY	NOZZLE DIA	.015		.019		.021		.015		.021		.021		.021		.019		.019		.015		.015	
	ZANN SEC.	15	4.5	>38	10.0	36	6.3	20	5.3	17	7.0	>38	9.5	30	5.6	49	8.45	46	8.5	16	4.6	16	4.6
	ZAHN CUP	2		5		2		2		5		5		2		2		2		2		2	
FLOW GPM		.26	8.0	.23	8.6	.23	8.6	.23	8.6	.32	6.6	.32	6.6	.25	8.2	.33	6.6	.28	7.6	.18	10.0	.16	10.0
WATER SOLUBILITY		Fair	4.0	Excel.	10.0	Good	7.0	Good	7.0	Good	7.0	Good	7.0	Good	7.0	Good	7.0	Good	7.0	Fair	4.0	Fair	4.6
EQUIPMENT COMPATIBILITY		Clogged pump in 30 min.	0	Excel.	10.0	Fair. Nozzle filmed in 20-30 min.	6.0	Fair. Nozzle filmed in 20-30 min.	6.0	Good	8.0	Good	8.0	Clogged pump in 30 min.	0	Good	8.0	Good	8.0	Fair	6.0	Fair	6.0
PH		2	0	8	9.0	2	0	7	10	9	8.0	9	8.0	8	9.0	8	9.0	8	9.0	8	9.0	7	10.0
ODOR	PRIOR TO CURE	None	5.0	Light	4.0	None	5.0	None	5.0	Light	4.0	None	5.0	None	5.0	None	5.0	None	5.0	None	5.0	None	5.0
	DURING BURN	Strong	1.0	Mild	3.0	Strong	1.0	Mild	3.0	Mild-Str.	2.0	Mild-Str.	2.0	Strong	1.0	Mild	4.0	Mild	3.0	Mild	3.0	Mild	3.0
SEALANT COST $ PER GAL.		8.63	6.0	10.50	2.0	7.05	5.0	6.60	6.0	5.83	5.0	7.97	5.0	2.50	10.0	7.80	5.0	2.50	10.0	3.04	9.5	3.17	9.4
PEEL STRENGTH POUNDS	WET	6.38	6.0	7.38	10.0	3.25	2	3.13	3.0	.88	0	3.50	2.6	8.63	10.0	2.50	1.35	.75	.25	2.13	2.4	3.63	2.6
	DRY	14.25		37.00		1.75		10.00		1.75		5.00		37.00		2.25		2.50		10.25		3.75	
COLOR WHEN DRY		Clear	1.0	White	6.0	Trans-lucent	3.0	Trans-lucent	3.0	Trans-lucent	3.0	White	6.0	Trans-lucent	3.0	Trans-lucent	3.0	Trans-lucent	3.0	Trans-lucent yellow	3.0	Trans-lucent yellow	3.0
SPRAY PRESSURE		1200	9.0	1800	6.0	1200	9.0	2000	5.0	1800	6.0	1200	9.0	1800	6.0	1500	7.5	1000	10.0	1000	10.0	1000	10.0
MIN. SET UP TEMP.		40°	7.0	50°	4.0	45°	5.0	47°	5.0	50°	4.0	50°	4.0	32°	10.0	45°	6.0	32°	10.0	32°	10.0	60°	1.0
SET UP HUMIDITY RANGE		30% - 90%	10.0		9.0	30% - 90%	8.0	30% - 90%	8.0	30% - 85%	8.0	30% - 85%	8.0	30% - 85%	10.0	30% - 85%	8.0	30% - 85%	10.0	30% - 90%	10.0	30% - 90%	10.0
TOTAL SEALANT SCORE			70.5		97.6		73.9		82.9		84.6		92.7	O	91.8		80.0		99.4	Δ	97.5	Δ	93.2

O POLYSAR XD674 HAS BEEN SUPERSEDED BY POLYSAR XD674 W/SOAP.

Δ DOW LATEX XD 8609.01 AND XD 8260.04 WERE ELIMINATED DUE TO CRACKING WHEN DRY ON WET SURFACE.

FIGURE 2
SEALANT EVALUATION CHART

2667-16117

- Drying time minutes
- Rheology
- Smoke
- Water solubility
- Flow Rate
- Equipment compatibility
- Ph
- Odor
- Cost per gal.
- Color when dry
- Peel strength
- Set up humidity range
- Spray pressure
- Temperature range
- Conclusion

2.1 Drying Time

To be compatible with the mine cycle, the ideal cure time for the sealant has been set at 60 minutes. This would allow the sealant to remain in the liquid state at the nozzle tip during the mining and sealing cycle. Since the average mining cycle is 60 minutes for a six pass cutting cycle, the sealant will not cause clogging problems if filming occurs after this amount of time. Maximum score is 5 points for each dry and wetted specimen surface. Every ten-minute deviation equals 1 point for wet and dry sections of test sample. This test was done on "Mine Guard" test specimens. Each specimen was wetted on half of the spraying surface for wet and dry cure time comparison. Total possible score is 10.

2.2 Rheology

The consistency of the ideal sealant should have a very low viscosity while passing through the nozzle orifice and have a high viscosity when applied to the mine roof. By viscosity reduction during spray application minimum power will be required for the spray cycle.

In order to rate the sealant material the following formula was generated.

$$\text{ZAHN CUP NO.} + \frac{\frac{T\text{(Zahn sec.)}}{D\text{ (nozzle dia.)}}}{1000} \times 2.50 = \text{SCOPE}$$

2.3 Smoke

The evaluation of the smoking characteristics of each sealant sample characteristics is based upon smoke with and without direct exposure to a propane flame. Time duration for direct exposure to the flame was thirty seconds. For every ten seconds of smoke subtract 1 point from the score. Maximum score of 5 points for no smoke during each condition.

2.4 Water Solubility

Water solubility is based on ease of cleanup using water only. No dilution of material with water was done during the tests. Excellent, good, fair and poor represent 10, 7, 4 and 3 respectively.

2.5 Flow Rate

Flow rate was checked for material following nozzle selection. The nozzle and pressure selection was based on complete coverage of inorganic coated panels. The panels were inverted following the spray coat to check for any dripping or running of the sealant prior to curing. For the nozzle selection the pressure was minimized for each sealant and nozzle orifice maximized to achieve a smooth even coat. The initial nozzle and pressure test were performed on a smooth cardboard surface to visually inspect the thickness and consistency of each sealant. An application rate and flow rate for each sealant was performed. For the application rate a time was taken for the required pass rate necessary to achieve full uniform coverage for the three (3) feet long cardboard panels. The flow rate was checked by spraying the sealant into a graduated beaker for ten seconds.

Since the minimum material used to seal the mine roof is most desirable, the minimum flow rate to satisfy these requirements would be most desirable. The minimum flow rate was .18 GPM and received a score of ten. For every .1 GPM increase in flow rate subtract 2.5 points from ten for the score.

2.6 Compatibility With Equipment

Some sealants were not compatible with carbon steel or aluminum. The sealant compatibility ranged from internal pump clogging to no apparent phase change on equipment during sealant tests.

Rating was based upon: unacceptable, poor, fair, good and excellent and scored 0, 3, 6, 8, 10 respectively.

2.7 PH Values

The sealant acidity or alkalinity is an important characteristic based upon skin irritation and corrosiveness of spray equipment. Most desirable PH value would be seven, this being a neutral condition. The sealant would be more acceptable if it has alkaline rather than acidic characteristics due to skin and pump compatibility. For the score of each sealant 2 points will be subtracted from 10 per PH value less than 7 and 1 point subtracted from 10 for each PH value greater than 7.

2.8 Odor

The sealant material odor characteristics is evaluated based upon human odor sensitivity using descriptions of no odor, mild, mild to strong, and strong.

The total odor score is based on the burning and non-burning state. In both cases no odor rated 5 points, strong odor rated 0. The sum of ratings for each phase is the total odor rating.

7.9 Sealant Cost

Cost is based on 55-gallon drum quantities. The sealant costing the least is given a score of ten, for every dollar greater than the lowest cost, 1 point was subtracted from 10.

2.10 Color

The sealant color is not considered to be a major factor in sealant selection. Most desirable color would be white and given a score of five. Translucent white and clear were given scores of three and one respectively.

2.11 Peel Strength

The peel strength score is based upon dry and water soaked specimens. Each specimen was made up of a pair of one inch wide by eight inch long denim cloth strips. Each strip was coated on a side, bonded together and allowed to dry. After the specimens were dry two of each sealant specimen were soaked in water for one hour and two hours and then pull tested to check peel strength. These values were then averaged to give a wet environment test. The dry specimen was pulled to achieve a dry environment test. A score for each is based upon a maximum value of 5 points for each wet and dry test. The largest force equalling 5 points and the lowest 0.

2.12 Humidity Range

The maximum humidity value is considered to be most critical for Humidity Range Evaluation. All sealants tested set up at 30 percent to 35 percent relative humidity so the score is based upon these maximum values. The actual maximum humidity value is 90 percent (based on manufacturing literature). A score of 10 was received if the sealant tested set up at 35 percent. For every ten percent reduction in relative humidity subtract 2 points from maximum score.

2.13 System Spray Pressure

Since pressure is a function of horsepower and minimum power is desirable, minimum pressure is desirable. Minimum pressure of 1000 received a score of ten. For every 200 psi greater than 1000 psi 1 point is subtracted from 10 pressure score.

2.14 Temperature Range

Minimum temperature is considered to be most critical for the Temperature Range Evaluation. All sealants tested set up at temperatures in the upper nineties, so the score is based on the minimum set up temperature value. The minimum temperature was 32 degrees F. This temperature gave a score of ten with 60 degrees F as highest minimum coellessing temperature receiving 1 point.

For every three degrees greater than 32 degrees F subtract 1 point from 10.

2.15 Conclusion

The evaluation chart shows that Polysar X0674[1] with soap to be the best selection. However, during testing, it was discovered that when the Polysar was put under pressure and heated up, it separated into water and coagulated sealant. This heating up took place when the sealant was going through the pumps. The pressure was approximately 2800 psi and the heat (hot to the touch) was generated by the pistons in the pumps. The resulting separation (water & sealant) caused clogging problems at the nozzles.

The sealant finally selected was American Energy Products Corporation Acrylic Latex VMX-50-BM[1] (same as Acrylic Latix 6877).

This sealant was selected because of its unique ability to keep from separating and solidifying after it has passed through the pumps. Out of all the sealants tested, this was the only sealant that did not cause clogging problems at the nozzles when it was left in the sealant lines for an extended period of time (72 hrs.). Figure 7 shows the sealant spraying after being left in the lines over a weekend after performing tests all Friday afternoon with the same sealant.

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[1]Reference to specific brands, equipment, or trade names in this report is made to facilitate understanding and does not imply endorsement by by the Bureau of Mines.

3.0 EQUIPMENT DESIGN AND FABRICATION

3.1 Physical Description

The equipment developed (Figure 3) consists of three major components: The power unit (Figure 4), the spray bar (Figure 5) and the control box (Figure 6). These three components are used as a unit to spray coal mine roofs with the selected sealant.

A typical application of the unit would be to spray mine sealant on the roof at the face. For this purpose, the unit is designed to fit on a continuous miner with the spray bar located just behind the head, the power unit located on the left rear corner, and the control box located inside the operator's compartment.

The power unit (Figure 4) contains the sealant tanks (two 25 gallon stainless steel tanks), two double acting positive displacement pumps, a hydraulic motor, 10 valves for reversing nozzles, a rocker head, and some reducing and pressure control valves. The power unit demands 7 gallons per minute at 1500 pound per square inch from a hydraulic power source to deliver 0.34 gallons of sealant per minute from the pumps to each of the nine nozzles. The rocker head controls the stroke on each pump thereby controlling flow from each pump. This is necessary for spraying two part sealant that requires a greater or less than 1 to 1 mixing ratio.

The Spray Bar (Figure 5) contains the sealant spray nozzles. The sealant, being under pressure from the pumps, is forced out through the nozzle forming a thin triangular shaped fan. This fan can be seen from just in front of the spray bar by looking at Figure 7. Notice that the fans converge a short distance above the nozzles (convergence line). To ensure complete sealant coverage to the roof, the spray bar should be located not less than this distance below the roof. This convergence distance is about 10 inches above the nozzles. As the spraying is being done, the continuous miner trams out of the circuit at approximately 1 foot/second to give a continuous even coating to the roof.

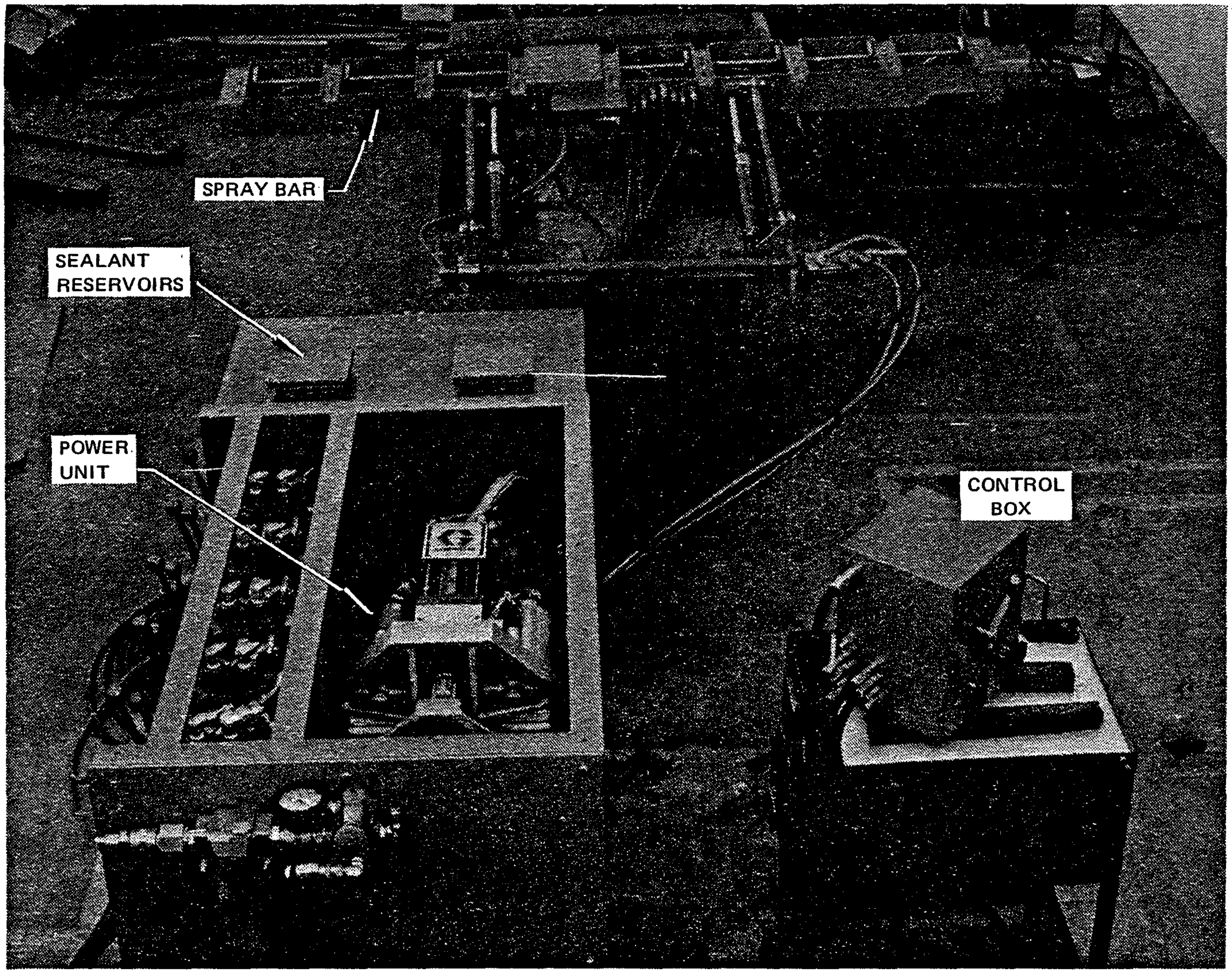


FIGURE 3
SPRAY SYSTEM

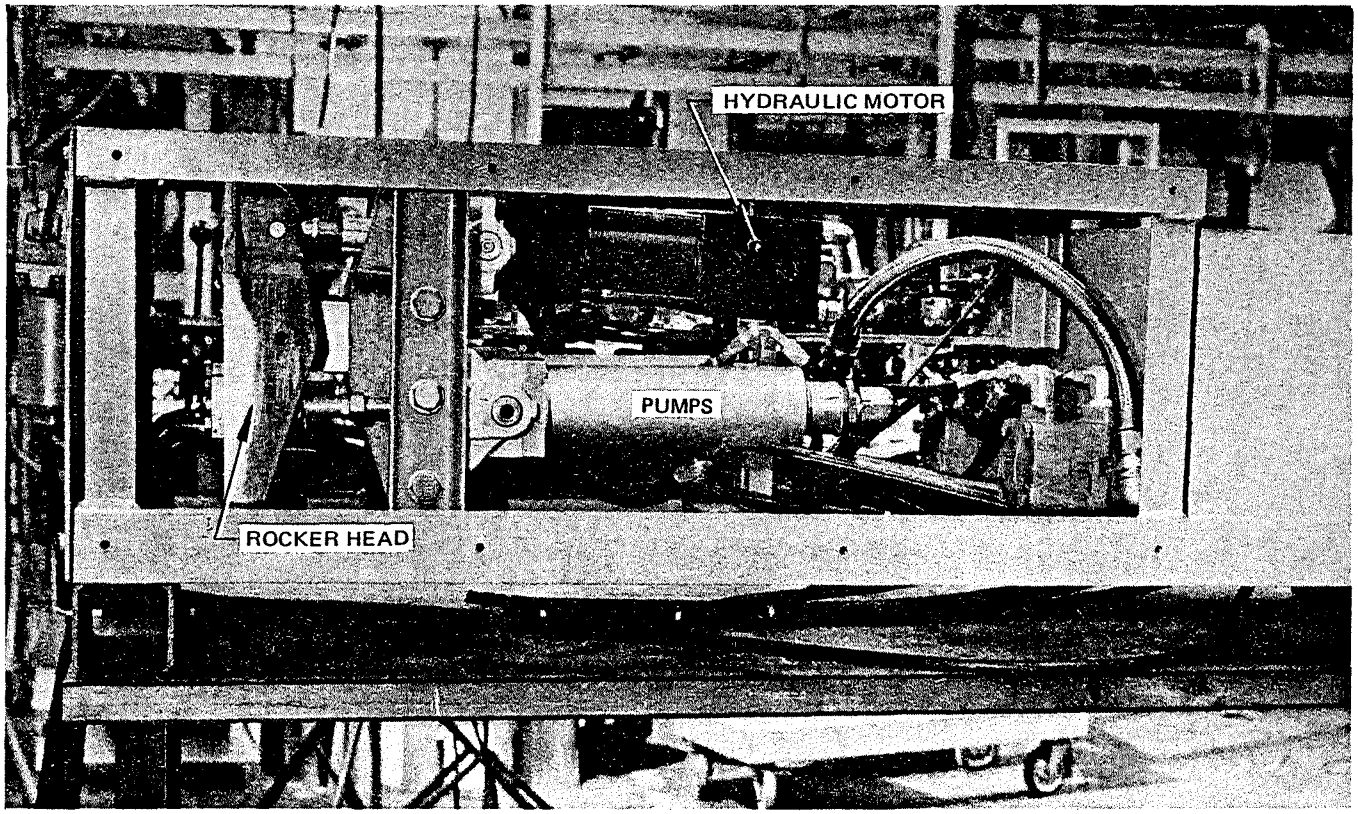


FIGURE 4
RESERVOIR AND POWER UNIT

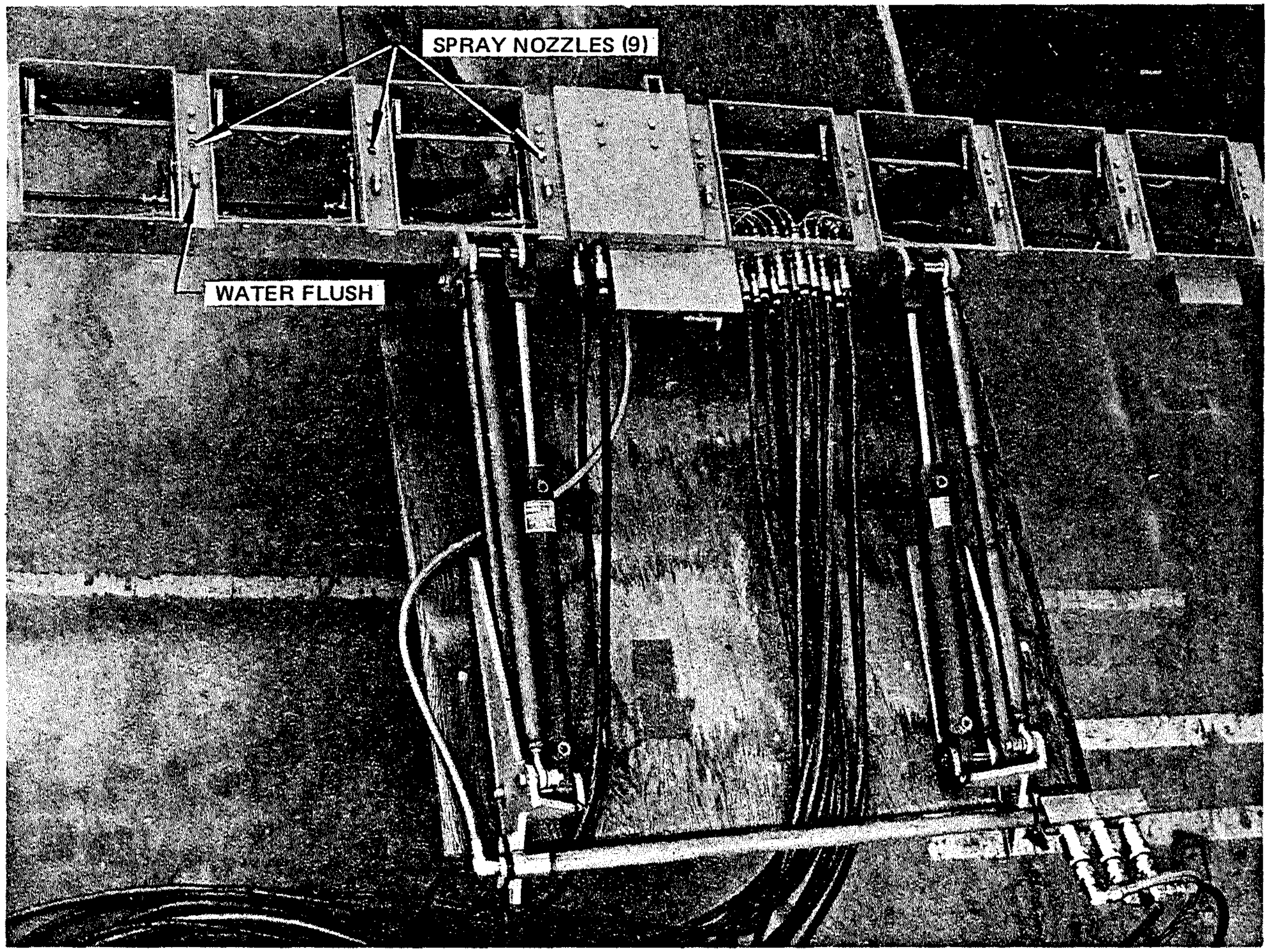


FIGURE 5
SPRAY BAR

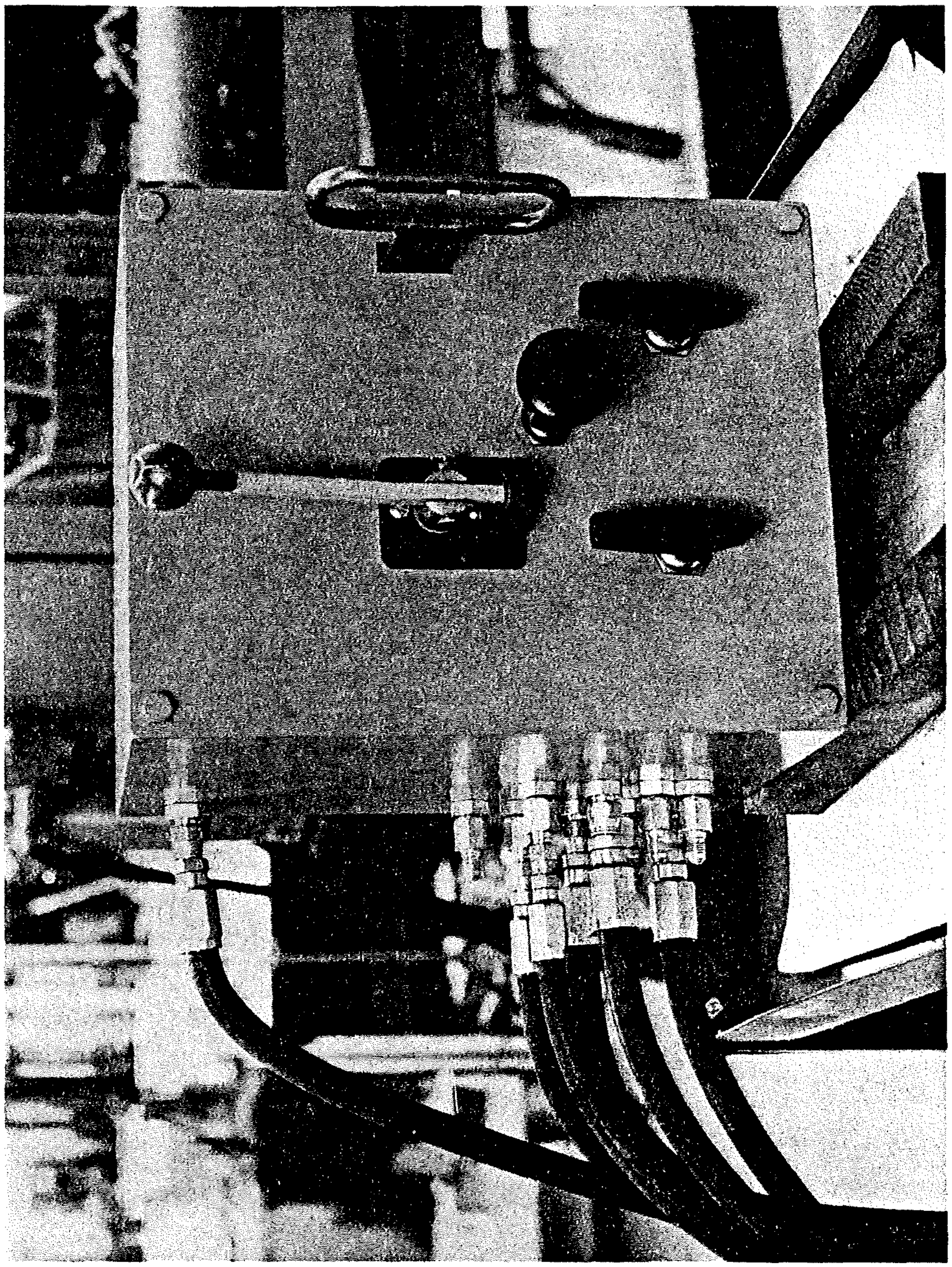


FIGURE 6(A)
CONTROL BOX (FRONT)

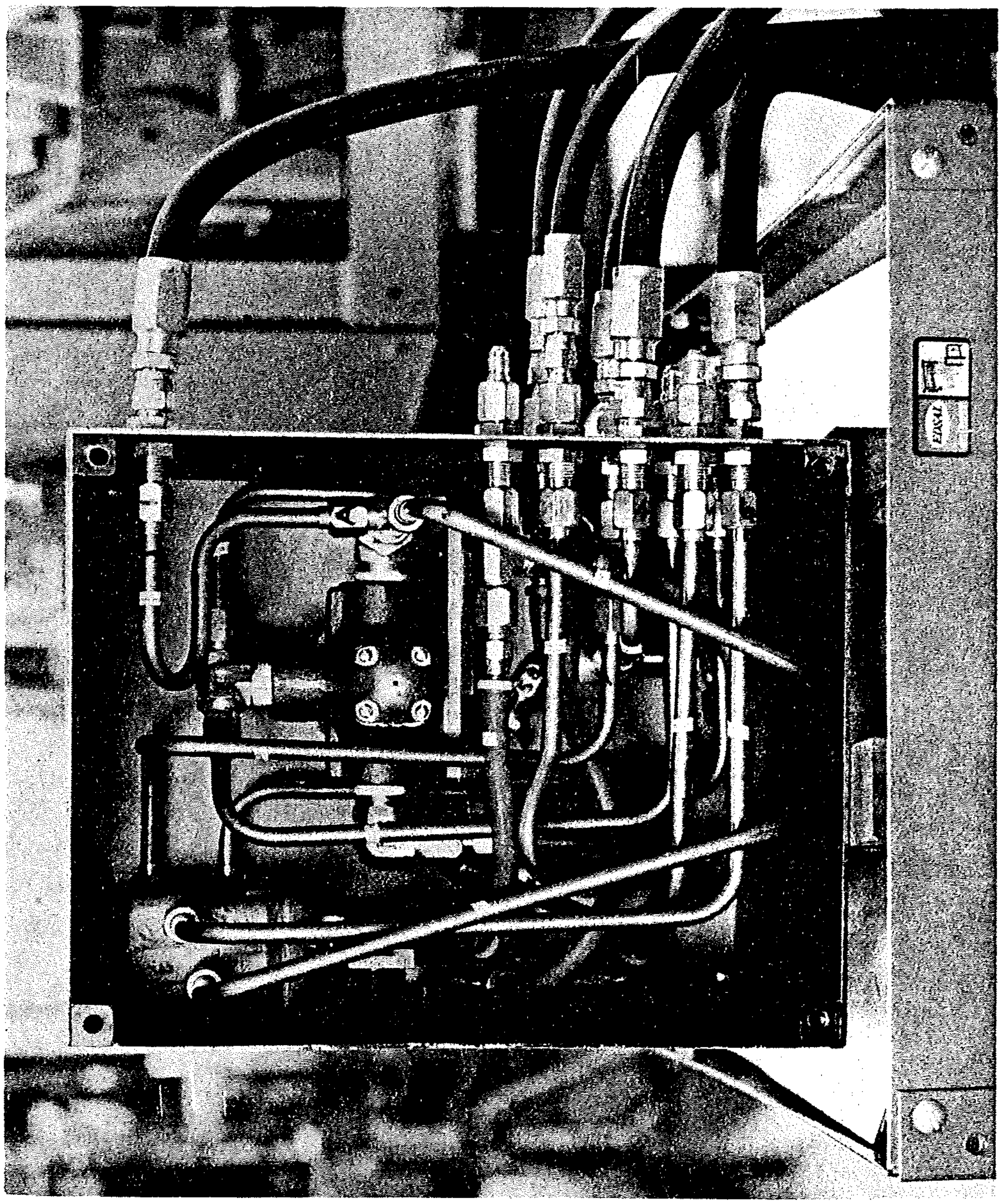


FIGURE 6(B)
CONTROL BOX (REAR)

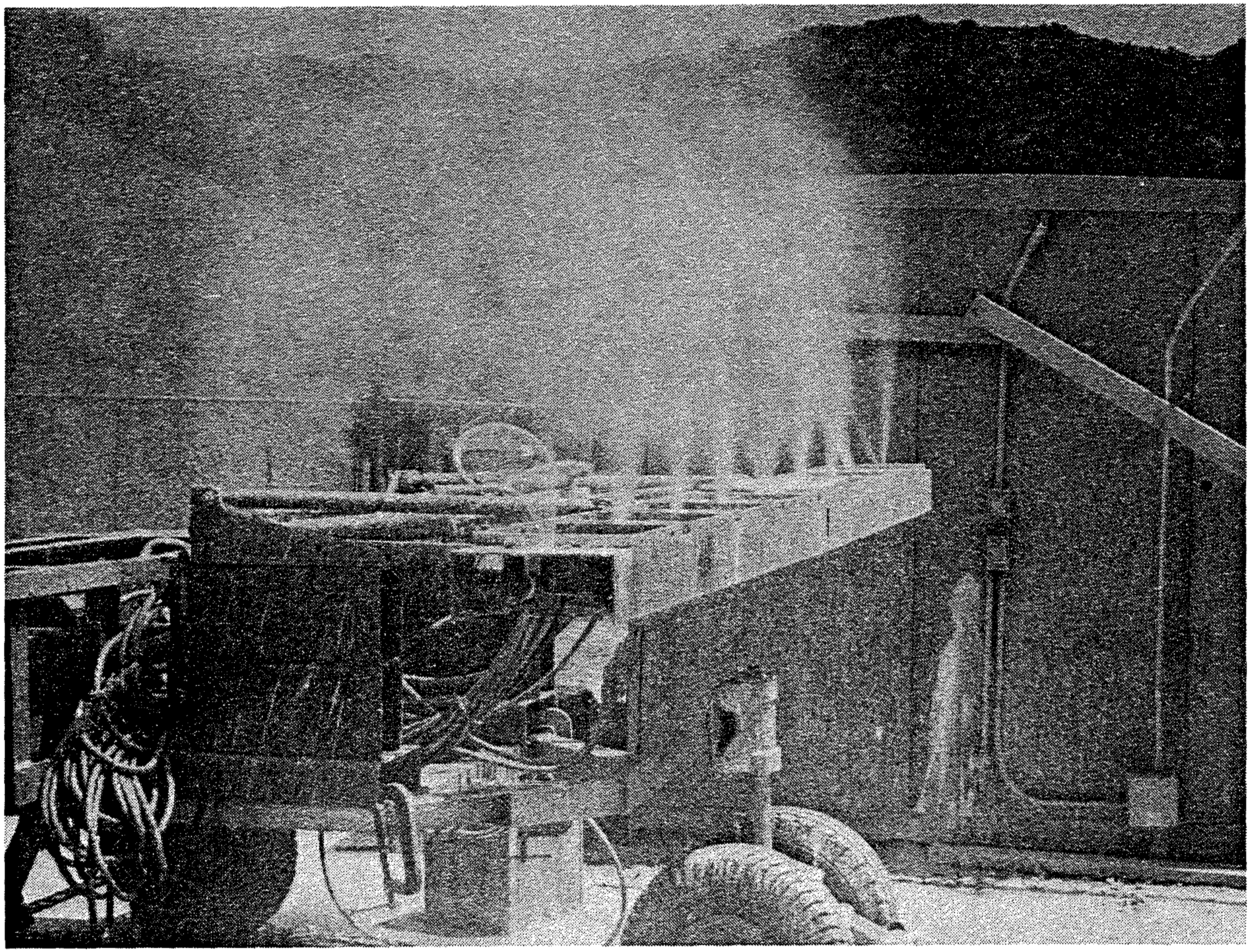


FIGURE 7
SPRAYING MONDAY MORNING

The control box (Figure 6) contains the on and off valves for control of the sealant, oil, and water. From the control box all functions can be performed, except the reversing of nozzles (used to clear plug-ups). Reversing of the nozzles is done by the miner's assistant at the power unit.

3.2 Functional Description

As the continuous miner trams out of the cut, the operator pulls the spray handle and immediately nine nozzles spray a mine sealant on the freshly exposed roof. The sealant is pumped from the tanks to the nozzle by means of a hydraulic motor driving two double acting positive displacement pumps. Between the pumps and motor there is a rocker head that has two slots. By varying the position of the pump shaft attachment bolt in the slot, different pumping ratios can be obtained. The sealant is sprayed on the roof at a rate of 3.06 gallons per minute and covers about 105 square feet per gallon.

3.3 Spray Bar Design

3.3.1 Nozzle Design

To successfully achieve a trouble free multi nozzle spray bar, a means of flushing the nozzle internally and externally was considered to be highly desirable. This type of design would be utilized prior to and after each spray period. By utilizing this design the sealant material would be diluted prior to the nozzle tip and be washed free or highly diluted at the outer surfaces of the nozzle. This method will eliminate film forming both internally and externally at the nozzle tip. Film forming and dirt particles are the two contaminants which cause nozzle clogging.

To further alleviate any nozzle clogging problems, reversible tip nozzles are used. The nozzles are remotely actuated from the pump - reservoir module. At this location the nozzles are all rotated simultaneously and individually cleared by spraying any one nozzle. The nozzle orifices can be exchanged for larger or smaller sizes when various viscosity material is sprayed.

For protection of the spray nozzles a cover plate that extends over the nozzle tip area is used to keep large pieces of debris from covering or damaging the nozzle. A 2" x 2" opening over each nozzle allows sealant to pass through the protective nozzle cover and be small enough to protect the nozzels from coal and rock. This design was selected in lieu of a movable cover plate that would be actuated in conjunction with the nozzle valve actuators. The total design concept is to be simple and rugged. The simple slotted cover plate concept meets this requirement.

3.4 Pump Selection

The following requirements were used for the selection of the pump system. Drawing SK0053-2025 shows the pump and reservior assembly as configured for adaptation to the continuous miner.

- Positive displacement
- Compatible with one and two-part sealant
- Adjustable ratio from 1:1 to 4:1
- Pump up to 50,000 centipoise
- Hydraulically operated
- [1] 4 GPM minimum flow rate
- [1] 2000 psi minimum pressure

The pump assembly that will meet all of the above requirements utilizes the following components:

- Graco Viscount II 210 - 107 hydraulic motor
- Two Graco 210-312 pumps
- Binks Model Formulator "G" rocker assembly

The overall height of the sealant pump is 18 inches. It is highly necessary to minimize all vertical dimensions of the equipment mounted on the top of the miner. This overall dimension is considered to be a minimum for the design requirements of the system.

[1] These minimum requirements were found to be necessary following the single nozzle tests performed during the sealant selection.

3.4.1 Positive Displacement

The Graco 210-312 pumps are reciprocating positive displacement piston type pumps. The pumps are double acting where both the extension and retracting of the pump rod pumps sealant material.

3.4.2 Compatible With One and Two-Part Sealants

Since the pump assembly is made up of two pump sections, the assembly will handle two-part sealants.

3.4.3 Adjustable Ratio

The pump assembly utilizes the Binks Formulator "G" rocker head which allows the pump section to be adjusted giving the 1:1 to 4:1 mix ratio. This ratio is achieved by varying the position of the piston rod anchor point on the rocker head from 1 inch to 5 inches from the pivot point of the rocker head. By moving one sealant pump rod and leaving the other positioned at the 5 inch setting the correct ratio range can be achieved.

3.4.4 50,000 Centipoise Capability

Data from ACME Chemical on their Hydrepoxy 156 and 300 indicate greater than 50,000 c.p.s. using a Brookfield Viscometer at 5 RPM for part A of both materials.

During the single nozzle tests both AMCE Chemical Hydrepoxy 156 and 300 were pumped with a pump section similar to the pump sections selected for the final design.

3.4.5 Hydraulically Operated

Due to ease of hydraulic power availability on any continuous miner, MBA feels an entirely hydraulic operated system is necessary. A minimum of 10 hydraulic horsepower is required to power the sealant spray system. This represents 10 GPM at 1500 psi with 85% efficiency. This pressure and flow represents the minimum requirements for the system. For example, the Lee Noris 455 miner has 3,000 psi and 30 GPM available.

3.4.6 A GPM Flow Rate at 2,000 psi

The Graco Pump Assembly produces 2,050 psi and 3.63 to 6.6 GPM at the minimum hydraulic power requirements. In the 4:1 mix ratio the total flow rate is somewhat less than the minimum requirement. With reduction in flow rate, the continuous miner, which is the vehicle for the spray system, will be required to tram out at a somewhat slower rate of speed. It has a speed capability of up to 70 feet/min. The speed required for complete coverage is approximately 65 feet/min. This is the average speed of the continuous miner as it trams out.

3.4.7 System Controls

The system controls are made up of the operator control box and the nozzle maintenance controls.

3.4.7.1 Operator Control Box

The operator control box contains the following controls:

- Sealant Spray Control
- Oil Control
- Water Flush Control

This control box has been sized to interface into the operator compartment of all continuous miners with minimum of modification to existing controls.

3.4.7.1.1 Sealant Spray Control

The sealant Spray Control is the "ON" - "OFF" control for the spray bar sealant spray system. During the "ON" or "OFF" stroke of sealant spray control, the internal and external water flush for each nozzle is activated. During the "ON" stroke, the sealant is spraying and the water is off. When the spraying is done and the "OFF" position selected the water flush for the nozzles is activated. This water flush keeps the nozzles moist preventing the sealant from drying on the nozzles.

3.4.7.2 Oil Control

This control valve supplies or stops the flow of hydraulic oil to the system.

3.4.7.1.3 Water Flush Control

This control valve supplies or stops the flow of water to the system.

3.4.7.2 Nozzle Maintenance Controls

The nozzle maintenance controls are located at the sealant pump - reservoir module. These controls have been located in this area due to the cramped operator area which can only handle a minimum of additional controls. The nozzle maintenance controls (10 lever operated valves) will be primarily operated by the miner helper. At the location of the controls the miner helper will always be located under supported roof. He also has good view of the spray bar from this location.

3.5 MBA Custom Reservoir Design

The input from U. S. Steel Mine Research Group indicated a critical need to reduce the overall height of the complete system. Due to the necessity to reduce all aspects of the spray system, a low profile custom reservoir design was implemented.

This design included a removable top for easy cleaning, a water flush bar for periodic system flushing, air cleaner (40 micron) and fill spout. The entire tank was fabricated from stainless steel. To fill the tank either the sealant could be poured via 5 gallon disposable pails into the reservoir or pumped using a heavy liquid type rotary hand pump. After completing the single nozzle tests, a flow rate was calibrated for the range of nozzles used based on a spray nozzle pass rate. Average cutting data for a continuous miner in a 6 to 7 foot high seam was used to determine mining rates of new roof. See "Calculations for Sealant Quantities" in Figure 8. In conjunction with the mining rate, dead time of miner, total roof exposed and required flow rate of sealant, the reservoir volume was determined.

FIGURE 8

CALCULATION FOR SEALANT QUANTITY

Average seam height: 6-1/2 feet

AVERAGE MINING TIME PER PASS: 11 minutes
Time includes; sumping, ripping, trimming, waiting for shuttle car, loading shuttle car and maneuvering.

SUMP TIME:	.30 MIN
RIP TIME:	.22 MIN
PARTIAL SUMP:	.25 MIN
PARTIAL RIP:	.23 MIN
TRIM TIME:	.20 MIN
LOAD SHUTTLE CAR:	1.75 MIN
WAIT ON SHUTTLE CAR:	1.5 MIN
MANEUVERING TIME:	6.55 MIN
MINER SPEED:	65 FT/MIN
PASS DEPTH:	6 FT

DETERMINE AVERAGE NUMBER OF CUTS PER SHIFT:

USING "6 PASS SYSTEM"

ACTUAL MINING TIME:	63 MIN
EXTEND CANVASS (2)	6 MIN
EXTEND CANVASS TO "B" (4)	6 MIN
SET JACKS D & E	6 MIN
SET JACK "F"	6 MIN
TOTAL CUT TIME PER PASS	87 MIN

USING 7 HOURS PER SHIFT:

$$\frac{7}{1.45 \text{ HR/PASS}} = 4.83 \text{ PASSES}$$

FIGURE 8

CALCULATION FOR SEALANT QUANTITY (Continued)

USING 24 FT/MIN AS ADEQUATE SPRAY SPEED: = 216 SQUARE FT/MIN

TOTAL AREA TO BE SPRAYED:

16 x 18 x 4.83 = 1,392 square feet

TOTAL TIME SPRAYED PER SHIFT:

$$\frac{1{,}392 \text{ square feet}}{216 \text{ square feet/min.}} = 6.44 \text{ MIN}$$

USING 3.5 GPM at 6.44 MIN

TOTAL SEALANT PER SHIFT:

22.54 gal.

F.S. of 2 approximately 50 gal.

TANK SIZE: FOR 50 gal. was calculated to 34" x 10"

4.0 FIELD TEST

4.1 Test Mine

The test mine selected is Armco Steel's Coal Mine #9 (Robin Hood Division) located at Twilight, West Virginia. Several factors influenced the selection of this mine. It has experienced roof sluffing. The roof clearance is adequate for testing purposes. The personnel are extremely cooperative.

No. 9 mine is located about 40 miles due south of Charleston, West Virginia, at an elevation of about 2100 ft. above sea-level. It has been an active coal mine since 1962. It mines the Dorothy Seam, extracting bituminous coal. It was noted at the belt line cuts, that the shale layer in the mine was located approximately 24" - 36" above the finished roof.

The mine has six entries which are suitable for testing. Each entry is approximately 16' wide x 7' to 8' high. Entries #1, #3 and #6 were chosen for spraying (See Figure 9) because each entry had different roof and air flow conditions. This decision was reached by the Spokane Research Center after approximately 3,730 sq.ft. of roof had been sprayed. These areas included 640 sq.ft. of unbolted roof and are located in the crosscuts between entry #2 and #3 and between entry #4 and #5. A small section of entry #4 and #5 was also sprayed. #1 entry is the intake air entry. This entry had a very moist roof (believed to be condensation from the air) and there was air flowing through this entry to the face. Entry #3 is the supply-way and had no moisture (except about 200 square feet near the face) and little or no air flow. Entry #6 is the return air and had about 400 square feet of moisture (dripping). This moisture is believed to be seepage from an underground stream. The rest of the entry was dry and air flows constantly through it from the face.

The worst roof sluffing was in entry #1 (intake entry) by a magnitude of about two compared to entries #3 and #6. Entries #3 and #6 were about equal in amount of roof sluffing. There were pieces in each

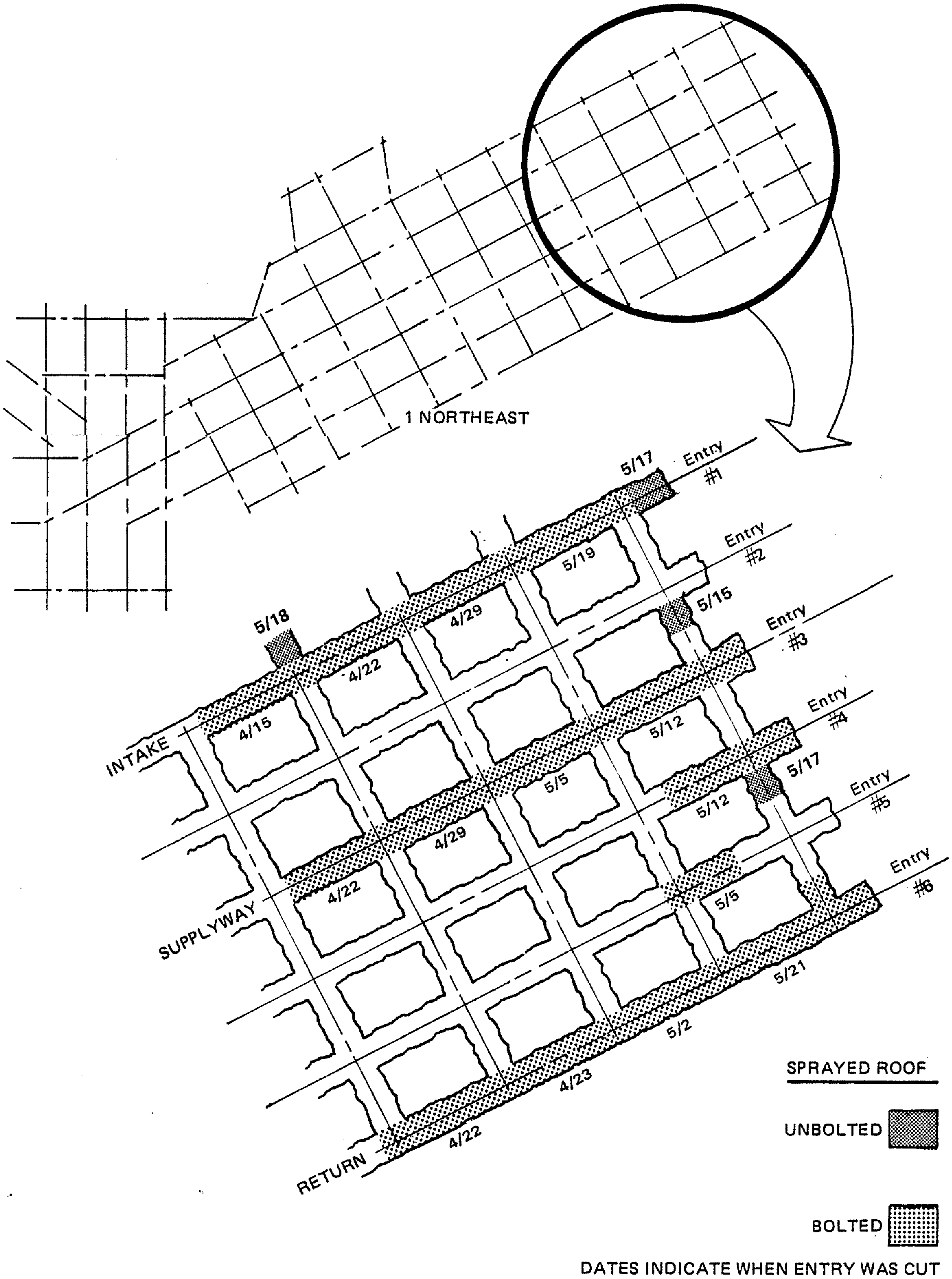


FIGURE 9
MINE LAYOUT OF TEST SITE

MBA
2829-16789

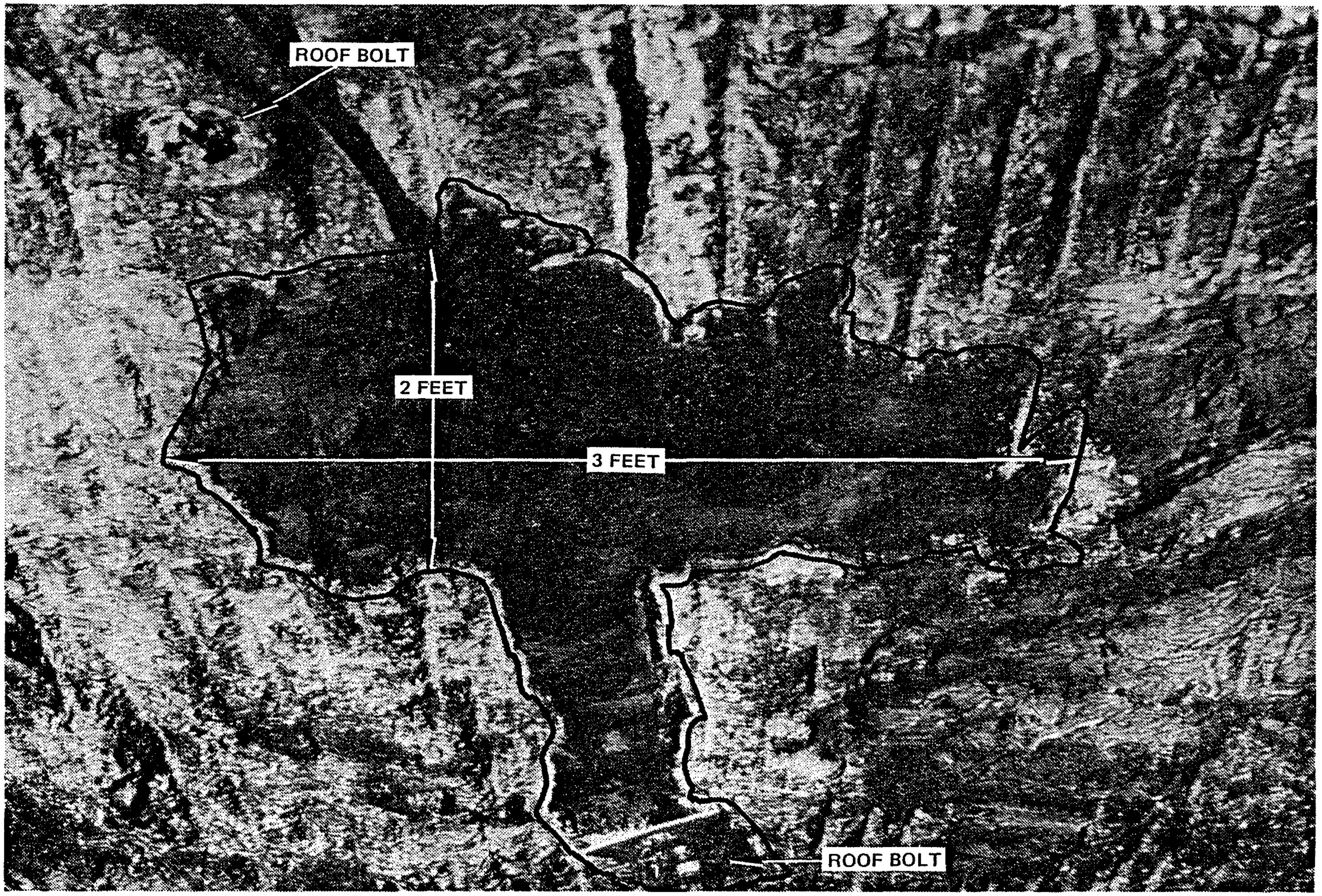


FIGURE 10
ROOF FALL AFTER SPRAYING BOLTED ROOF
ENTRY #1

entry ranging from 9 square inches to 10 square feet. About 50% of the larger falls were kettle bottoms (Figure 10). These kettle bottom were prevalent in entries #1 and #6.

4.2 Problems

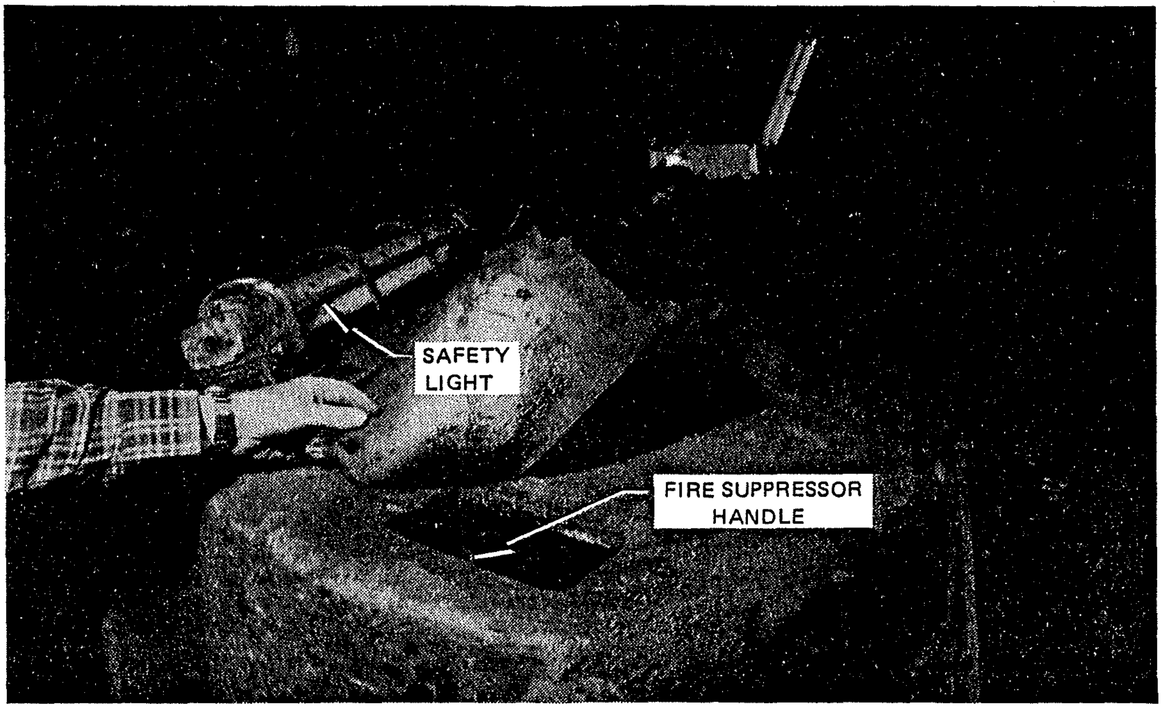
The one major problem encountered was mounting the equipment on a continuous miner, as stated in the original contract. The first test mine selected was U. S. Steel #20 at Thacker, West Virginia. However, in this mine, when the continuous miner was tramming out, the power unit was tall enough to drag along the roof resulting in damage to the power unit and/or the power unit being torn off the miner. This was tested with a wooden mockup mounted on the continuous miner. The height of the power unit is 18 inches. The height of the continuous miner is 54 inches. By adding these two figures together it would show that the power unit could clear a minimum of 72 inch cut (6 feet). However, due to the amount of coal that is piled up behind and beside the continuous miner during mining between the floor and ceiling to vary considerably thus allowing the power unit to occasionally come in contact with the roof.

This resulted in a relocating to a new mine site that had adequate roof clearance. Armco's No. 9 had the roof clearance, but the only area on the continuous miner that the power unit could be placed would have (1) blocked the access door to the fire suppressor handle (see Figure 11); (2) made access to the pumps and motors (located below proposed location) impossible when against left rib without complete removal of power unit (see Figure 12). It was then proposed to Spokane Research Center and accepted that the host vehicle be a scoop. The spray bar was then mounted on a tubular extension with the power unit and control box located adjacent to the operators cab. This proved to be a very satisfactory arrangement. The scoop could be moved very quickly from entry to entry thus allowing more than one fresh cut roof to be sprayed. The spraying was not affected by a "downed" (non-operating" continuous miner. The scoop could be moved to a entry that was still being mined.

The sealant did not adhere completely to a moist coal mine roof. When entry #1 (air intake entry) was sprayed, it was noted that the roof was very damp. This dampness was not evident at entry #3 (the supply way), entry #6, except for a 50 ft. section (air return entry), and at the face of entry #1. The dampness seen in entry #1 is believed to be either (1) condensation formed from the incoming air being cooled or (2) moisture from the scrubbers on the continuous miners working upwind from the area being sprayed. This dampness and the small amount of rock dust that was hand thrown upon the roof seemed to keep the sealant from adhering completely to the roof. Yet in another place the sealant penetrated the rock dust and formed a skin between the roof and the rock dust. This was noted on 15 May at the unbolted section of roof between entry #2 and #3. During the follow-up visit in July, about 20% of the area of cured sealant in entry #1 was hanging down from the roof. In these areas it looked as though the moisture on the roof and the rock dust had formed blisters between the sealant and the coal mine roof. The sealant appeared to have failed in tension at the blister due to the weight of the falling roof section.

The 50 foot section in entry #6 was actually dripping moisture while the sealant was being applied. It is believed that this seepage is from a stream that can be seen from the outside of the mine. During the follow-up visit in July, it was noted that <u>all</u> of the sealant had been "washed off" the roof in this area. This was the only place in the mine that had so much moisture on the roof that this occurred. This indicated that (1) the sealant should be applied during the winter months when the mine is dry, and (2) the sealant does not film over moisture to form a barrier.

During the development stages a few problems were encountered with the equipment. On two different occasions the cast aluminum rocker head broke at and near the pin clevis. The first break occurred because the motor pin had worked its way out of one side of the casted clevis. It appeared that the set screw that held the pin in place was missing.



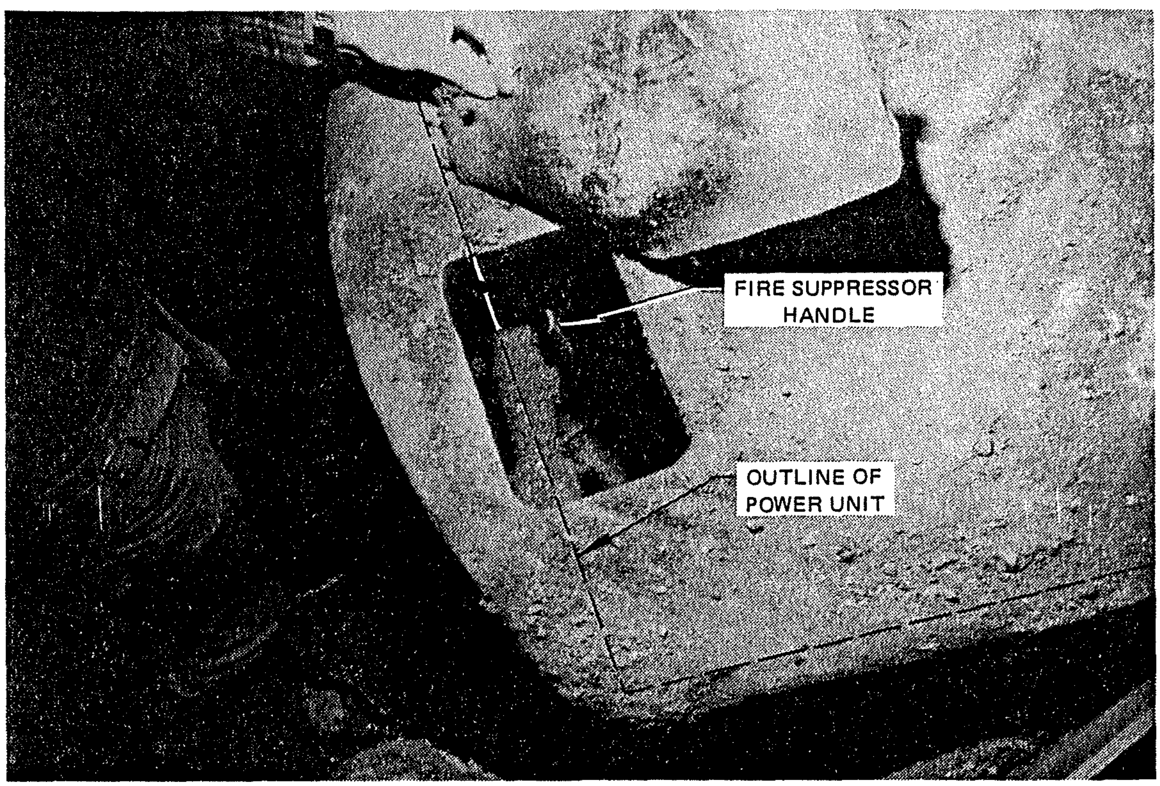


FIGURE 11
FIRE SUPPRESSOR HANDLE AT
REAR OF CONTINUOUS MINER

MBA

2829-16791

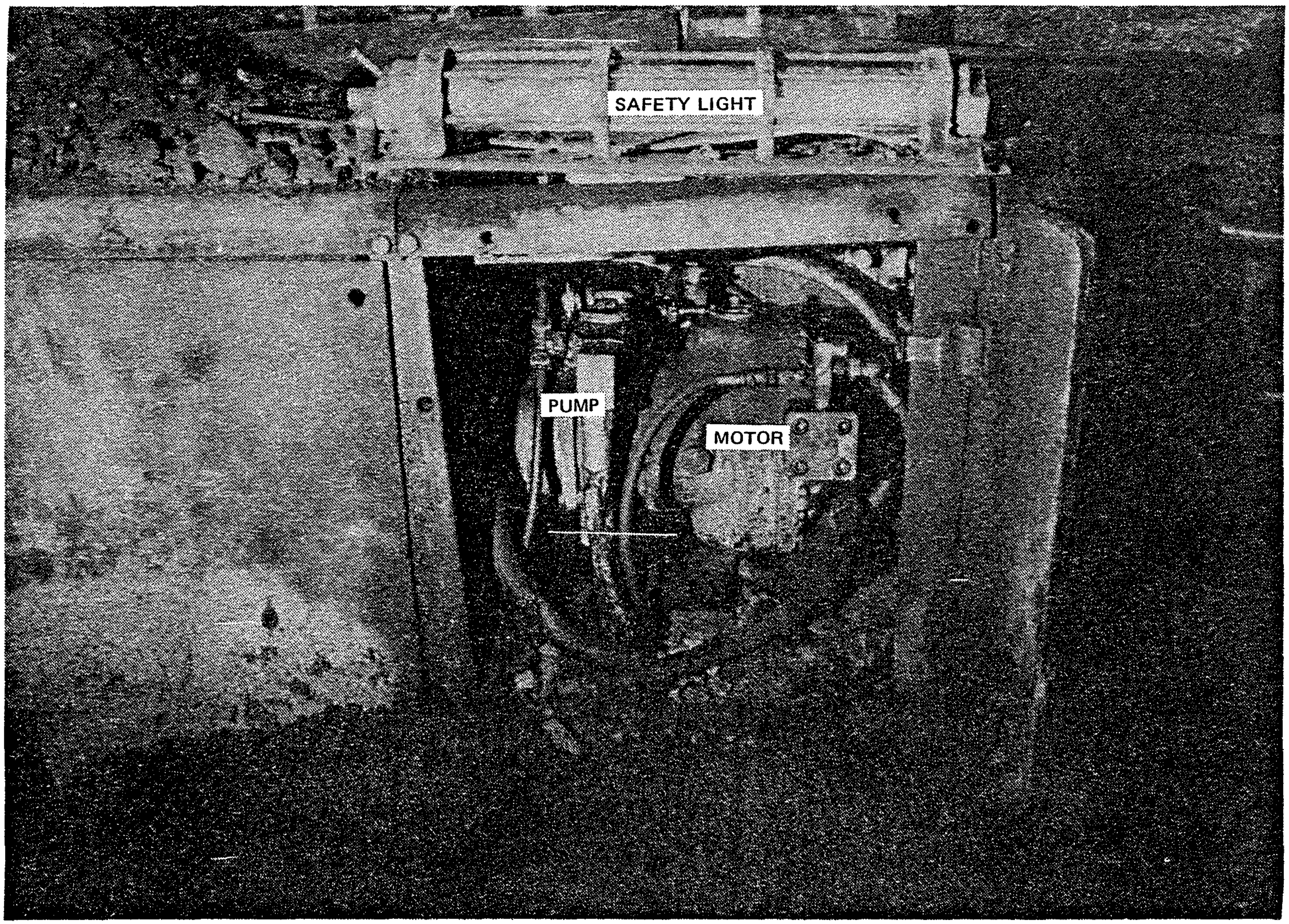


FIGURE 12
ACCESS TO PUMP AND MOTOR ON CONTINUOUS MINER

The second break occurred behind the pin hole in the clevis. There are two probable causes for this breakage. (1) The casting has a weak section or (2) because there was no spraying being done, there was pressure on the sealant lines. This caused a blockage that the motor was working against. The hydraulic system to the motor lines has a recirculation system so it kept working. The motor kept trying to force the sealant pumps to pump and the casting gave before the sealant lines.

However, this was not always the case. There were four broken sealant lines due to too much pressure in the lines. As a result, it is highly recommended that a recirculation system be included in the next machine. (See section on Recommendations for Design Improvement).

4.3 Positive Results

As described below, the system will spray mine sealant on the roof of a coal mine soon after exposure.

The system was mounted on a scoop. (See Figure 13). The spray bar was fastened to a piece of square tubing. This tubing was attached to the blade of the scoop. The blade moves forward about 10 feet thus allowing the spray bar to be moved under unbolted roof for spraying. The power unit was mounted directly across from the operator's cab and the control box was located next to the operator's cab.

With the system mounted on a scoop, the maneuverability and versatility were greatly increased. The scoop was able to move from one entry to another with ease thus allowing spraying of the unbolted roof as soon as the continuous miner was done. This is especially advantageous when more than one continuous miner is used.

During an inspection visit to the mine site on 17 July 1979, it was observed that the sealant used did stop the sluffing from 50% up to 95%. These values were based on a walk-thru inspection of each entry that was sprayed with sealant with the following noted: Entry #1 (Air Intake Entry). The unbolted section of entry #1 (640 sq.ft.) had only 2 small (6" x 4") pieces of coal fall since it was sprayed. Looking at the roof beyond the sprayed section, it was noted that about 50% of the roof had fallen since it was cut. The bolted section of roof that was sprayed had only about half of the roof falls that the unsprayed roof just before it had. Entry #3 (supplyway). This whole section of sprayed roof was bolted when it was sprayed. The first 100 feet of sprayed roof (as you approach area from portal) had approximately 95 % of the roof without a fall. The last 220 feet (toward face) had very little in the way of falls. Looking beyond area sprayed (toward face at unsprayed roof) it was noticed that approximately 60% of the roof had fallen since it was cut. Entry #6 (Air Exhaust Entry). This whole section of sprayed roof was bolted when it was sprayed. The results in this entry were very similar to entry #3 with two exceptions. (1) A 50 ft. section was completely washed out. This is believed to be due to a surface stream noted in the problems section. (2) Most of the falls here were kettle bottoms. Other than those two exceptions, the roof had approximately 90% of the roof without a fall. In order to meet contract requirements, as much unbolted roof as possible was sprayed. This took special arrangements between MBA and the mine. The roof had to be sprayed immediately after the continuous miner left and before the bolter arrived. Approximately 1,300 square feet of fresh cut roof areas, the sluffing was reduced by 95% as compared to the fresh cut non-sprayed areas. The remaining 18,750 sq.ft. of roof was sprayed after the bolting operation. The longest exposure to air was in the intake (entry #1), which was exposed for a period of 30 days.

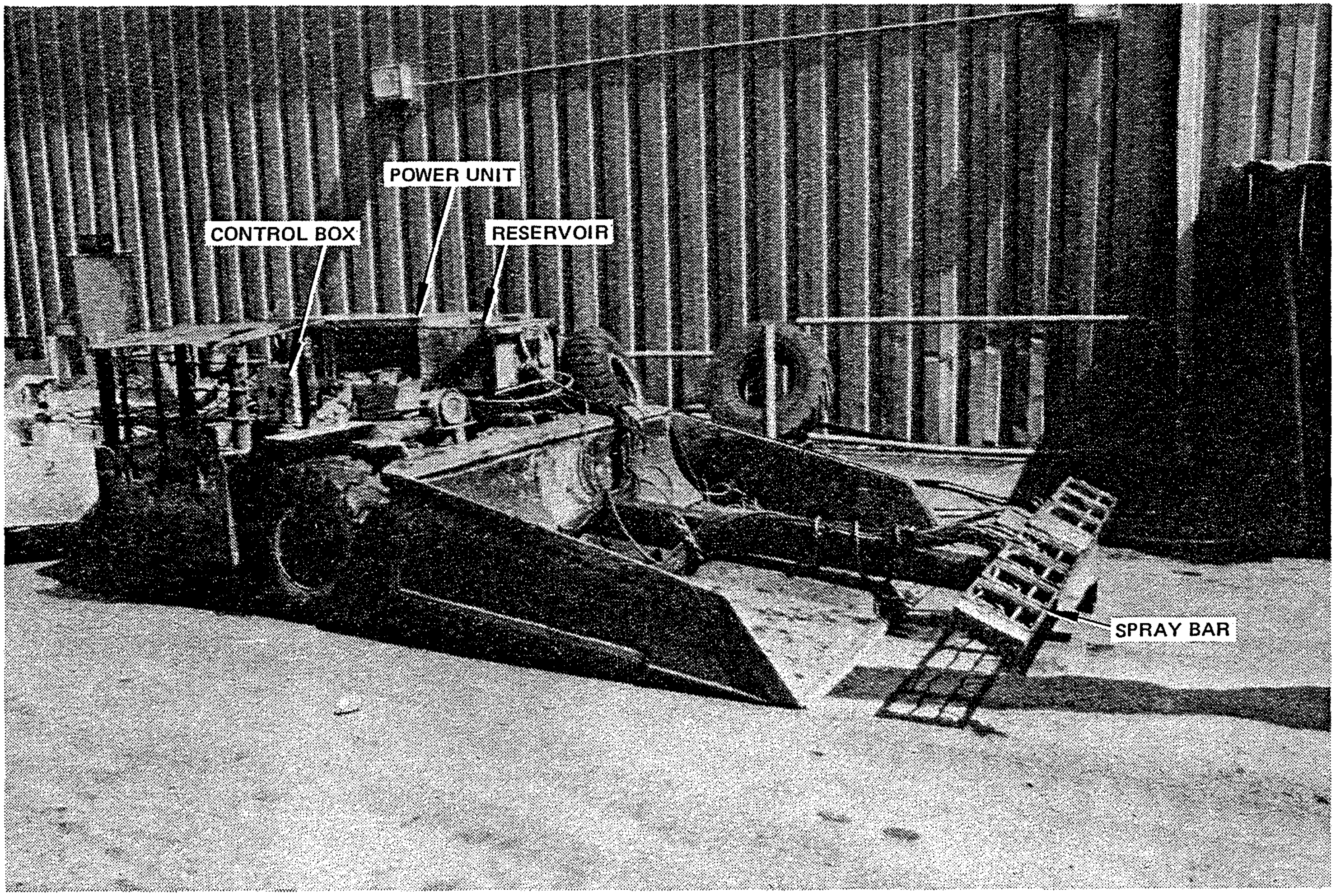


FIGURE 13
SPRAY SYSTEM MOUNTED ON A SCOOP

United States Department of the Interior

BUREAU OF MINES

SPOKANE RESEARCH CENTER
EAST 315 MONTGOMERY AVENUE
SPOKANE, WASHINGTON 99207

August 25, 1981

Memorandum

To: Librarian:
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National Mine Health & Safety Academy, Beckley, WV

On comp. Ready for binding & final processing

From: Technical Project Officer, Spokane Research Center

Subject: Distribution of Contract Report No. H0272008 "Application of Weathering Protection at the Face"

One copy of the subject final report from MBAssociates is enclosed. A copy of the memorandum from the Director approving open file placement is also enclosed. The Open File Report No. is OFR #71-81.

John C Franklin
J. C. Franklin

Enlosures

DISTRIBUTION OF
MINERALS RESEARCH CONTRACT REPORT

Report Title: APPLICATION OF WEATHERING PROTECTION AT THE FACE

Type of Report-- Final, Interim, Etc.: Final

Report Date: April 17, 1980

Contractor Name: MBAssociates

Contract #: H0272008

Total Contract Funding $ 181,391

TPO: J. C. Franklin

TPO Initials: JCF

Date: 1/15/81

Program Manager: John Karhnak

Date received by Branch of Technology Transfer: ________

Has Contractor filed a Patent Form DI 1217? NO YES (If "Yes", attach a copy of Solicitor's approval.)

Recommended for:

Open File: YES NO*

OFR # 71-81

NTIS: YES NO*

NTIS # ________

\# Of Pages 48

Price of (Paper) $ ________

*If Recommendation is No, Program Manager must state reason below;

I Concur: [signature] Date [illegible]
Program Manager

[signature] Date [illegible]
Branch Chief

[signature] Date 1/26/81
Program Director

The following is a table showing the percent of falls occurring in the sprayed/non-sprayed areas.

Location	Ft^2	Exposed time before spraying	Fall Expressed as a % of total area		Remarks
			Sprayed	non-Sprayed	
Air Intake Entry (Entry #1)	640	5 minutes	5%	50%	Unbolted roof
	4960	1 to 30 days	50%	50%	see Figure 9 for actual dates entry was cut.
Supplyway (Entry #3)	5120	13 to 29 days	5%-10%	60%	See Figure 9 for actual dates entry was cut.
Air Exhaust Entry (Entry #6)	5600	1 to 28 days	10%-12%	60%	See Figure 9 for actual dates entry was cut.
Cross-cuts	640	5 minutes	5%	50%	Unbolted Roof
Entry #4,5	3090	5 to 12 days	10%	60%	See Figure 9 for actual dates entry was cut.

5.0 CONCLUSIONS

Almost all objectives of this contract were successfully attained. The exceptions were the equipment could not be successfully mounted on a continuous miner, and not all 20,050 sq.ft. sprayed was fresh cut roof. The resulting hardware performed well in a typically harsh underground coal mine environment and (as of 17 July 1979) the selected sealant has stopped approximately 75% of the sluffing in the test area.

5.1 Cost Analysis

There is approximately 191 gallons of sealant on 20,050 square feet of coal mine roof for an average cost of $0.16 per square foot. This amounts to an average coverage of 104.97 square feet per gallon at an average thickness of 0.0007 inch. The above does not include the sealant that was unusable (reasons explaining in summary section). The costs and coverage with the unused sealant included in the total costs amount to $0.1345 per square foot at an average coverage of 83 square feet per gallon.

5.2 Miners Reaction

The reaction of the miners to the spray and the experiment was at first apprehensive but later turned to enthusiastic support. The miners did not like the dripping that occurred after application of the sealant to the roof. One miner complained that he felt nauseated from the odor. This complaint occurred during the first day's test only. During the remainder of the test there were no complaints from the miners, quite to the contrary. After the first day's testing, the miners became enthusiastic about the test and were involved in the application procedure.

6.0 RECOMMENDATIONS FOR DESIGN IMPROVEMENT

To ensure that maximum benefit is serviced from the accomplishments detailed in this report, MBAssociates recommend that further development be pursued by the Bureau of Mines as soon as practical.

The following are some improvements recommended by MBAssociates.

- Design of a mobile system that will make use of a telescoping spray bar. This will eliminate the necessity of having the spray bar following the motions of the scoop or continuous miner as it traverses over uneven ground. It will also give an even coating to the roof.
- Use a recirculation system in the sealant lines. At present the sealant lines can develop too much pressure and break.
- Make the sealant thixotropic to reduce the amount of dripping.

APPENDIX A

DEVELOPMENTAL STEPS

FINAL REPORT H0272008

APPLICATION OF WEATHERING PROTECTION AT THE FACE

PHASE I

1. Obtained sealant technology from John Franklin, TPO, Spokane Research Center on 21 May 1977.
2. Received sealant samples for evaluation.
3. Rented test equipment.
4. Began sealant selection.
5. Meeting with U. S. Steel on 16 June 1977 to discuss future sealant tests, equipment interface, and personnel contacts.
6. Began spray bar design.
7. Completed spray bar design.
8. Select pumping system.
9. Completed spray bar design.
10. Visit to U. S. Steel Mine #20 to confirm design concepts with continuous miner and operator on 15, 16 August 1977.
11. Design review meeting with U. S. Steel and TPO to discuss equipment design on 8, 9 September 1977.
12. Completed system design.
13. Conducted test at U. S. Steel Mine #20 with Polysar XD674 to determine application and aging characteristics on 13 September 1977.
14. Submitted Phase I technical report to TPO on 16 September 1977.

PHASE II

15. Began system fabrication November 1977.

16. Completed simulated mine design to be erected at MBA.

17. Purchase sealant. (Fifty gallons of Polysar, fifty gallons of Hydrepoxy 300).

18. Underground test site arrangements complete. January 1978.

19. System fabrication complete. January 1978.

20. Erected simulated mine roof.

21. Generate test procedures.

22. Perform spray test and demonstration with TPO at MBA on 22 March and 28 April, 1978.

23. Trip to mine site to assure integration with continuous miner and personnel on 5 April 1978.

24. Modified system and evaluated new sealants 22 May 1978.

25. Selected American Energy Products Corporation Acrylic Latex VMX-50-BM as the test sealant.

26. Shipped spray equipment and sealant to mine site on 28 June 1978.

27. After much delay from test mine, a new test mine was located on 30 January 1979.

28. Received official OK from new mine site on 26 March 1979.

29. Shipped equipment from old mine site to new mine site.

30. Arrived at mine site to begin field test (Phase III) on 8 May 1979.

PHASE III

31. Modified test vehicle to be a scoop versus a continuous miner.

32. On 15 May 1979, underground test began.

33. Because of difficulty involved, both bolted and unbolted roof was to be sprayed.

34. On 25 May 1979, the spraying was completed with approximately 1300 square feet of unbolted roof and approximately 18,750 square feet of bolted roof sprayed.

35. Shipped equipment back to MBA.

36. On 10 July 1979, the system successfully sprayed two part sealant.

37. Inspection visit to mine site on 17 July 1979.

38. Shipped equipment to Spokane Research Center, Spokane, Washington.

39. Submitted final report draft to TPO on 18 December 1979.

40. Upgraded and delivered required quantity of final report copies to TPO.

CALCULATIONS

Data

Date	Sealant Used	Sealant, Not Used	Area Covered	Hours (2 Men)
5/15/79	15 gallons	10 gallons	3,190 sq.ft.	25
5/17/79	20 gallons	30 gallons	1,510 sq.ft.	16
5/18/79	55 gallons	1 gallon	5,850 sq.ft.	30
5/22/79	50 gallons	4 gallons	3,960 sq.ft.	26
5/25/79	51 gallons	4 gallons	5,540 sq.ft.	26
Totals	191 gallons	49 gallons	20,050 sq.ft.	123 Hrs.

Average Sealant Cost $ 7.08/gallon

Shipping Cost $562.20

Miners Wages $ 9.86/Hr. (use two miners/hr.)

Average Coverage

$$\frac{20{,}050 \text{ sq.ft.}}{240 \text{ gallons}} = 83.5 \text{ sq.ft./gallon}$$

Total Average Cost Per Square Foot (includes 49 gallons not used)

$$\frac{\$1{,}770 \text{ (sealant)} + \$562.20 \text{ (shipping)} + \$1213 \text{ (labor)}}{20{,}050 \text{ sq.ft.}} = \$0.18$$

Average Thickness

$$\frac{191 \text{ gal. } (231)}{20{,}050 \text{ sq.ft. } (144)} (.5)^{1} = 0.007 \text{ inch}$$

[1] 50% of the sealant is water that evaporates.