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LARGE SCALE FIELD TEST
OF
PUMPABLE ROOF BOLTS

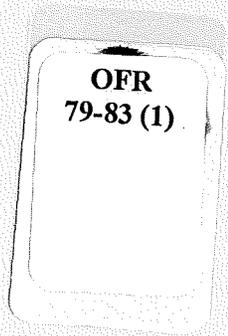
Prepared for
UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

By
EIMCO MINING MACHINERY
Division of
ENVIROTECH CORPORATION



FINAL REPORT
on
CONTRACT NO. HO 232041

October 15, 1976



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16. Abstract A prototype roof bolt which can be remotely placed by pumping has been developed by the Bureau of Mines. It is known as the "Pumpable Bolt". With the objective of field testing the effectiveness of the Pumpable Bolt roof support system a mining machine was developed capable of installing Pumpable Bolts in the normal production cycle of a typical underground coal mine. The machine was built and the Pumpable Bolt concept tested and evaluated as a total system in shop and mine tests. The machine was operated in the mining cycle of two mines and Pumpable Bolts were installed at both mine sites.			
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FOREWORD

This report was prepared by Eimco Mining Machinery Division, Salt Lake City, Utah under USBM Contract Number HO 232041. The contract was initiated under the Coal Mine Health and Safety Program. It was administered under the technical direction of SMRC, with Mr. Robert Thompson acting as the Technical Project Officer. Mr. R. J. Simonich was the Contract Administrator for the Bureau of Mines.

This report is a summary of the work recently completed as part of this contract during the period 25 June 1973 to 25 June 1976. This report was submitted by the authors on 15 October 1976.

TABLE OF CONTENTS

	<u>Page</u>
<u>FOREWORD</u>	v
<u>TABLE OF CONTENTS</u>	vi
<u>LIST OF FIGURES AND TABLES.</u>	viii
<u>INTRODUCTION.</u>	1
<u>SUMMARY</u>	4
Construction of Machine.	4
Construction of Bolt	4
Bolt Forming Process	4
Bolt Resin System	5
Work Performed and Results Achieved	5
<u>CONCLUSIONS AND RECOMMENDATIONS</u>	19
Conclusions.	19
Recommendations.	20
Pumpable Bolt Resin	20
Pumpable Bolt Concept and Machine	20
<u>PROBLEM DISCUSSION.</u>	21
Materials and Processes.	21
Equipment.	27
Plastic System	28
<u>DESCRIPTION OF EQUIPMENT AND EQUIPMENT OPERATION.</u>	32
Equipment Specifications	32
Machine Subsystem Details.	36
Resin Delivery System	36
Wetting Resin System.	43
Roving Feed System.	46
Purge System.	50
Resin Heating System.	51
Bolt Injection Head	51
Control System.	56
Bolting Turret.	69
Resin System.	69

TABLE OF CONTENTS (Cont.)

	<u>Page</u>
<u>SHOP TESTS.</u>	76
Results of Shop Tests.	76
Material Selection	79
<u>FIELD INSTALLATION OF PUMPABLE BOLTS.</u>	80
Introduction	80
Installation at Carbon Fuel.	80
Installation at Energy Development	83
Conclusions From Mine Installation	97
<u>OPERATING PROCEDURES.</u>	98
Resin Mixing Procedures.	98
Preparation for Bolting.	100
Bolting Procedure.	106
Clean Up Procedure	108
<u>SUBJECT INVENTIONS.</u>	113
<u>BIBLIOGRAPHY.</u>	114

LIST OF FIGURES & TABLES

<u>Figure No.</u>		<u>Page</u>
1	Diagram of Pumpable Bolt	3
2	Eimco Pumpable Roof Bolting Machine.	7
3	Pumpable Roof Bolting Machine.	8
4	Pumpable Roof Bolting Machine.	9
5	Bolt Pumping System	10
6	Pre-Injection Sequence	11
7	Injection Sequence	11
8	Purge Sequence	12
9	Final Operation.	12
10	Head Detail.	12
11	Testing of Pumpable Bolt Machine	13
12	Testing of Pumpable Bolt Machine	14
13	Testing of Pumpable Bolt Machine	15
14	Testing of Pumpable Bolt Machine	16
15	Testing of Pumpable Bolt Machine	17
16	Installation of Bolts in Mine Roof	18
17	Roving Bundles Traveling Through Wetting Chamber.	22
18	Roving on Storage Spools	24
19	Head Valve	29
20	Pumpable Bolt Machine.	33
21	Operator's Station	34
22	Bolt Pumping System.	37
23	Supply Tanks	39
24	Injection Pump	40
25	Injection Pump	41
26	Mixing Valve	42
27	Wetting Resin System	44
28	Wetting Chamber.	45
29	Roving on Storage Spools	47
30	Vent Tube Supply Reel.	48
31	Vent Tube Drive.	49
32	Purge System	50
33	Resin Heating System	52
34	Bolt Injection Head.	53
35	Head Valve	54
36	Static Mixer	55
37	Bolt Forming Roof Seal	57
38	Cut Off Saw.	58
39	Control System	59
40	Control System Component Location.	61
41	Operator's Control Box	62

LIST OF FIGURES & TABLES (Con't.)

<u>Figure No.</u>		<u>Page</u>
42	Pumpable Bolt Process Flor Diagram.	68
43	Drill in Drilling Position.	74
44	Pumping Head in Bolt Injecting Position	74
45	Dust Collection System.	75
46	Pumpable Bolt Test Installation Plan.	81
47	Pumpable Bolt Test Site	82
48	Pumpable Roof Bolt at Face in Carbon Fuel Mine.	84
49	Pumpable Roof Bolts at Carbon Fuel.	85
50	Badly Fractured Rock at 85th Cross Cut.	86
51	Test Site - Energy Development Co.	87
52	Pumpable Bolt Installed Using Wood Block and Styrofoam Seal.	89
53	Rifling Bit	89
54	Pumpable Bolts with Steel Mats and Styrofoam Seals	91
55	Pumpable Bolts and Instrumentation Point.	92
56	Bolts Installed in Intersection of Mine	93
57	Bolts Installed in Intersection of Mine	94
58	Fractured Roof.	95
59	Six-Way Valve	101
60	Resin Supply Tank	102
61	Air Supply to Solvent Tank.	103
62	Resin Injection Pump.	105
63	Pumpable Bolt Process Flow Diagram.	108
64	Six-Way Mixing Valve.	110
65	Resin Supply Tanks.	111

Table No.

1	Pumpable Bolt Formulation	73
2	Various Hose Types and Evaluation	78
3	Summary of Bolt Tests at Energy Development	96
4	Amounts and Formulation of Resin and Chemicals.	99

INTRODUCTION

The Bureau of Mines has for a long period of time worked to improve existing ground support technology. In 1970, the Bureau embarked on a program of developing and testing a new type of roof bolt now known as the Pumpable Bolt.

The concept embodies the basic principles of the conventional expansion shield type roof bolt and in support mechanism parallels the resin grouted roof or rock bolt.

The basic elements of the Pumpable Bolt are the tension member in the form of strands of continuous fiberglass and a grout or cement in the form of an organic resin.

The fiberglass is fed into the bolt hole conventionally drilled in the mine roof and the resin is pumped into this hole to grout the hole and bond the glass strands to the roof rock.

The nontensioned bolt thus formed is illustrated in Figure 1.

The resin system consists of a catalyzed component "A" and a promoted component "B". When mixed, these two monomers polymerize into a solid, bonding the glass strands to the roof rock.

The major advantages seen in such a roof bolt are:

Compared to conventional expansion shield, point anchor bolts, the pumpable bolt furnishes a continuous full length bond to the roof rock. Experience with resin grouted bolts which provide similar support, has shown this type of anchorage superior to that furnished by expansion shield anchors.

In contrast with grouted bolts, the pumpable bolt can be installed remotely from under secured roof.

Based on laboratory tests, the Bureau of Mines reports a tensile strength of this bolt of 40-44000 lbs, a shear strength exceeding 13,000 lbs, and a holding strength of 25,000 lbs/ft in dry strata.

On the basis of these favorable data, the Bureau has undertaken to evaluate the feasibility of the Pumpable Bolt concept by large

scale field tests in two operating coal mines. An existing commercial roof bolting machine was modified to install the pumpable bolts.

This report describes the results derived from this effort.

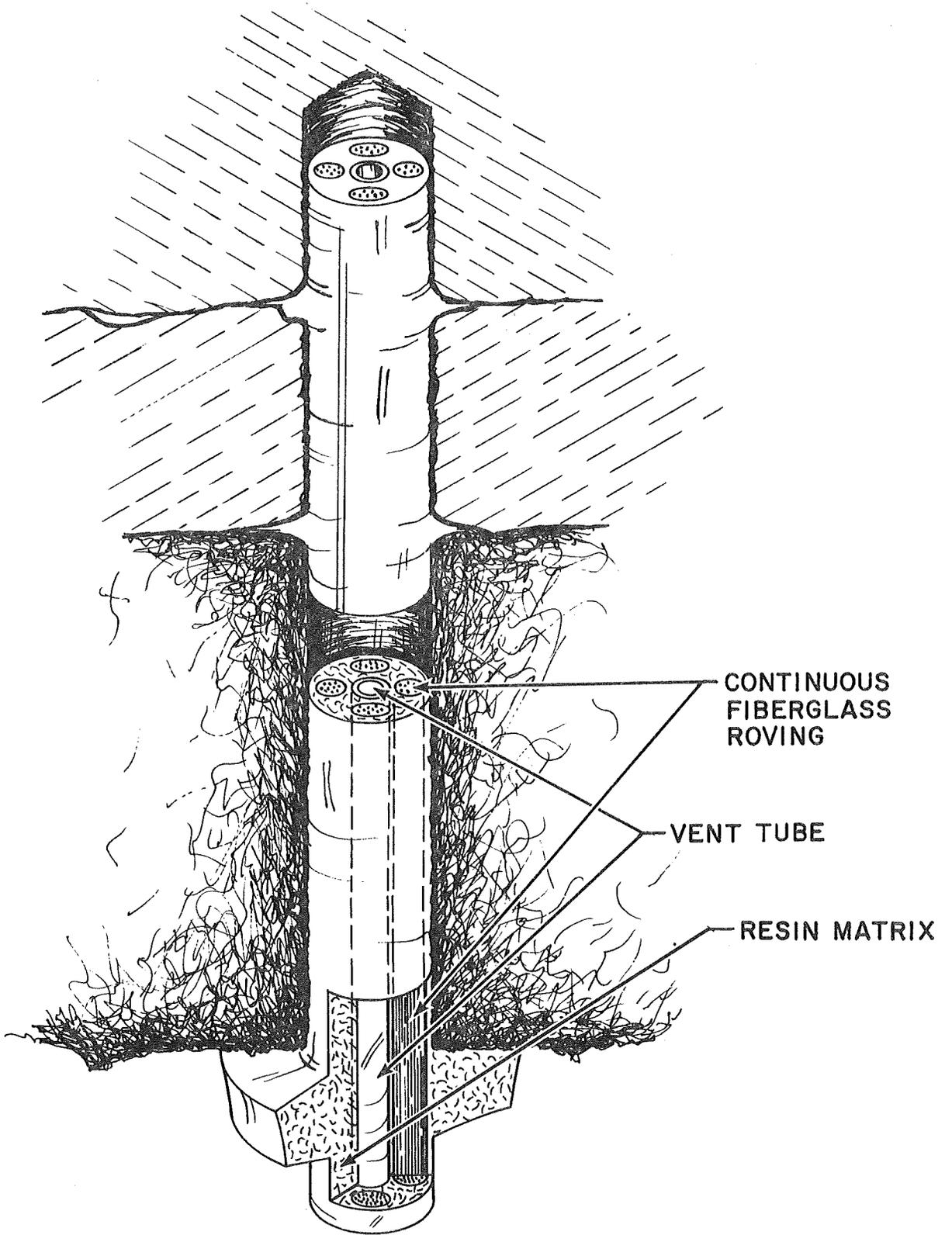


DIAGRAM OF PUMPABLE BOLT
Figure 1

SUMMARY

Construction of the Machine

The Pumpable Bolt machine shown in Figures 2, 3 and 4 is a modification of the Eimco/Secoma standard Roof Bolting Machine.

Construction of the Bolt

The essential components of the bolt are shown in Figure 1.

Tensile strength is provided by fiberglass roving, which enters the bolt in four bundles. The tensile strength of the bolt is around 40,000 lbs.

Load is transferred from the rock to the roving by a two component resin. The resin is of a high viscosity, (approximately 15,000 cp) to avoid the resin excessively running out along cracks in the rock, before curing.

The fiberglass roving is attached to a flexible tube which is driven up the hole pulling the roving along with it. This tube also serves to vent the air from the drilled hole as the resin is pumped into it.

The bolt locks to the rock along its full length. A molded bolt head is included to aid in holding loose surface rock.

Bolt Forming Process

A diagram of the most important parts of the injection system is shown in Figure 5.

The plastic roof bolt is formed in the following sequence of operations.

A 1-3/8" diameter hole is drilled into the mine roof.

The bolt forming head is advanced to and sealed against the roof.

A vent-tube, to which four fiberglass roving bundles are attached is advanced into the hole. The resin is injected. The injection process is most easily visualized by means of the accompanying sequence of illustrations:

In Figure 6, the resin injection cylinders are filled from the supply tanks in preparation for bolt injection.

Figure 7 shows the vent tube and roving driven into the bolt hole and the two components of the resin forced through a static mixer into the bolt cavity, where the cure reaction begins.

The portions of the system subject to the presence of mixed plastic components (catalyzed and promoted) are purged by a flow of solvent (Trichloroethane). This is shown in Figure 8. During this period, and for a timed period sufficient to insure that the plastic has cured enough to be structurally stable, the bolt forming head is held against the mine roof.

The bolt forming head is then withdrawn, and a saw cuts off the stub end of the bolt, leaving the rovings bonded to the vent tube by the remains of the stub, ready for the next bolt. This is illustrated in Figures 9 and 10.

Bolt Resin System

The pumpable bolt resin system consists of a mix of monochloro-styrene and fire-retarded polyester resin. Milled glass is used as a filler, silane promotes bonding between the polymers and the rock, fumed silica thickens the resin, polystyrene pellets control shrinkage, and hydroquinone is added to increase shelf life.

Work Performed and Results Achieved

The machine was tested in the shop before going to the mine for field installation of bolts. Photos, Figures 11, 12, 13, 14 and 15, show various phases of this test period.

In this phase of the program, a number of problems became evident and modifications to the machine were made accordingly.

Among these, the more important include leakages at the bolting head primarily at the roving seal; chemical attack of resin and solvent on hose material, on various plastic components in the bolting head, and on pump and valve seals; premature polymerization of the base resin and the wetting resin.

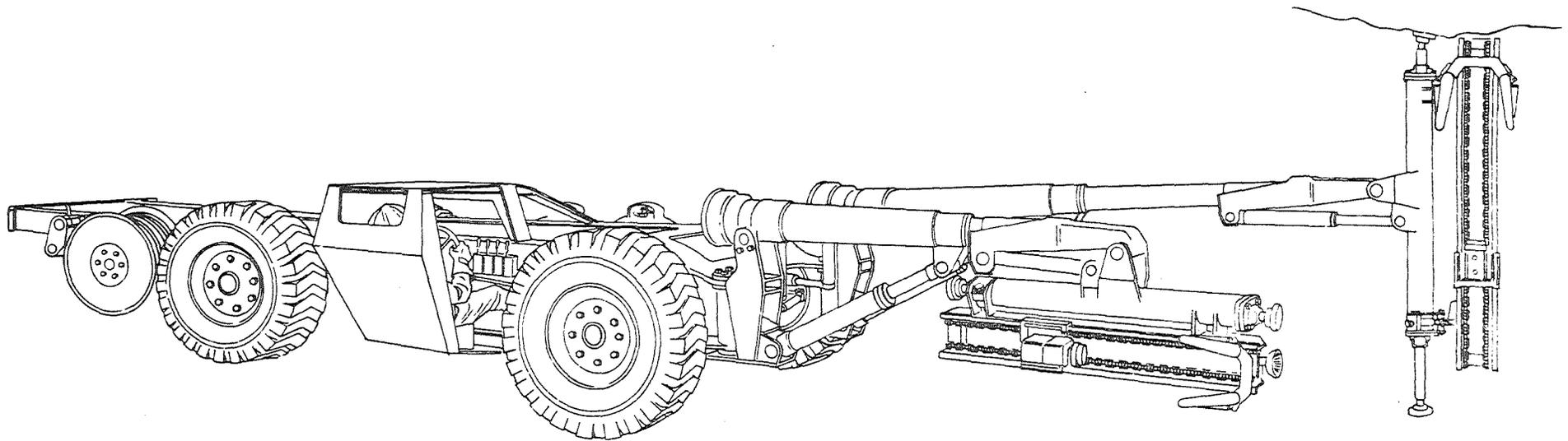
Solution to these problems were found and are discussed in detail in the body of this report.

Bolts were installed in two underground coal mines, Carbon Fuel at Helper, Utah, and Energy Development Vanguard #3 Mine at Hanna, Wyoming. Figure 16 shows examples of bolts installed in these two mines.

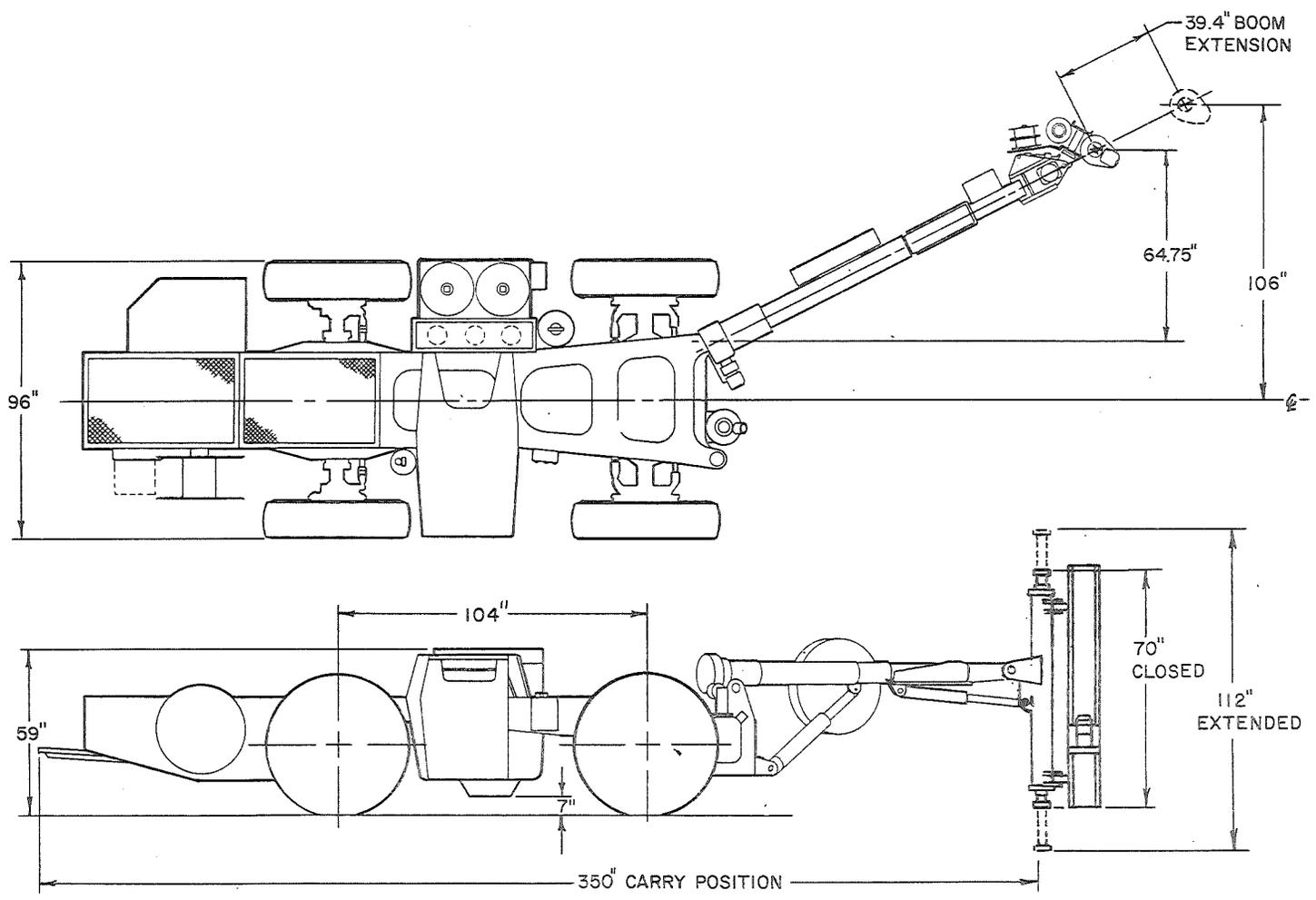
Unforeseen severe roof problems at both mines and floor problems at Vanguard #3 mine limited the installation to about 200 bolts. These roof problems were wholly unrelated to the performance of the pumpable bolt.

Much valuable experience was gained with regard to the performance of the Pumpable Bolt concept, while complex and demanding in terms of design and operation, is clearly viable from a design and operational point of view.

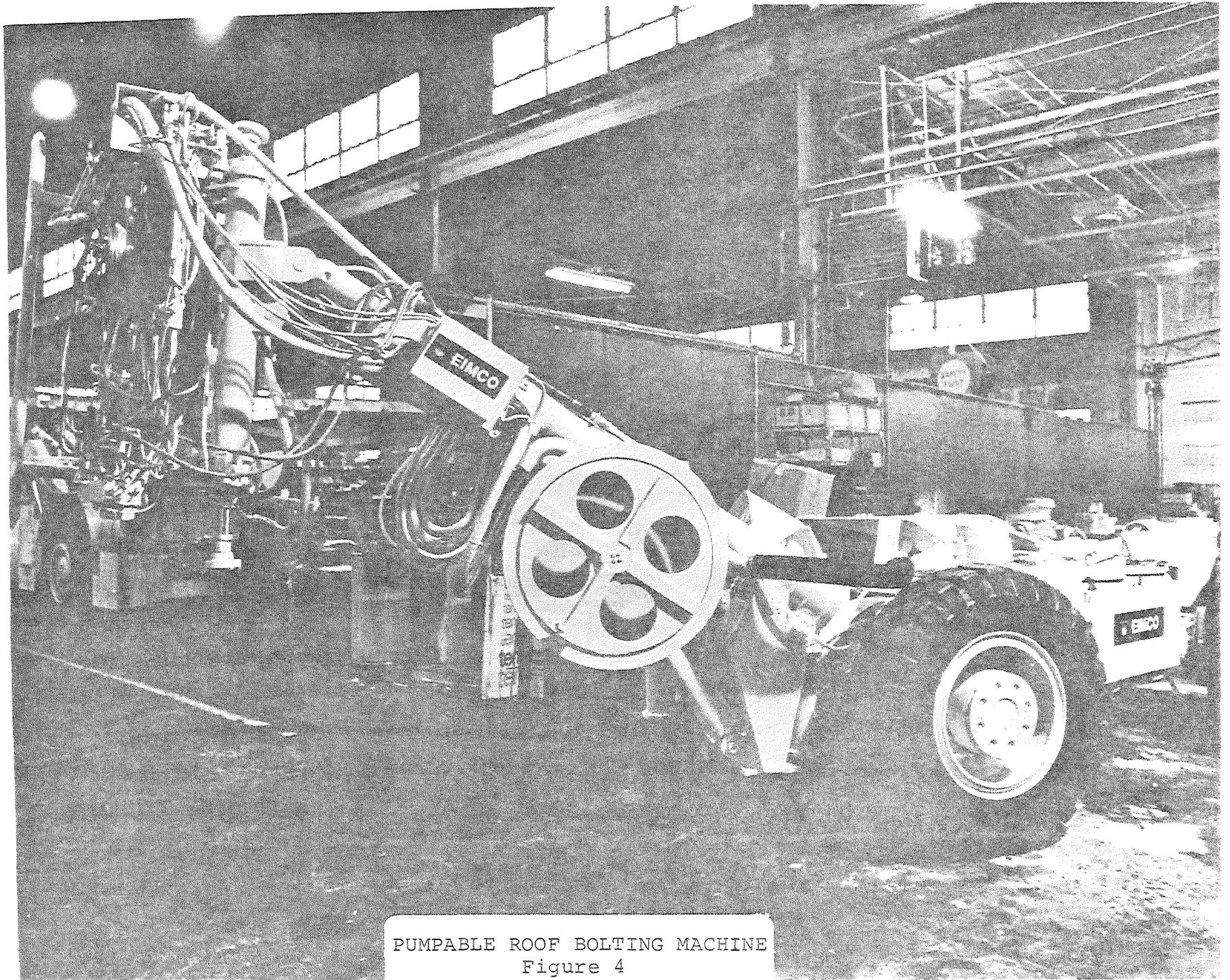
The major negative factors encountered in the mine were a degree of unpredictability in resin performance and difficulties in pumping and cure of the resin at low mine temperatures (+7° C and below).



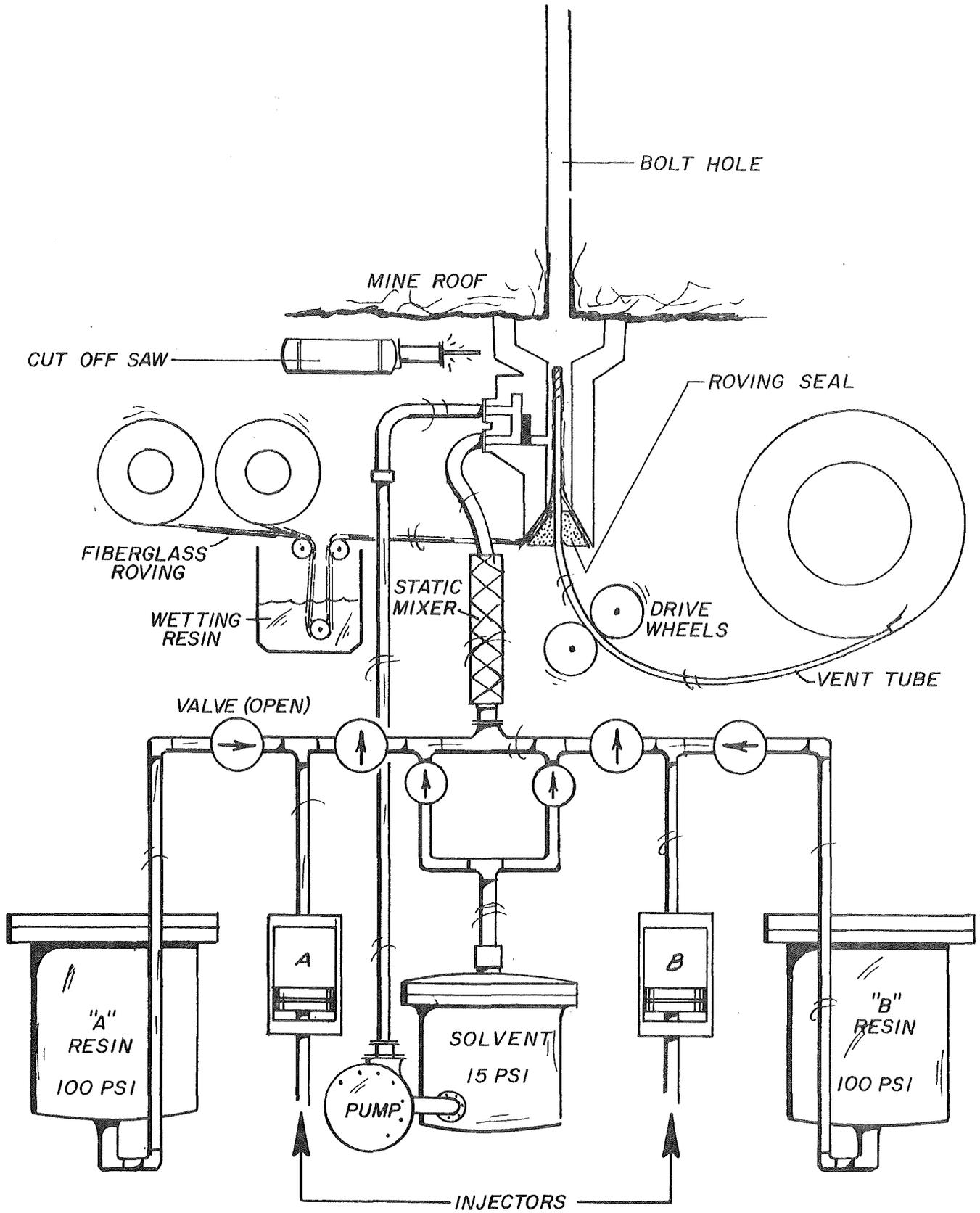
PUMPABLE ROOF BOLTING MACHINE
Figure 2



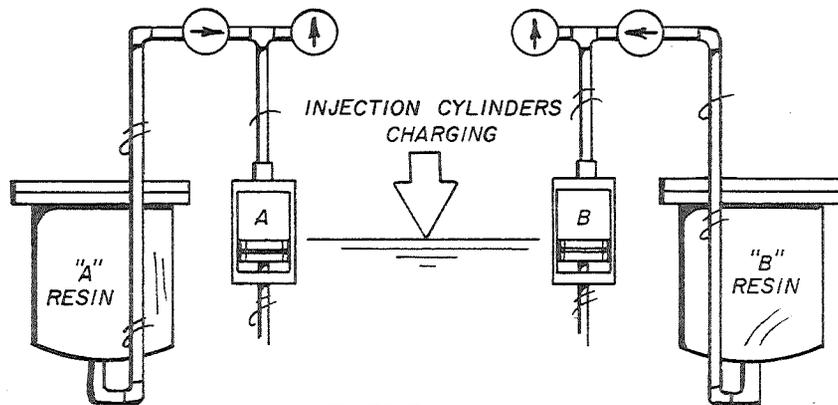
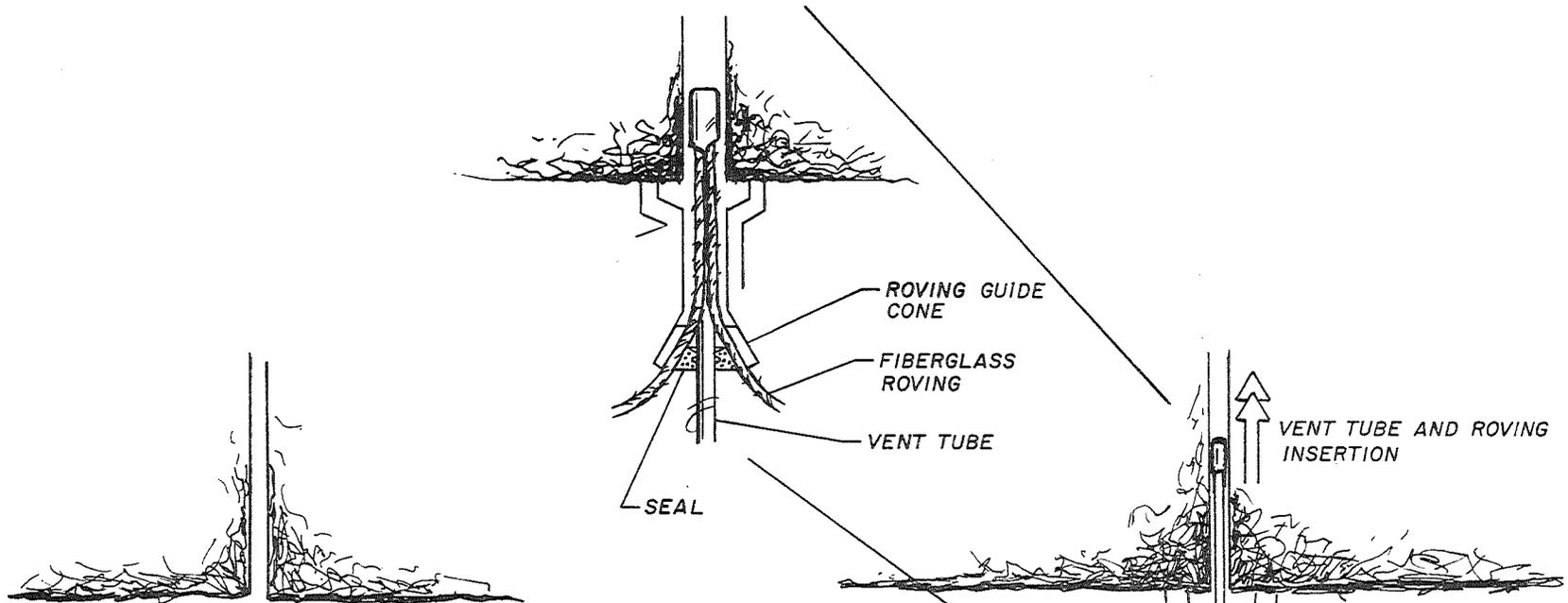
PUMPABLE ROOF BOLTING MACHINE
Figure 3



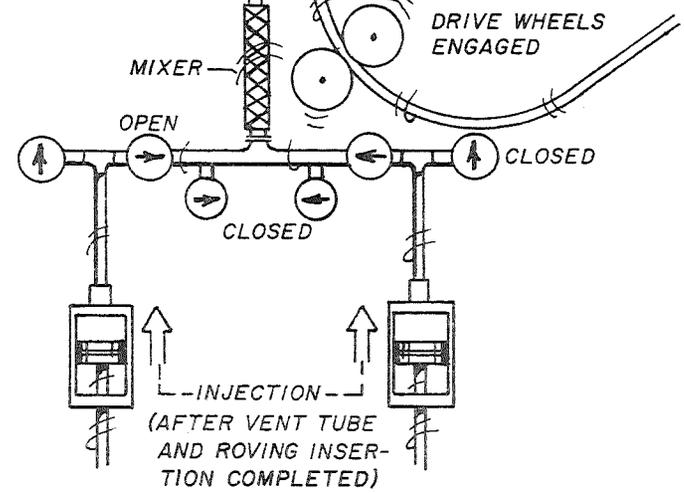
PUMPABLE ROOF BOLTING MACHINE
Figure 4



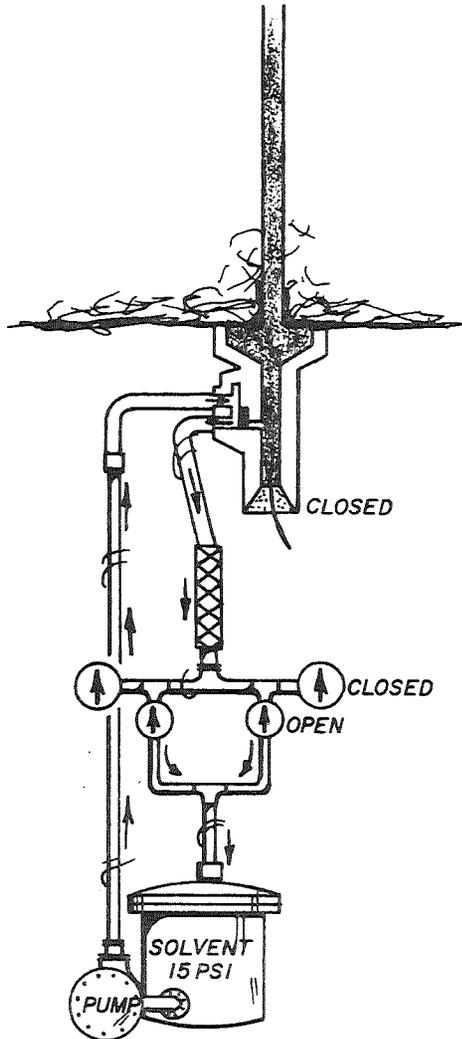
BOLT PUMPING SYSTEM
Figure 5



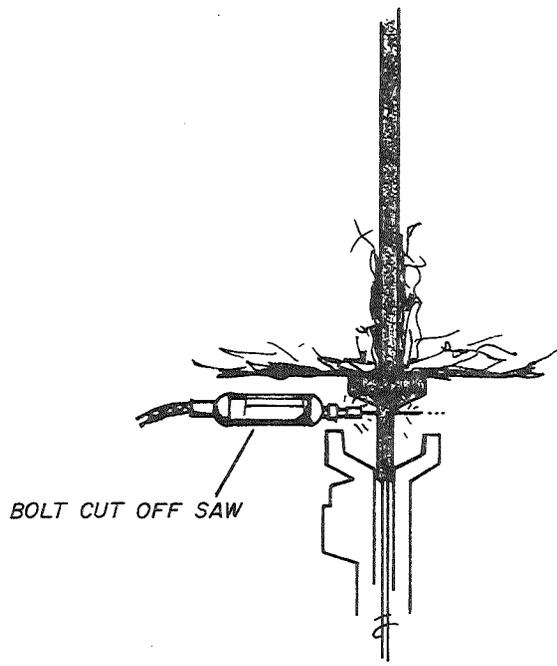
PRE-INJECTION
Figure 6



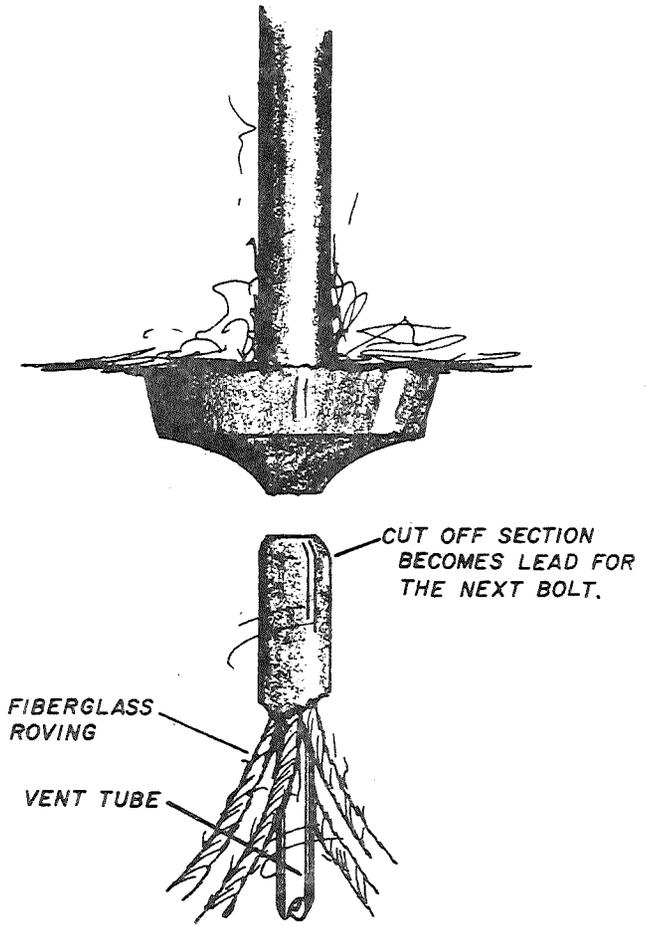
INJECTION
Figure 7



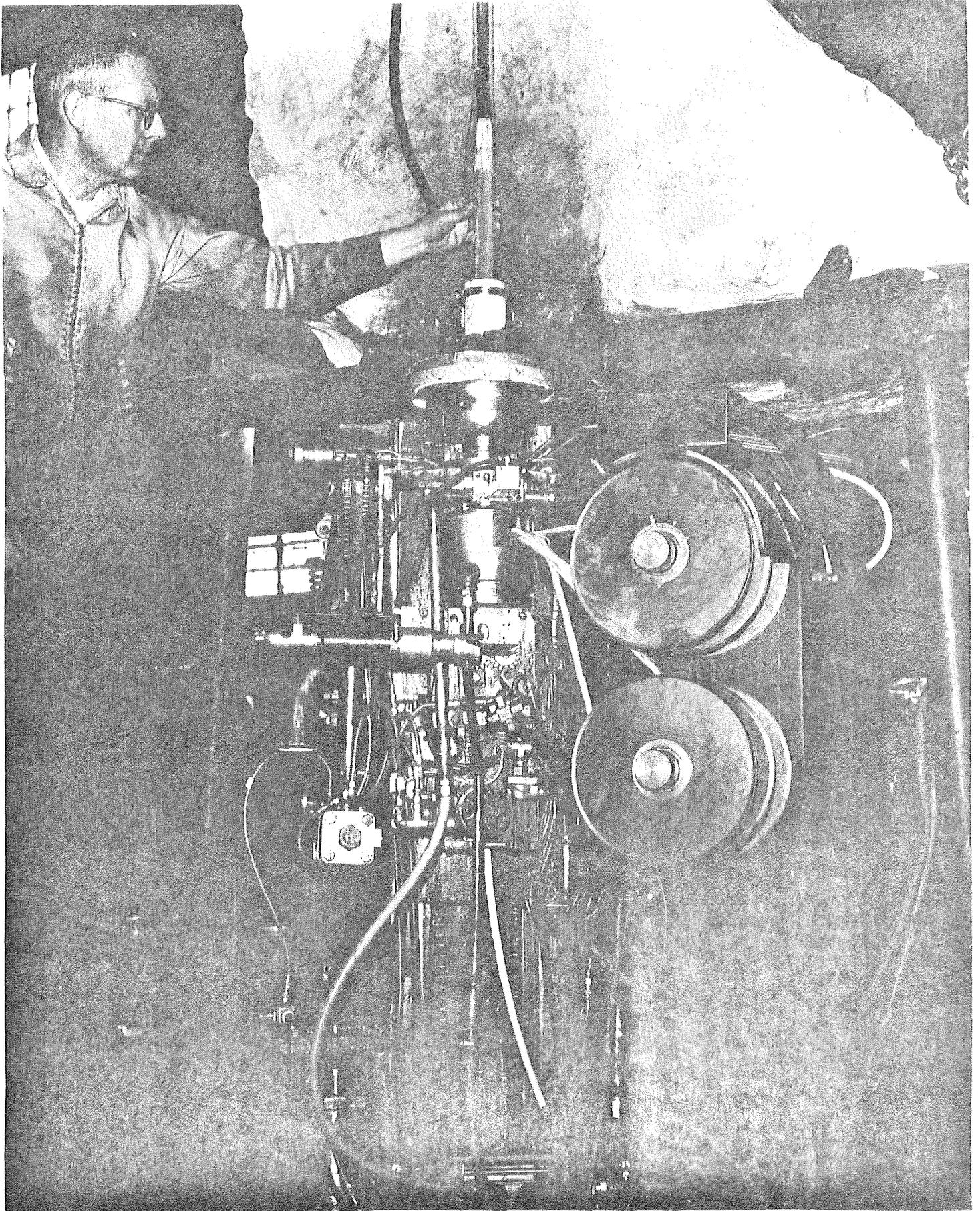
PURGE
Figure 8



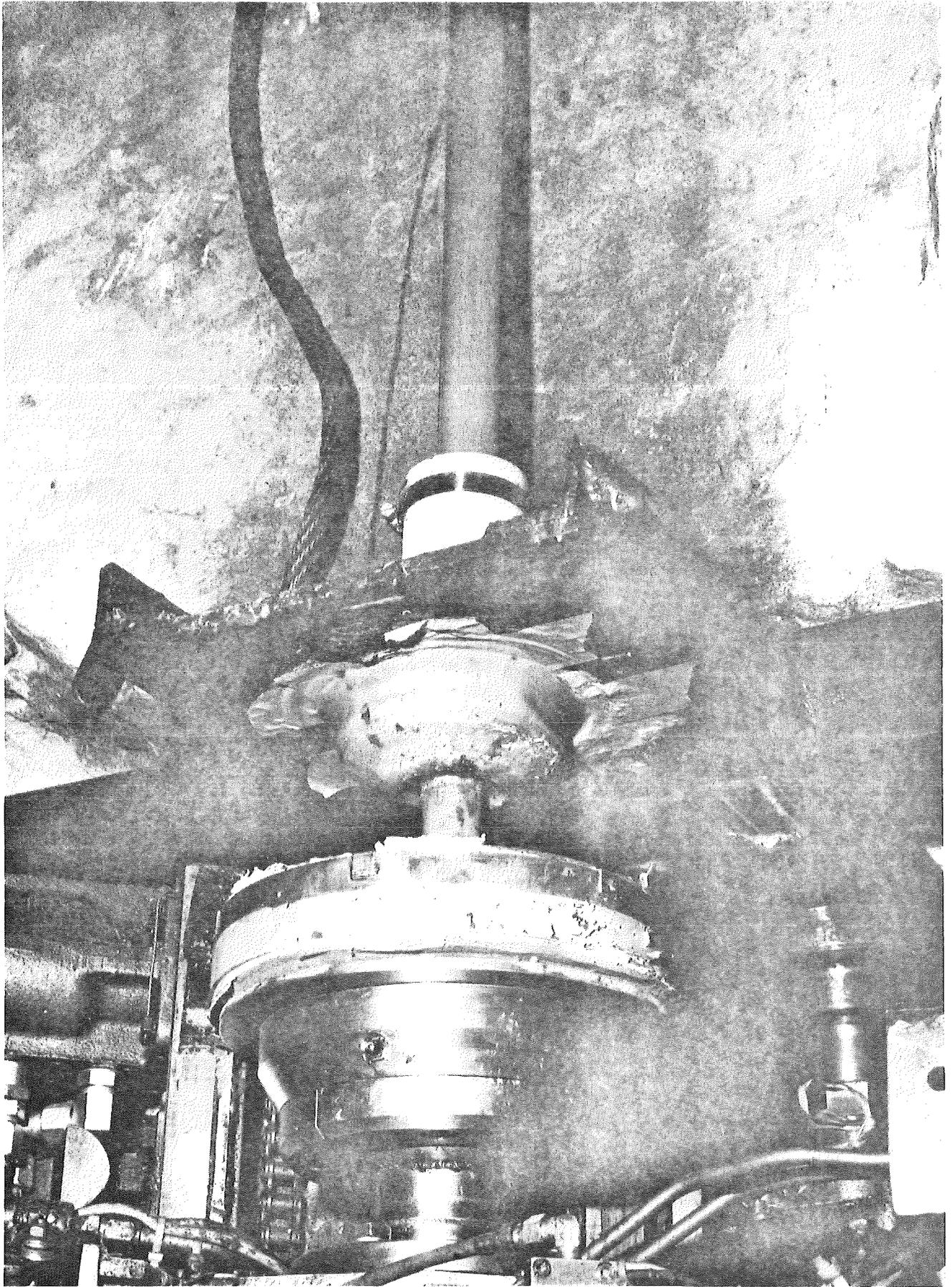
FINAL OPERATION
Figure 9



HEAD DETAIL
Figure 10

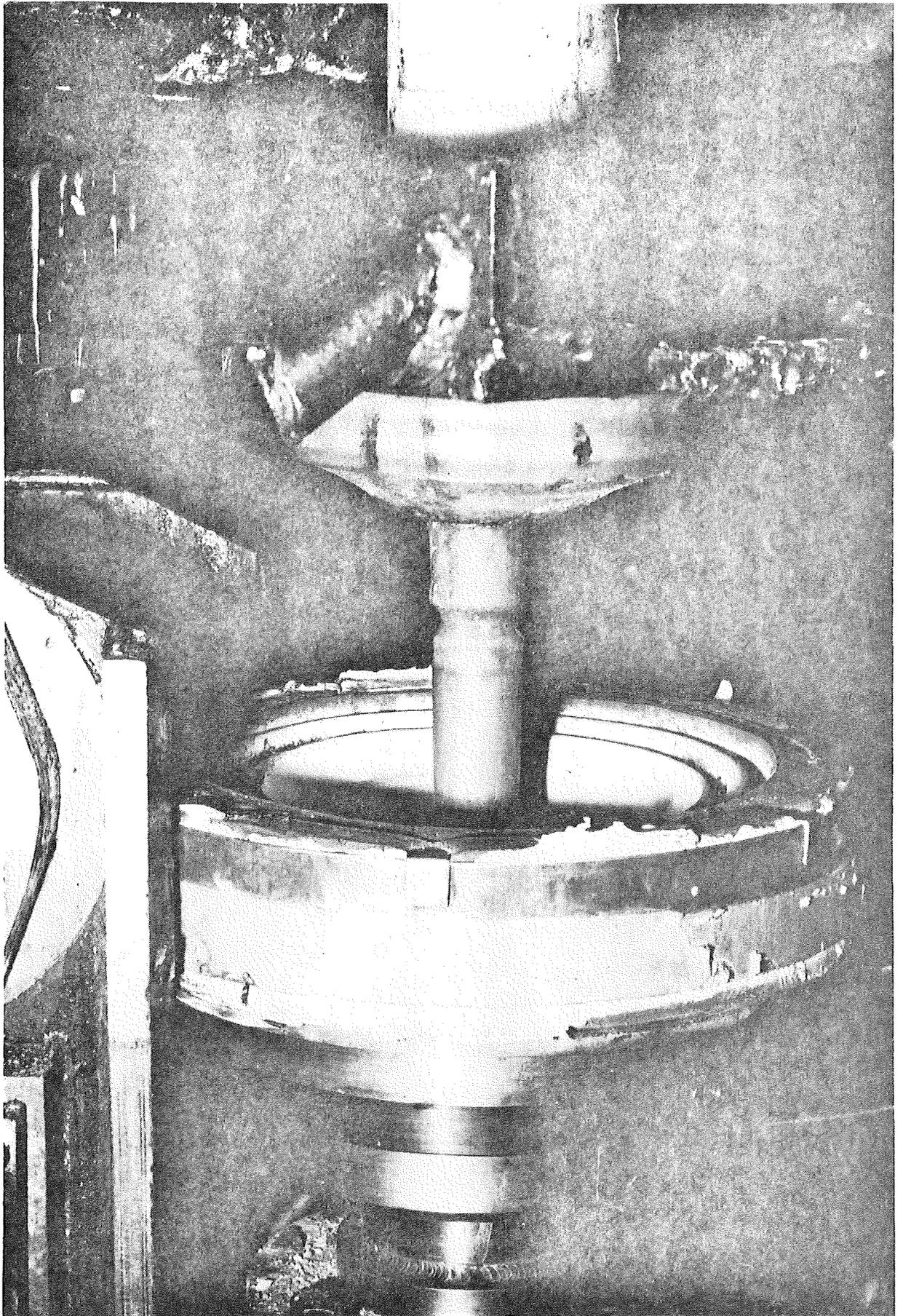


TESTING OF PUMPABLE BOLT MACHINE
Figure 11



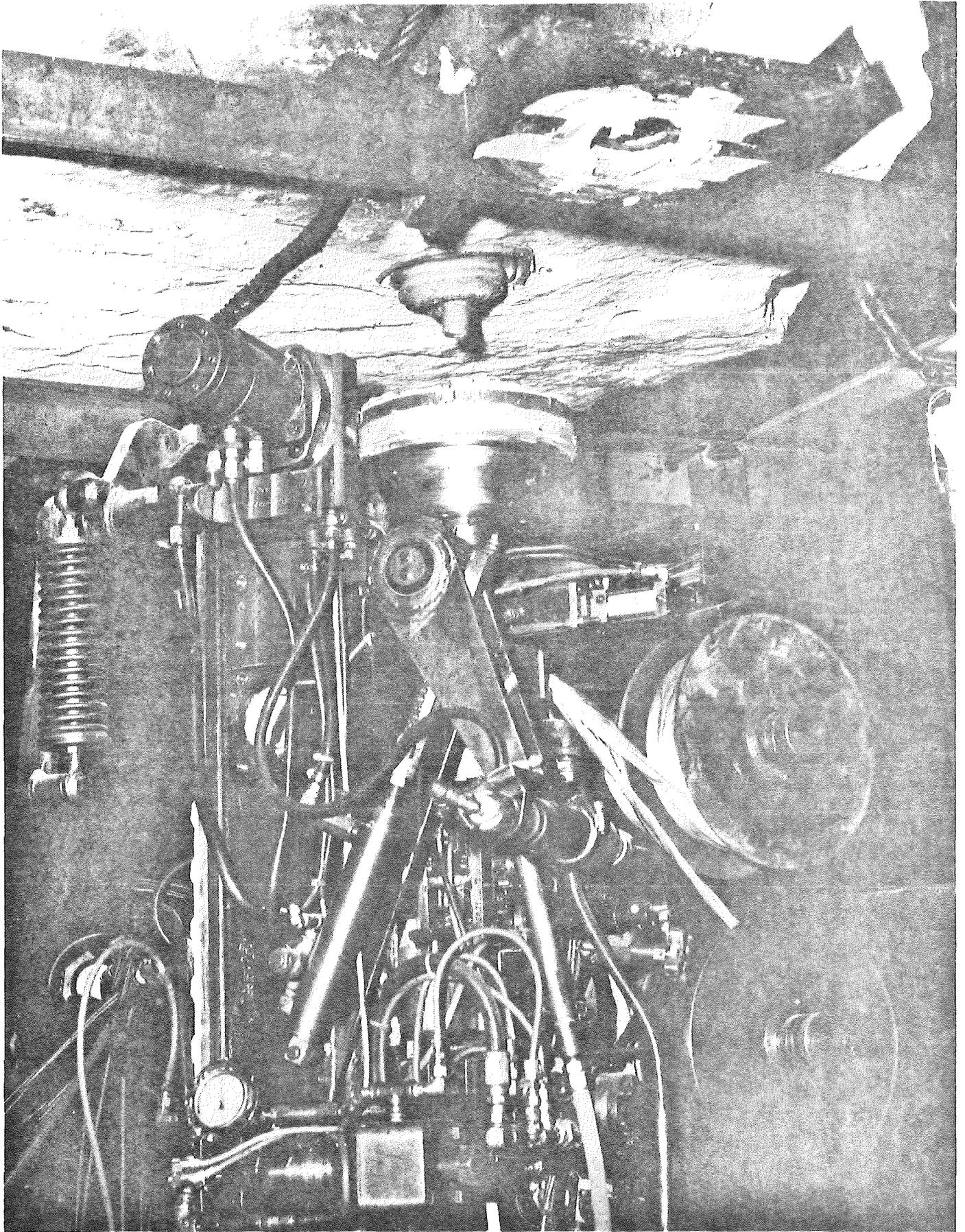
TESTING OF PUMPABLE ROOF BOLT MACHINE

Figure 12



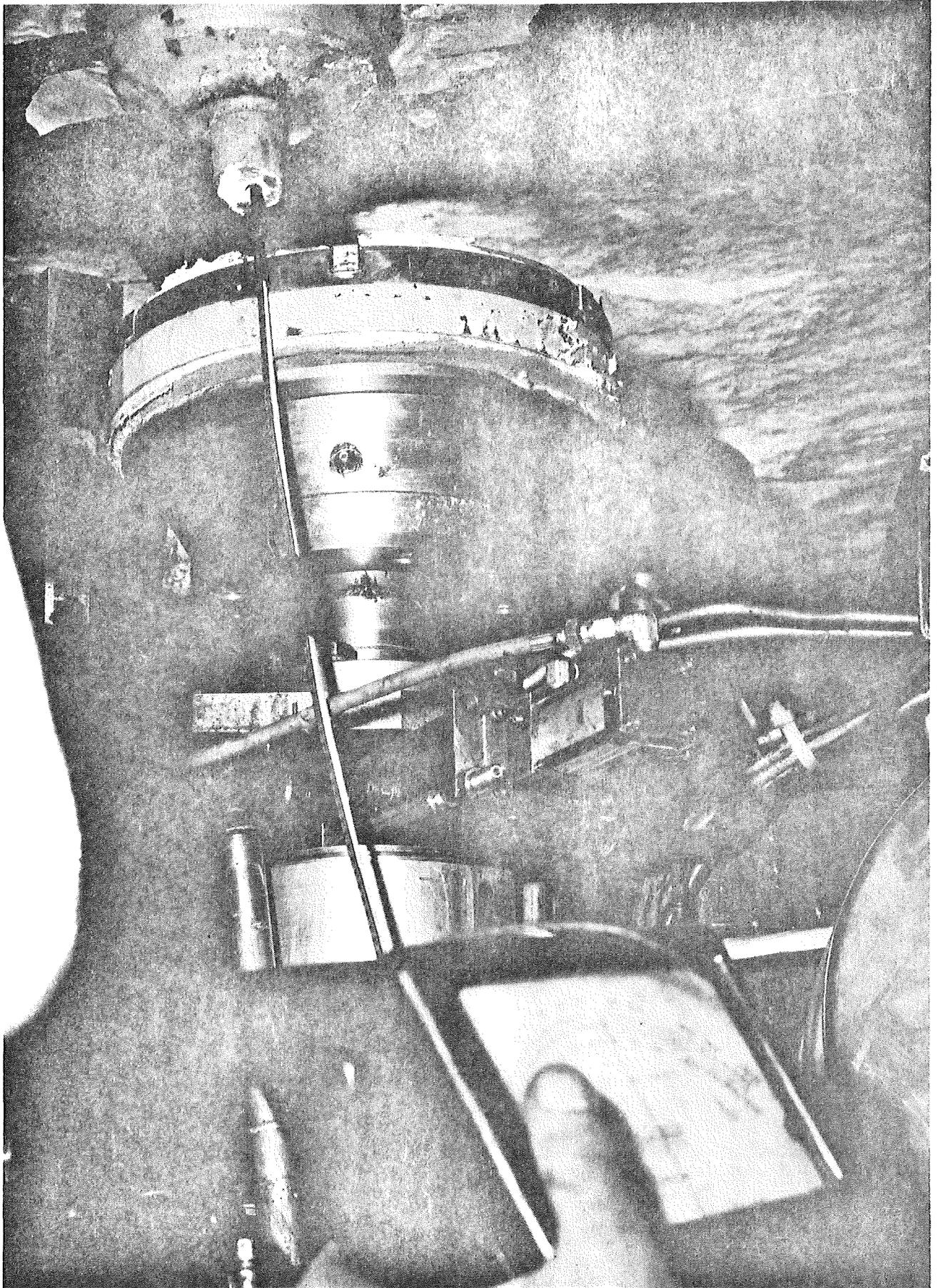
TESTING OF PUMPABLE ROOF BOLT MACHINE

Figure 13



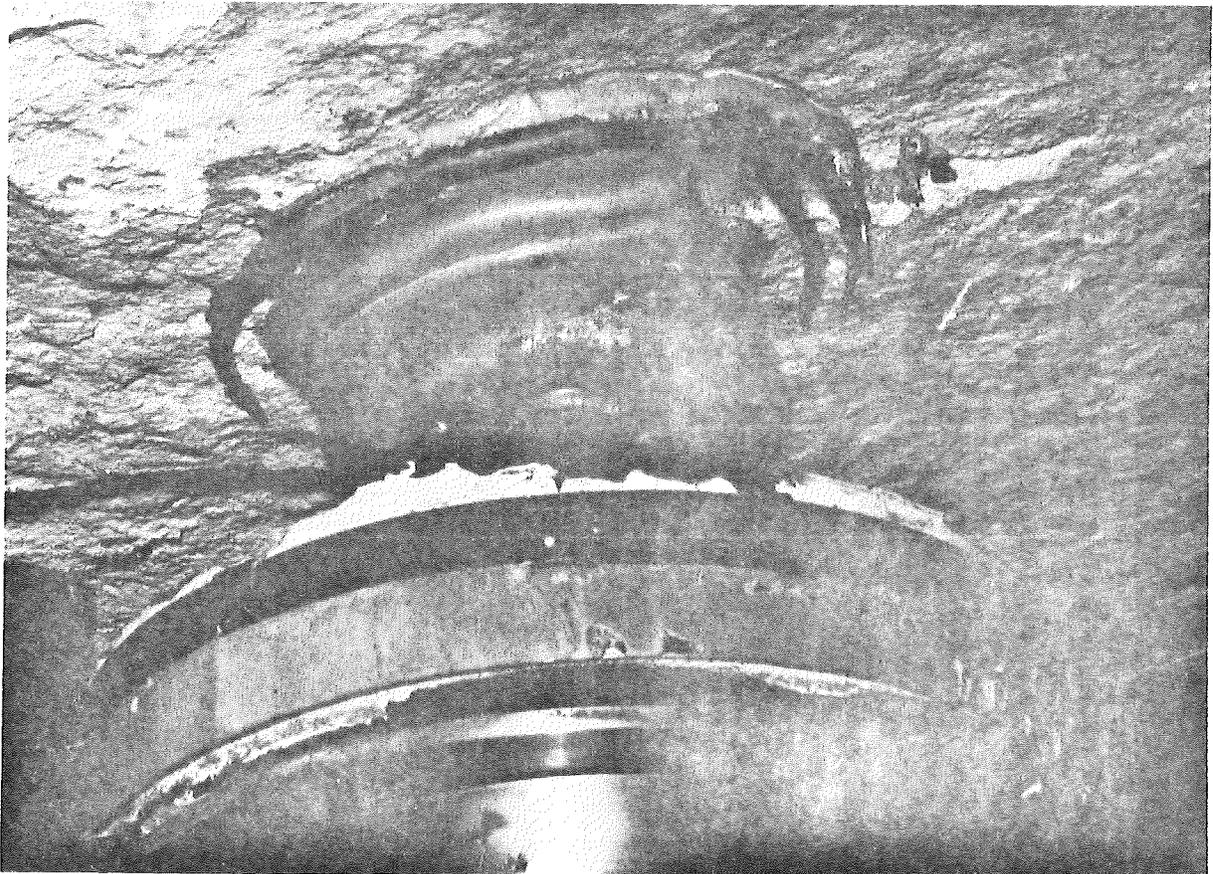
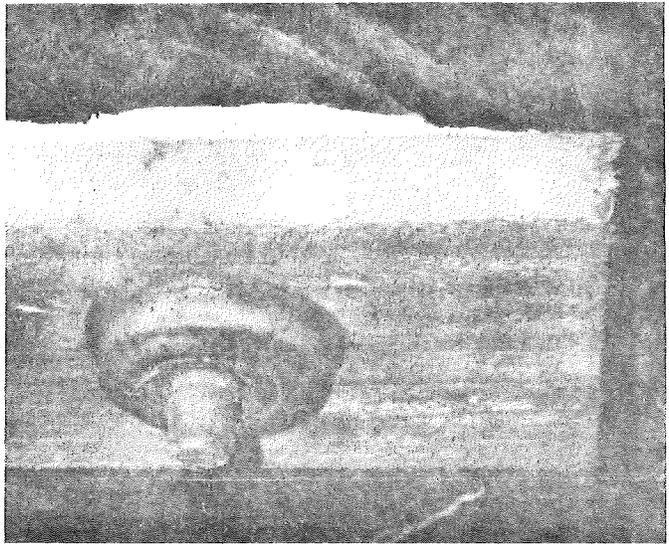
TESTING OF PUMPABLE ROOF BOLT MACHINE

Figure 14



TESTING OF PUMPABLE ROOF BOLT MACHINE

Figure 15



PUMPABLE BOLTS INSTALLED IN MINE ROOF
Figure 16

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The pumpable bolt concept has been tested in hardware and it has been possible to identify problem areas quite specifically as a result of the program just concluded. Solutions to these problem areas have been or can be formulated. Eimco is of the opinion that a machine can be constructed with the capability of remotely installing pumpable bolts at rates which are commensurate with present mining practices.

The design of such a machine is more demanding and involves a broader spectrum of technology than does a conventional roof bolter. In particular, a thorough knowledge of resin handling characteristics and compatibility between resin and machine materials is required.

The operation of the Pumpable Bolt Machine in its present form, particularly the loading, start up and shutdown procedures are more complex than the operation of a conventional roof bolter and require greater attention to detail as well as a thorough understanding of the machine functions. It is doubtful that the typical bolter operator of today would successfully operate the machine in its present form.

Size and complexity of the injection apparatus is a negative factor in arriving at a practical, reliable machine design.

The current resin system is high in cost, uncertain in supply and does not work well in cold or wet conditions.

It was established that it is possible to achieve a filler loading in the resin (up to three times the original 15%) without adversely affecting strength. It is necessary to choose proper filler particle size and shape mix to achieve this.

Although the pumpable bolt concept has merit and the potential of materially increasing safety in underground mining, there was a wider gap to bridge between concept and practical application than had been supposed. It was not possible to completely close this gap during the program.

On the basis of the experiences gained from the operation in the working cycle in two underground coal mines, a follow-on program comparable in extent to the program just completed is judged necessary to establish absolute acceptability to the operating miner of the Pumpable Bolt system.

Any additional development work undertaken with regard to simplification of the Pumpable Bolt Machine must go hand in hand with any work performed on the basic bolt concept and the grouting medium in view of the many problems associated with handling of a resin in a machine system and the interaction between machine components and resin and solvents.

Recommendations

It is recommended that additional work on the development of the Pumpable Bolt concept be concurrently undertaken in the following areas.

Pumpable Bolt Resin or Grout

Development toward lower cost.

Replacement of Chlorostyrene.

At Resin/Rock Interface, exploration for:

Improved adhesion to wet surfaces.

Improved handling at low temperatures.

Improved cure and bonding in cold rock.

Pumpable Bolt Concept and Machine

Development directed towards:

Replacing loose roving with "organized" pretreated fiber.

Stronger bolt head.

Heating rock boundary in hole.

Smaller diameter/lower cost bolt.

Modification of the machine to suit the above.

PROBLEM DISCUSSION

Materials and Processes

Roving

The roving is difficult to handle in its present loose form, especially in the underground mine environment.

At the start of bolting operations, the four bundles of roving required for the bolt must be manually threaded through the roving seal and then fastened by taping to the vent tube. Refer to Figure 17.

The roving filaments break in the handling and threading process, causing knotting and difficulty in achieving smooth unhindered movement through the bolt head.

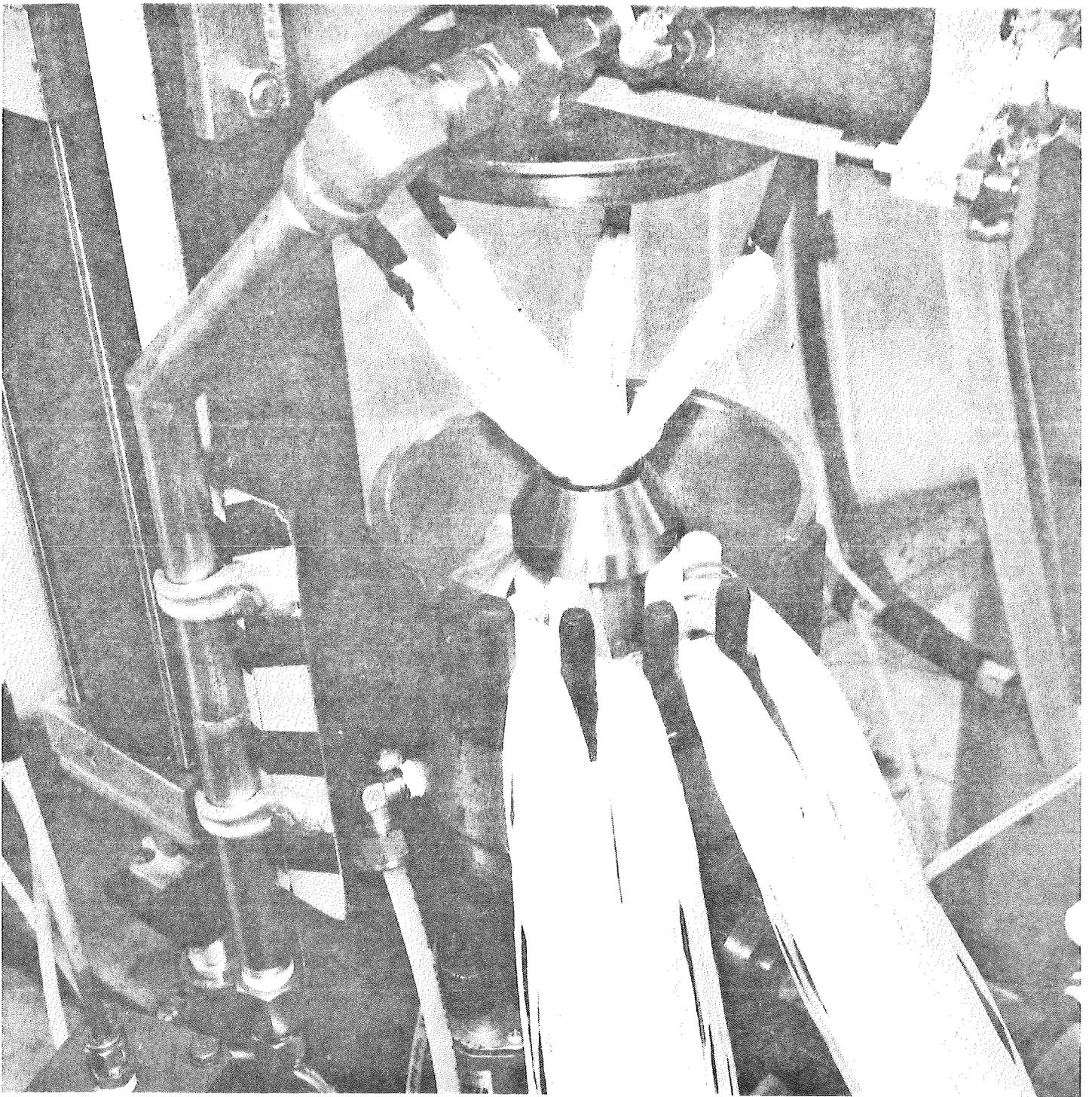
The feeding of the roving up into the drilled bolt hole requires a push tube of a minimum column stiffness. This in turn bears on the problem of reducing the size of the pumpable bolt from its present 1-3/8" diameter to a more desirable 1" diameter. Such a reduction of size would cut the amount of resin used nearly in half. (Reduction of bolt mass requires adjustment to resin formula to maintain exotherm level).

Wetting

The four bundles of roving must be prewetted with a special wetting resin to assure that all roving filaments develop full tensile strength.

To do this efficiently requires that the roving be guided through the wetting resin in a manner which exposes all the filaments to intimate contact with the fluid. This in turn requires a guiding and spreading arrangement which makes the initial installation of the roving in the system difficult.

The wetting resin is catalyzed and, therefore, has a finite pot life; considerable trouble has been experienced with this resin setting up in the plumbing associated with the wetting system. On the other hand, the wetting resin as now constituted has often not cured completely but has remained soft for long periods after installation. The catalyzed resin requires the heat from the bolting resin exotherm to cure.



ROVING BUNDLES TRAVELING THROUGH WETTING CHAMBER

Figure 17

To improve handling, the roving has been given a slight pre-twist. A reduction in wetting efficiency results so that this tradeoff must strike a balance between satisfactory handling and sufficient wetting.

Handling of the four bundles of roving requires four separate storage spools. Refer to Figure 18. Handling of the wetting resin requires a supply tank, a pump, plumbing and a wetting chamber with guides. This total requirement increases the complexity and size of the bolt forming system and reduces its reliability.

A possible solution to all of the above would be to replace the loose roving with a pretreated fiber bundle.

A very excellent candidate for such a pretreated fiber would be a glass rope. Glass ropes are produced commercially in an epoxy matrix but are expensive. A simplified form of rope could be produced, however, with a built-in vent tube in a polyester matrix.

The fiberglass resin matrix combination is still flexible due to the fact that the fiber is helically wound.

A commercial pulltrusion could also replace the loose roving but would be considerably stiffer than rope. A possible way to overcome this stiffness would be to produce the pulltrusion as a flat tape and force it into a tubular shape as it entered the bolt forming head. This then would provide a venting channel.

Vent Tube

Considerable work was expended in the program to come up with a vent tube with the following qualities.

- Sufficient column strength to pull the roving into the bolt hole.

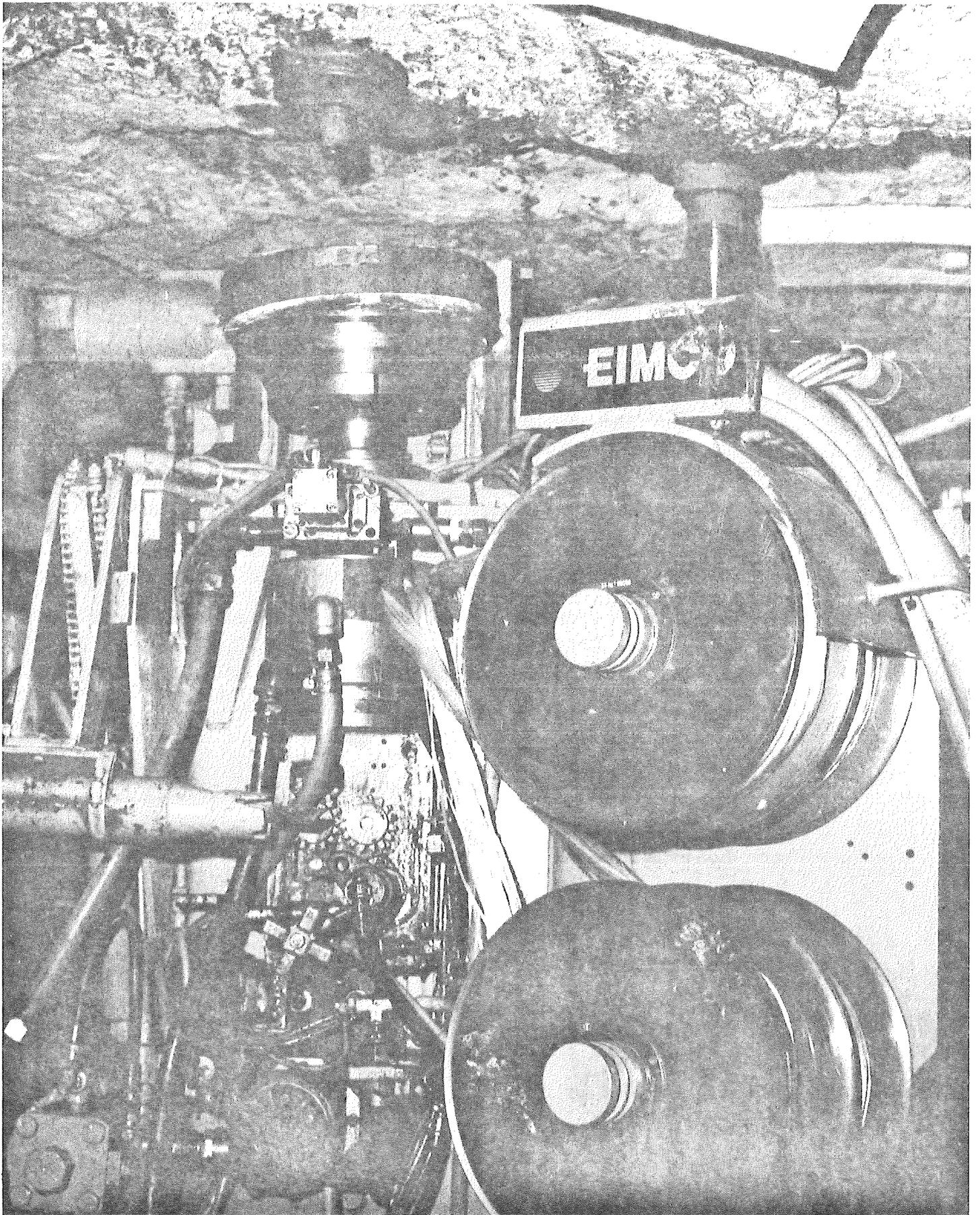
- Compatibility with the resin system - must bond but not dissolve.

- Must be able to withstand the heat of the exotherm.

- Must be flexible enough to be stored in a reel.

- Must be able to resist drive roll pressures.

The material chosen is chlorinated poly vinyl chloride in 3/8" standard pipe size (.504" OD). Non chlorinated PVC does not bond to the present resin system, chlorinated does. However, the CPVC becomes brittle in contact with the



ROVING ON STORAGE SPOOLS
Figure 18

presently used solvent and from all appearances, also from the solvent fumes. This caused considerable trouble with vent tube breakage during field installation.

None of the commercially available plastics other than CPVC - meets the above requirements. A metal tube has been tried but does not meet all the listed requirements. Change to a pre-preg or fully cured fiberglass resin matrix with built in vent tube would eliminate this problem.

Installation Sequence and Metering

Two forms of bolt installation were used in this program.

Simultaneous Injection of roving and resin. This requires that the movement of the roving be synchronized with the flow of the resin so the resin doesn't overflow the vent tube.

Injection of roving first, followed by injection of resin.

Simultaneous injection of resin mix and the advance of the vent tube-roving combination requires that the seal around the vent tube and the rovings be open (or relaxed) so that vent tube and rovings can pass through during the injection phase. This gave continuous trouble; enough injection pressure to create a four-foot bolt was enough to force the injected plastic or resin mix down (against the movement of the rovings) into the wetting chamber. This plastic mix would then set up, in the wetting chamber or its associated plumbing or in the slots through which the rovings were admitted to the bolt forming chamber. This latter problem would either cause the withdrawal of the bolt from the mine roof when the machine head was withdrawn or prevent the withdrawal of the machine head if the bolt was sufficiently cured and strong. In either case, it then required disassembly of the head of the machine, and manual removal of the cured bolt from the bolt forming head.

Delaying the injection of the resin until the roving is installed and the roving seal fully closed cures the sealing problem completely and is the method ultimately used in this program.

However, under this method the high viscosity resin flow into the bolt hole is somewhat resisted by the roving.

As a result, the resin does not always completely fill the bolt hole and an incomplete bolt may sometimes result.

A pretreated form of roving might reduce fluid friction to a point where a more complete bolt always results.

The application of vibration to the bolt being formed should aid.

Incomplete Bolt

This question was discussed in part in the preceding item. The specter of an incomplete bolt worries miners. The problem exists also with resin grouted bolts where oversized holes and incomplete mixing result in incomplete bolts.

Attempts were made to use the torque on the vent tube drive to sense when the vent tube hits the top of the hole. These attempts failed because of insufficient excess torque available to trip a sensing device. The operator instead relies on hearing and sight to sense when the vent tube reaches the top.

A system to measure resin flow as well as linear roving motion could be derived with a read out to show operator extent of total bolt injection.

Material Compatibility

In the design of a Pumpable Bolt system, it is necessary to carefully choose proper materials for those parts which come in contact with the resins or solvents.

An example of material incompatibility experienced in this program is the fact that the resin components used stick to compression molded Teflon. Linear polyethylene, which in contrast is nonporous, performs well.

Purge

A continuous purge is desired when not injecting resin. This is partly due to the trichloroethane being a poor solvent for the resin mix. In effect, the mix has to be "washed away" or eroded by the flow of solvent over a period of time. The presence of the liquid solvent inhibits the curing of the resin mix. Continuous purge provides adequate cleaning of the conduits and components of the system.

Some problems were encountered initially with the centrifugal pump used to circulate the purge liquid. These problems centered around vapor locking of the pump, especially under no flow conditions, which also caused overheating of the shaft seal.

A possible solution is the substitution of a piston injected purge.

Bolt Head

The bolt head strength, as indicated by many pull tests, is about 10,000 lbs. The bolt itself has a tensile strength of more than 40,000 lbs.

In the present bolt, the head strength depends solely on the shear strength of the plastic. There is no fiber reinforcement at the head/bolt junction.

If part of the roving could be made to extend into the head area, the head would be strengthened. This solution to achieve greater strength will not be possible if pretreated roving is used. The bolt head could be thicker, but miners, especially in low coal, prefer that the bolt projection out of the roof be kept to a minimum.

Polyesters with much higher shear strength than that used are available for consideration in alleviating this problem also.

Equipment

Targeting on Bolt Hole

The drilling turret indexes from drill position to bolting position automatically and targets on the drilled hole with perfection. However, the roving and vent tube combination is flexible and does not always point to the hole with perfection. This made it necessary for a man to be positioned at the head of the machine to, when required, guide the flexible tube-roving combination into the hole.

A solution attempted during the project was to squeeze a bolt being formed in the bolt head thereby reducing its diameter at the cut off point. This was accomplished by inserting a silicon rubber tube into the bolt forming head, the inside diameter of which was reduced conically. The rubber was soft enough to allow removal of the full diameter bolt through the reduced mold diameter. This tube, however, tore easily and wore out quickly.

A finger mechanism could be added to the top of the bolting head to stabilize and thus guide the bolt stub into the hole in the roof. The finger would have to be mechanically moved out of the way on insertion of the stub into the hole.

Cut Off Saw

The present cut off saw is an air driven reciprocating commercial saw mounted on a swing arm. It does not always succeed in cutting off the freshly made bolt, especially when cure is slow and the bolt material soft. It occupies a large amount of space and, therefore, adds to the size of the bolt head.

A circular saw, a band or wire saw (with unidirectional motion) and a mechanism to hold and stabilize the stub combined with a finger mechanism discussed under "Targeting on Bolt Hole" would solve this problem.

Head Valve

This valve is the port that opens the flow of resin to the bolt hole in the mine roof. By definition it must handle mixed resin in a state of polymerization. The valve is shown in Figure 19.

Polymerizing resin continually builds on the valve parts and frequent cleaning is required. Once every 8 bolts was the required cleaning frequency during the operation in the mine.

Redesign to provide a valve which can be quickly and easily replaced is recommended.

Roof Seal

The present seal consists of a bowl onto which is fastened a silicone rubber seal. This arrangement works well except on extremely rough roofs or in conjunction with the installation of wood blocks, mats or mesh.

A crushable foam piece applied to the top of the seal or between the block or mat and the roof will fill the space which cannot be covered by the seal lip. This method was used in the actual mine installation of the pumpable bolt with success.

Size of Bolt Head

The pumpable bolt forming head in its present configuration, is larger than is desirable for a practical mining machine. This large size reduces its ability to reach up into all areas of a broken roof.

Size reduction can be accomplished through redesign.

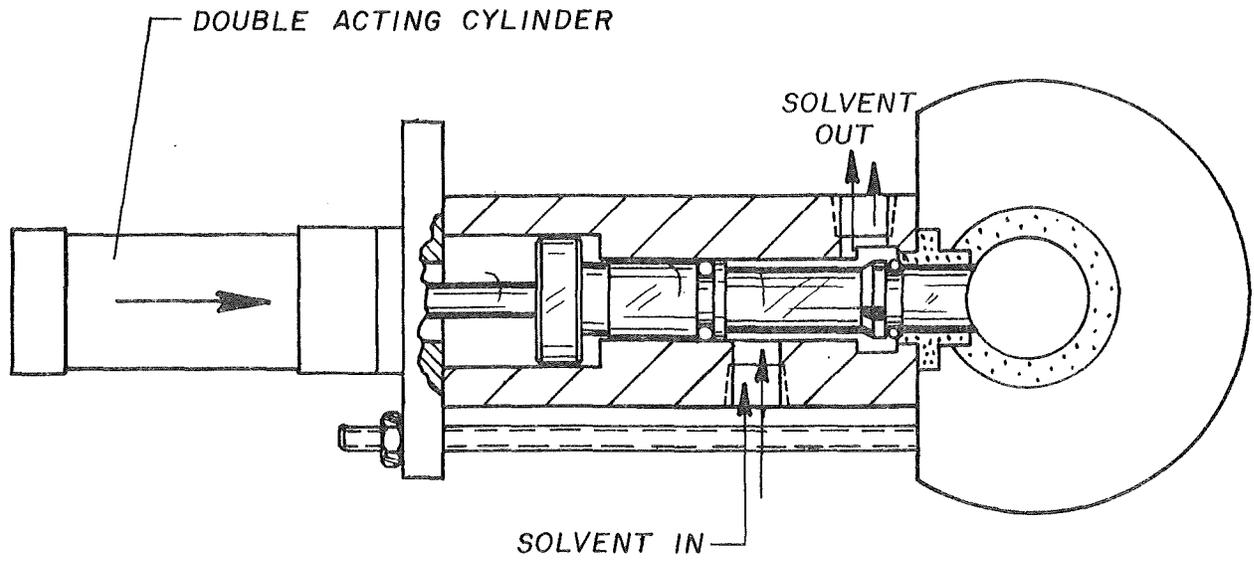
Operator Location

The Pumpable Bolt Machine is designed for operation from the operators cab, remotely and under supported roof. However, in actual operation it proved necessary to place one man at the bolting head to observe the bolting process and signal the operator in case of any snags or malfunctions. The potential of a completely remote operation, however, remains and should be achievable through redesign.

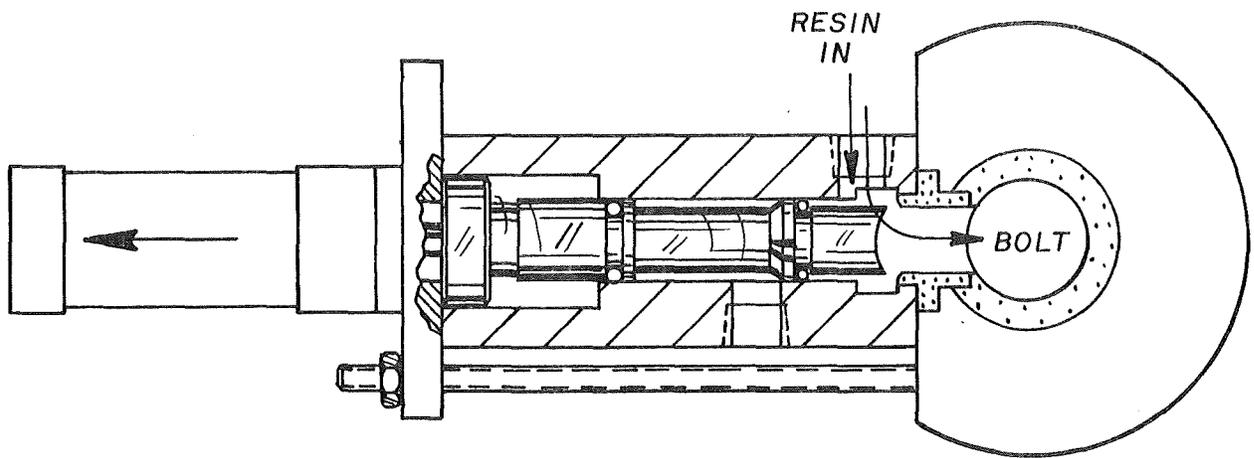
Plastic System

This program concentrated on the development of a system for placement of liquid bolting material in drilled holes in coal mine roofs. It did not have as its objective an assessment of such bolts or the cost of materials.

Problems associated with the bolt resin include:



PURGE POSITION



INJECTION POSITION

HEAD VALVE
Figure 19

Temperature

Temperature is a crucial factor in the shelf life and ease of handling the resins. Generally, the lower the temperature the longer the shelf life. Unfortunately, at lower temperatures the viscosity of the resins increases dramatically and the resin movement through the pumpable bolt injection system is slower than desirable. Below 7°C, the resin must be heated to facilitate adequate flow through the injection system as well as cure. If, in addition, the roof rock is below this approximate temperature, preheating of the resin is an absolute necessity for rapid and complete cure. If the temperature of the catalyzed resin (Resin B) gets too high (near 170°F) premature polymerization takes place.

Providing permissible heating with close control increases the complexity of an already complex machine.

Cost

Analysis indicates that the cost of the present mix is excessive primarily due to high cost of chlorostyrene. Availability of chlorostyrene is a major problem. It is only produced in relatively small quantities in Japan. The possibility of cessation of production is real and could happen at any time.

Secondary cost factors are the use of silane coupling agent, glass filler, and high cost of polyesters. It has been estimated that the cost of the resin could be reduced to at least half the present cost by changes in formulation.

Resin/Rock Interface

Performance comparison between resin grouted bolts (spun in place to mix polymers) and pumped bolts in some cases (especially with wet and clay like roof) indicate better roof to plastic bond for the grouted bolt. This is thought to be a result of shear in the rock/plastic interface during mixing of the grout. This shear could be induced in the pumpable bolt by adding an up/down motion during initial cure. The reaction force experienced during this motion could be sensed and used as positive indication of curing.

Bolt-Rock Adhesion

Adhesion of bolts to a wet hole is significantly lower than to a dry rock. To some degree this is characteristic of polyesters. Bond strength could be improved by chemical redesign of polyesters. Additionally, the poor adhesion to wet rock raises the substantial question concerning the stability of the silane in the formulation.

Thermodynamics of the Resin Reaction

It was found through laboratory simulation that reaching of proper exotherm temperature in the bolt resin inside the drill hole in the rock was very problematic.

High temperatures are needed for uniform cure and for curing the wetting resin in the roving. This appears to be a basic problem which should be addressed specifically. Solution will lie in:

Reformulation of the resin for compatibility with a span of temperatures commonly found in underground mines. Controlled preheating of the resin on the installation machine.

Addition of heat during the curing, which is possible for example by vigorously moving the resin in the bolt hole. A reciprocating motion as discussed elsewhere in this report or a rotary motion could be used.

Preheating of the rock wall inside the hole just prior to injection. This could be done as part of the drilling process by blowing heated air through the drill. The arrangement could also allow for a silane mist treatment through the drill steel during drill withdrawal.

DESCRIPTION OF EQUIPMENT AND EQUIPMENT OPERATION

Equipment Specifications

The machine which carries the pumpable bolt system is a modification of a Standard Eimco/Secoma Model 359-2G Roof Bolter.

The complete Pumpable Bolt Machine is shown in Figure 20.

Chassis

The machine is a four-wheel drive, four-wheel steering unit designed to operate in a 60 in. headroom. It has a 12 in. ground clearance and can negotiate a 12' x 12' intersection.

Power

Power is from a 440 volt, 50 horsepower motor that drives the hydrostatic tramming system, hydraulic service system, air compressor and blower for dust collection. Power is received via trailing cable.

Cable Reel

Operation of the cable reel is automatic; constant tension is maintained on the trailing cable regardless of the direction of the machine motion.

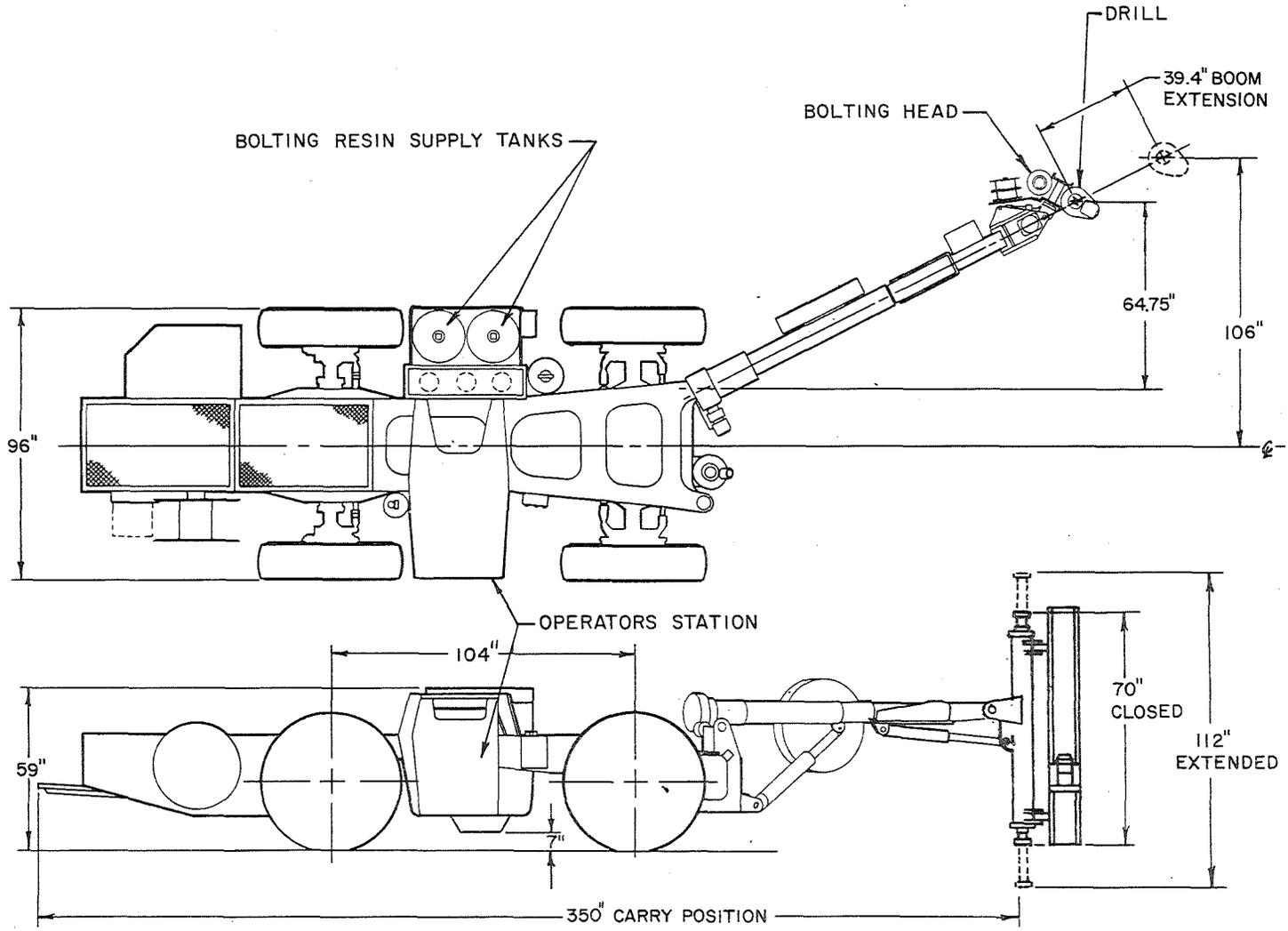
Brakes

The machine is equipped with four-wheel hydraulic power assisted service brakes, parking brakes, and fail safe brakes.

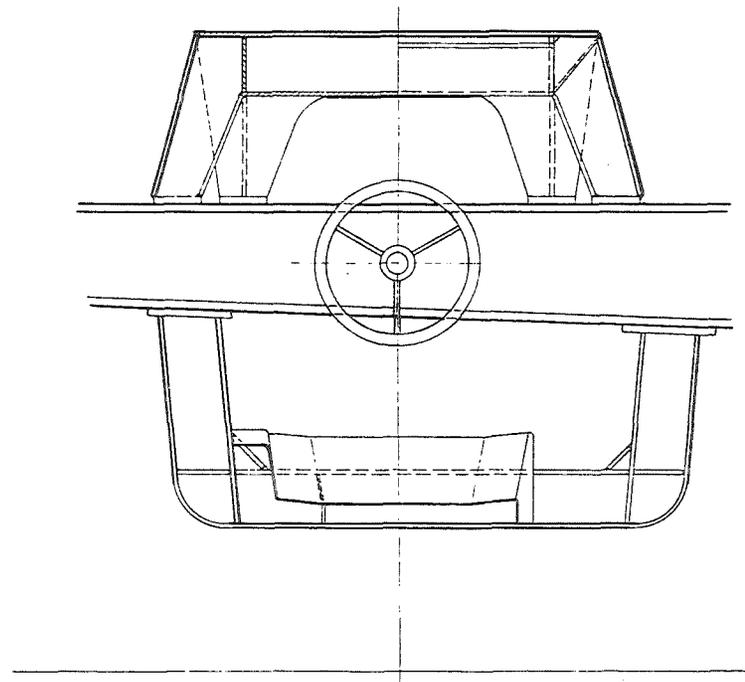
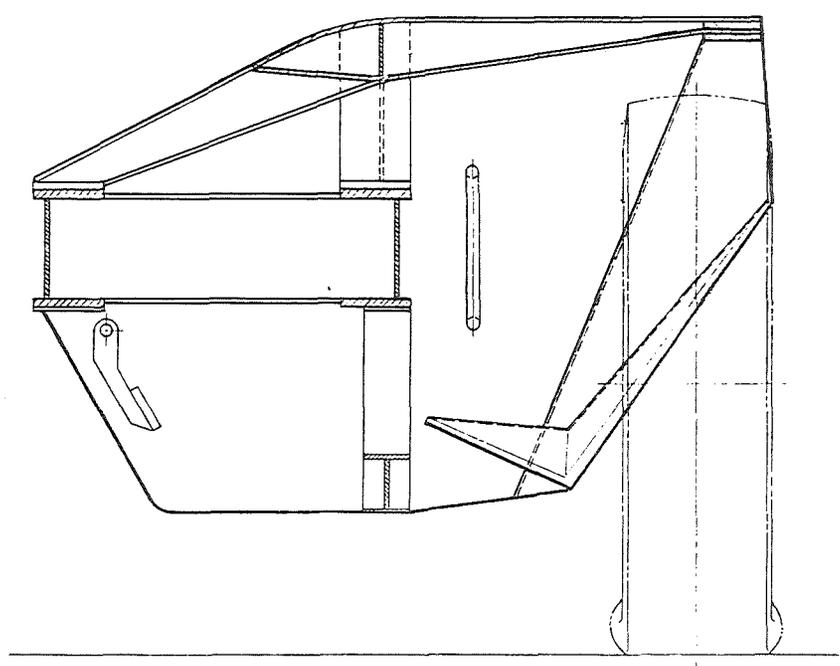
Operator's Station

The operator station is cross-mounted in the center of the machine, and is illustrated in Figure 21. The operator station is designed as a non-crushable "capsule" structure capable of withstanding a 15 psi load.

The drive system, hydraulic steering, and plastic system controls are located so the seated operator has access to all of the operating controls of the machine.



PUMPABLE ROOF BOLTING MACHINE
Figure 20



OPERATOR'S STATION
Figure 21

Hydraulic System

The service hydraulic system is a closed-center constant pressure system equipped with an unloader-accumulator system to decrease horsepower requirements and heat generation.

Boom

The machine is designed for two booms, hydraulically operated with full 360° rotation of the drill about the boom axis, and extension of one meter (39.37 inches) and a swing of 88" each way from center position. Under this program, only one boom and one bolting system was mounted and used.

Jackleg

The turret end of the drillboom carries a hydraulic jackleg which locks the drill turret into position between floor and roof. Approximately eight tons of force are available; ball-jointed pads top and bottom distribute this load into the thrust areas.

Turret

A unique combination drill and bolt turret arrangement function to index the drill and bolt functions so that no manual repositioning of the machine or boom is necessary (after the hole is drilled) to install the bolt.

Drill

Two types of drilling methods are used depending on rock conditions. The first type is hydraulically operated rotary drill, sufficient for normal conditions.

For more adverse rock conditions, a pneumatically operated rotary percussive "stoper" type drill is mounted on the turret. This type requires an external source of air whereas the first type requires only machine supplied power.

Dust Suppression

An automatic dust suppression system is supplied with this machine. When the drill drive is started, a 375 CFM exhauster is also started. This system has been tested, approved and certified by MESA, approval #25B-214.

Plastic System

Tankage, pumps, mixing devices, etc., necessary to form, in place, the glass reinforced polyester bolts are all incorporated on the machine. Also, on the machine are reels of glass roving, a fiber which forms the longitudinal reinforcement in the bolt. Pneumatic control devices automatically control the various steps in the bolt forming process. An automatic timer

withdraws the bolt forming head when the cure cycle is complete and the bolt is sawed free of the machine.

Machine Subsystem Details

The pumpable bolt machine major subsystems are:

Resin Delivery System

Wetting Resin System

Roving Feed System

Purge System

Resin Heating System

Bolt Injection Head

Control System

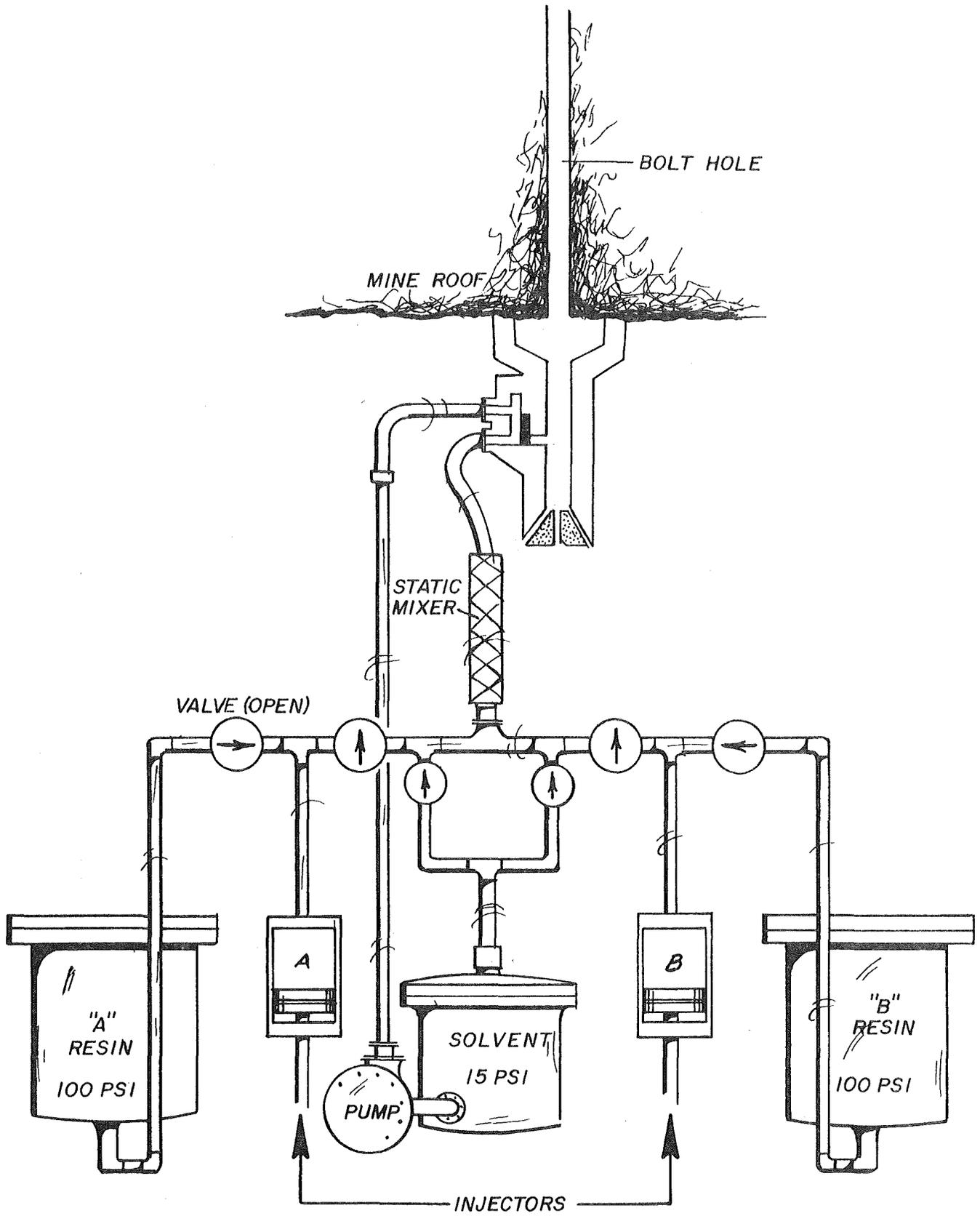
Bolting Turret

Resin System

Resin Delivery System

This system is shown in simplified form in Figure 22. Requirements for the system are:

1. A 1-3/8" diameter ten foot long bolt must be pumped in 1/2 minute to finish injection and allow purge time before resin starts to set.
2. Two resins must be combined accurately in a fixed ratio.
3. The pumping system must be capable of delivering a 15,000 cps fluid to the bolt head.
4. The pumping system must resist abrasion and chemical attack from the resin system.
5. Under shut-off conditions it should not be possible for Resin A to enter the Resin B area.
6. If one resin line is blocked, flow in the other must stop also.
7. Some means of indicating bolt resin volume pumped should be provided.



BOLT PUMPING SYSTEM
Figure 22

The resin is forced by supply tank pressure (100 psi) to fill a pair of injection cylinders which in turn, force the resin into the bolting head. Advantages of this system are:

- a. Injection of bolts can be done rapidly.
- b. Metering at a fixed ratio (Resin A/Resin B) is accomplished by mechanically tying the two cylinders together. If one line is clogged, the cylinders cannot move; it becomes impossible to inject only one resin (which would result in a faulty bolt), and impossible for one resin to enter the other resin's territory (which would cause the resin mass to set in the lines).
- c. Injection cylinders can be filled at a low rate keeping pressure drop and line sizes small.
- d. The pressure feed system to the injectors is simple and avoids the maintenance problems with mechanical pumps.

Supply Tanks

The supply tanks, Figure 23, are pressurized by 100 psi air for the movement of the resin, A & B, to the Injection Pump.

A separate container filled with bolting resin is placed within the pressure tank. The supply lines dip into this container which is filled with bolting resin. This particular arrangement removes the need for purging and/or cleaning of the tanks and makes loading of the system simple.

Injection Pump

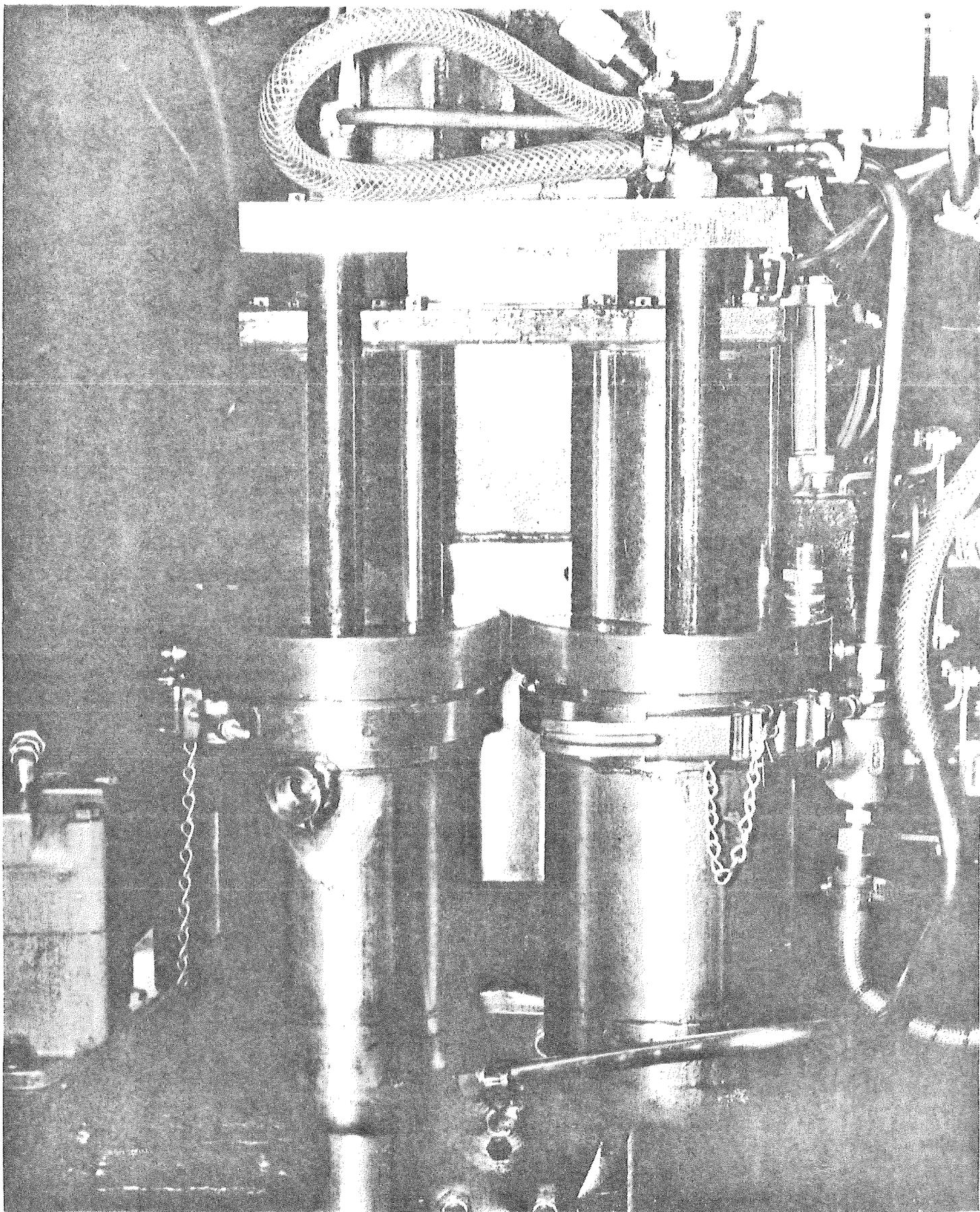
The Injection Pump is shown in Figure 24, 25. When the pumping cycle starts, high pressure hydraulic fluid is routed to the injection pump which causes the plungers to expel resin. The position of the plungers serve as a direct indication of bolt resin volume injected.

Mixing Valve

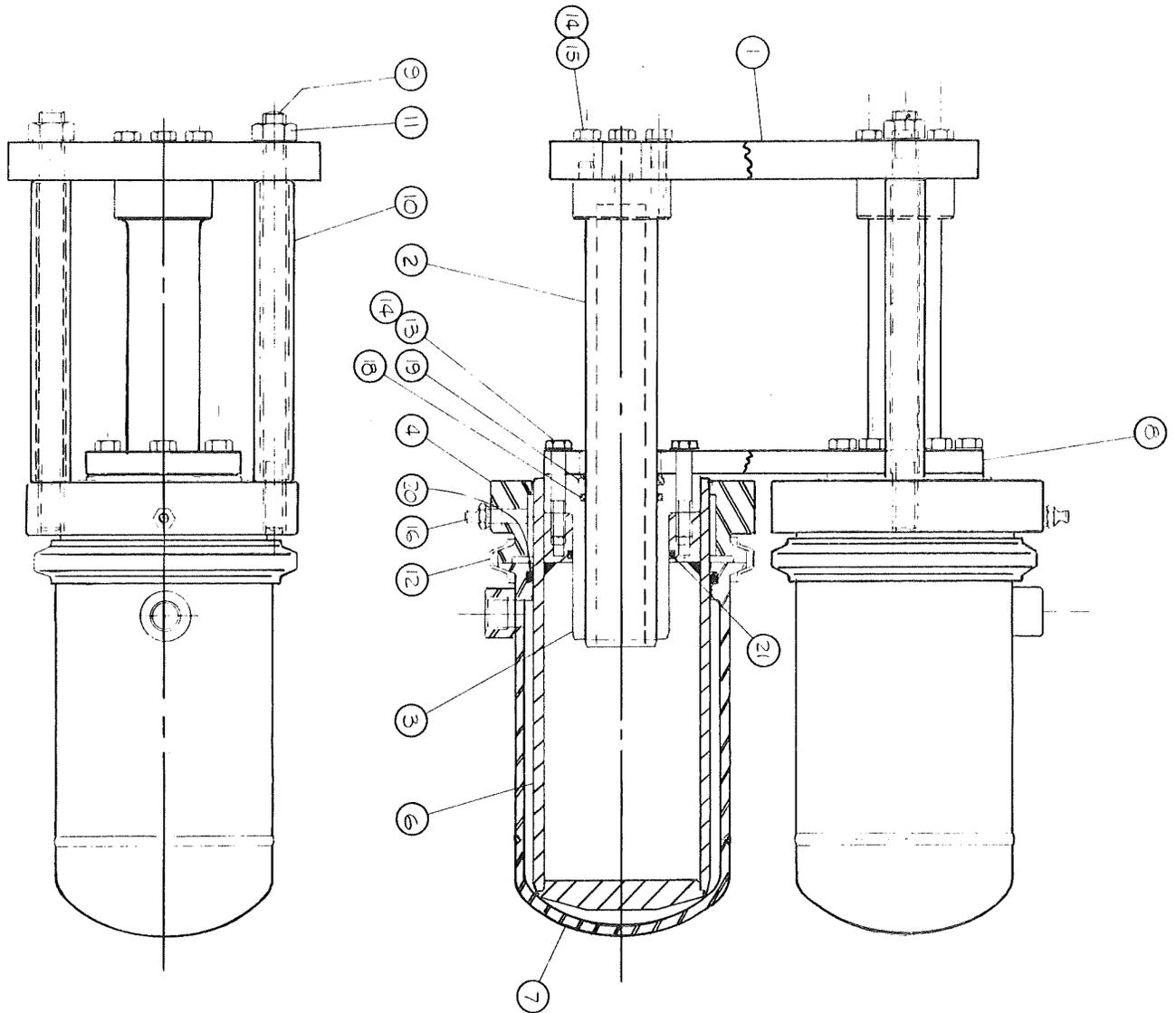
The mixing valve, Figure 26, is a six-way sliding plate valve. The position of this valve controls the flow from the injection pump to either the head valve or back to the supply tanks.



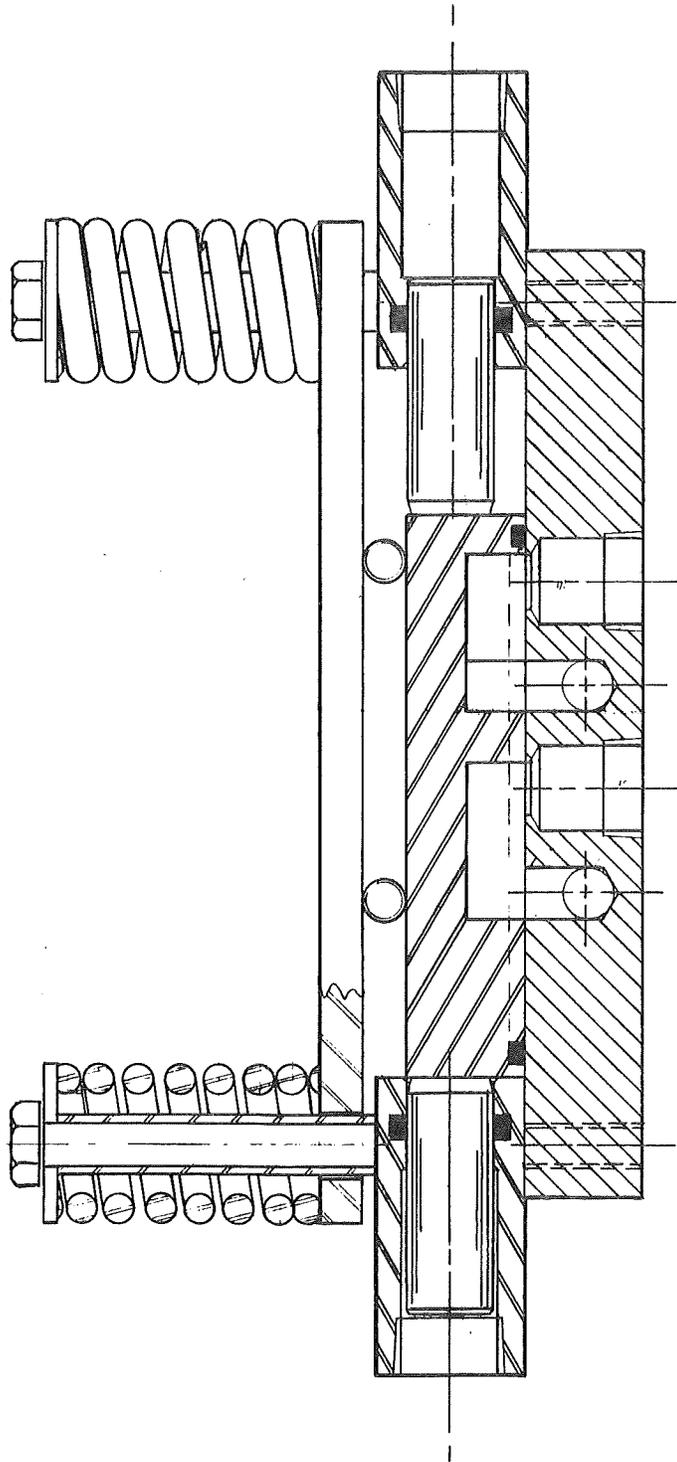
RESIN SUPPLY TANKS
Figure 23



RESIN INJECTION PUMP
Figure 24



RESIN INJECTION PUMP
Figure 25



MIXING VALVE
Figure 26

Wetting Resin System

This system is shown in Figure 27.

The tensile strength of the bolt is provided by fiberglass roving.

The roving is dense and cannot be thoroughly penetrated by the basic bolt resin. Therefore, it is pre-wetted with a lower viscosity "wetting resin." This "wetting resin" is catalyzed base resin without glass filler and sets when exposed to the high exotherm temperature of the total system.

Since it is absolutely necessary that the roving be pre-wetted, a constant wetting resin supply must be assured. For this purpose a system was devised which supplies measured quantity of fluid before each bolting cycle, then withdraws the remaining fluid.

Wetting Resin Pump

The wetting resin pump, Figure 27, is capable of transferring a measured quantity of wetting fluid to the wetting chamber and returning 100% of that fluid to the supply tank.

At rest, the piston and bell are in the position shown allowing fluid to fill the barrel through its exposed holes. To forward resin to the wetting chamber, the piston moves down, and flow to the wetting chamber commences after the piston passes the holes in the barrel. At the end of the piston down stroke, the holes are covered by the bell.

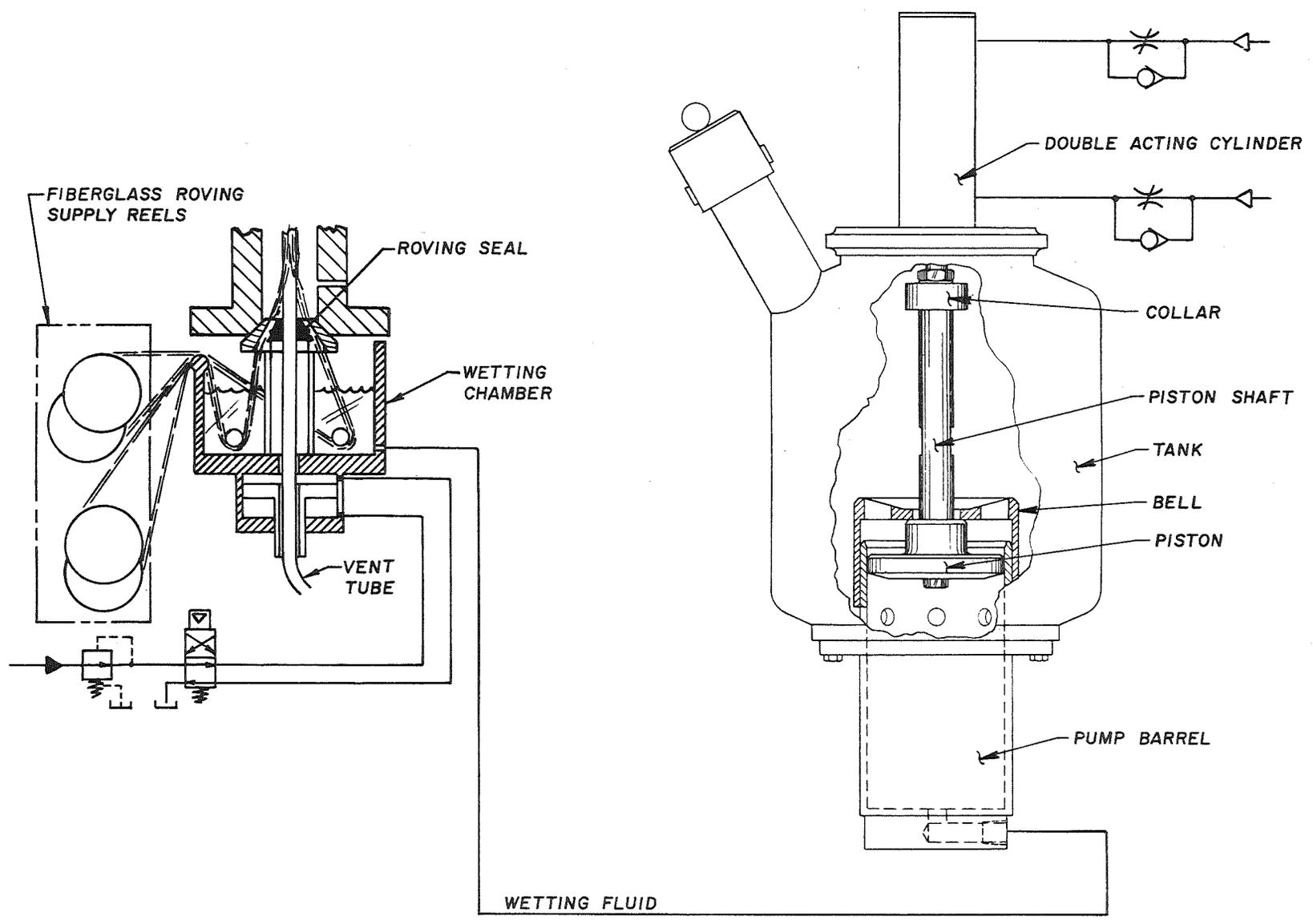
The fluid is removed from the wetting chamber and moves up on the return stroke. The piston is free to move past the now closed holes thus displacing a greater volume than on the delivery stroke.

The system resets itself when the piston on the return stroke moves the bell up, uncovering the holes through which the barrel is replenished.

Wetting Chamber

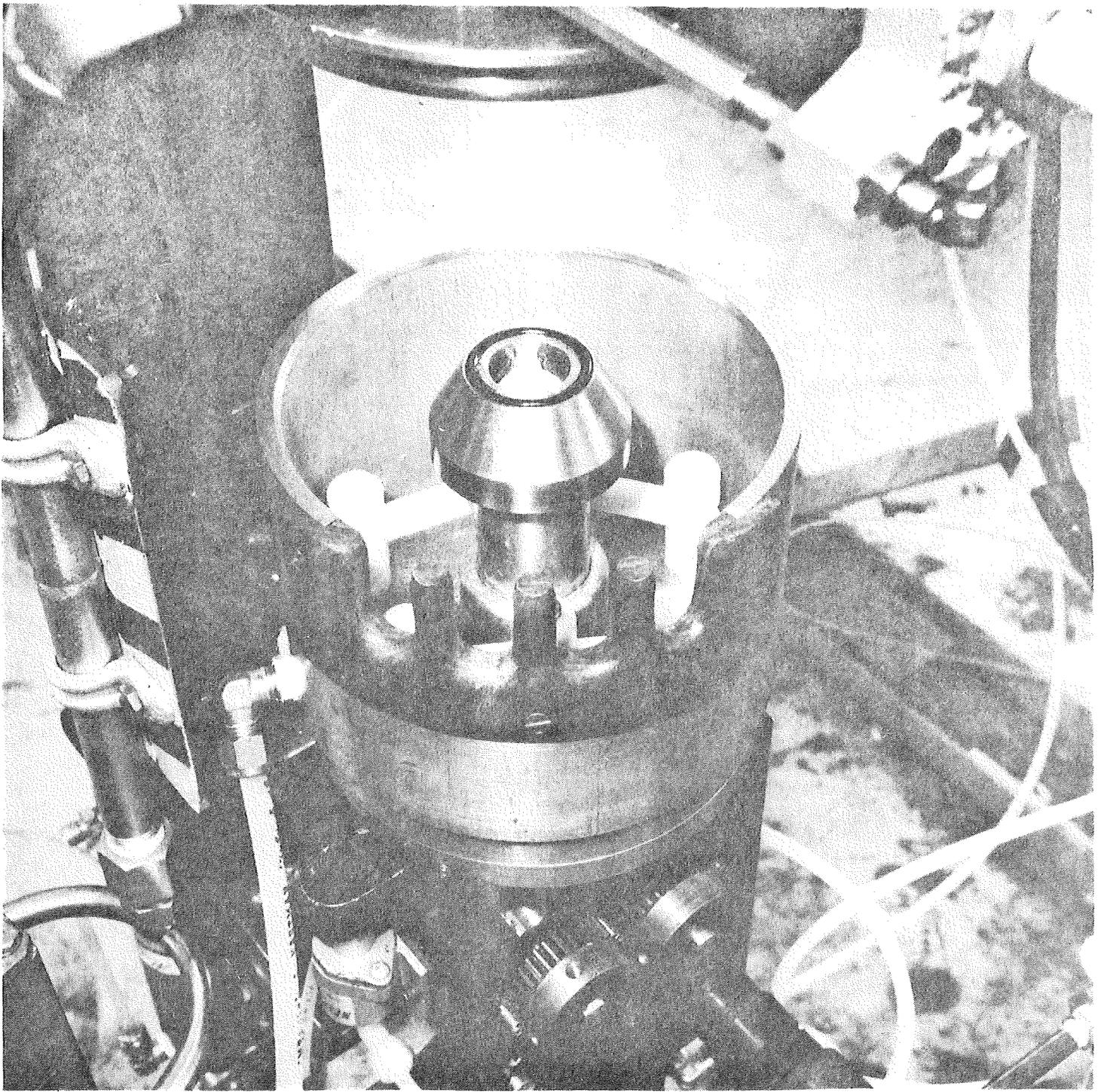
The wetting chamber is shown in Figure 28. It holds the clear wetting resin that pre-wets the loose dry roving. It contains an assembly called the roving bridge which spreads the roving out as it passes through the wetting resin.

The wetting chamber can be dropped away from the bolt forming head to thread the roving through the bridge and through the roving/vent tube seal.



Wetting Resin Pump

WETTING RESIN SYSTEM
Figure 27



WETTING CHAMBER
Figure 28

Roving Feed System

The roving consists of four bundles of continuous glass fiber. Each bundle contains forty strands of 60 filaments.

The roving bundles are spooled on reels and fed from these through the bolting head.

To achieve complete wetting of the glass fibers it is desirable that the roving be loose and fluffy as it passes through the wetting fluid. However, it is difficult to feed the roving through the system in this manner. Therefore, the roving bundles are twisted slightly as they are spooled onto the reels. This slight twisting produces a rope-like product which can be fed through the bolting head with less difficulty.

Roving Reel

Four separate reels are required, mounted as shown in Figure 29. The reels are each sized for 250 feet of roving, are ball bearing mounted and have an adjustable brake to induce some drag to keep a degree of roving tension.

Vent Tube

A chlorinated poly vinyl chloride tube serves the dual function of pulling the roving into the drill hole and venting air out of the hole as it is filled with resin. The tube is left in the bolt.

The vent tube is a semi-rigid 1/2 inch diameter pipe. It is stored on the machine in a 150 foot roll in a dispensing type storage reel as shown in Figure 30.

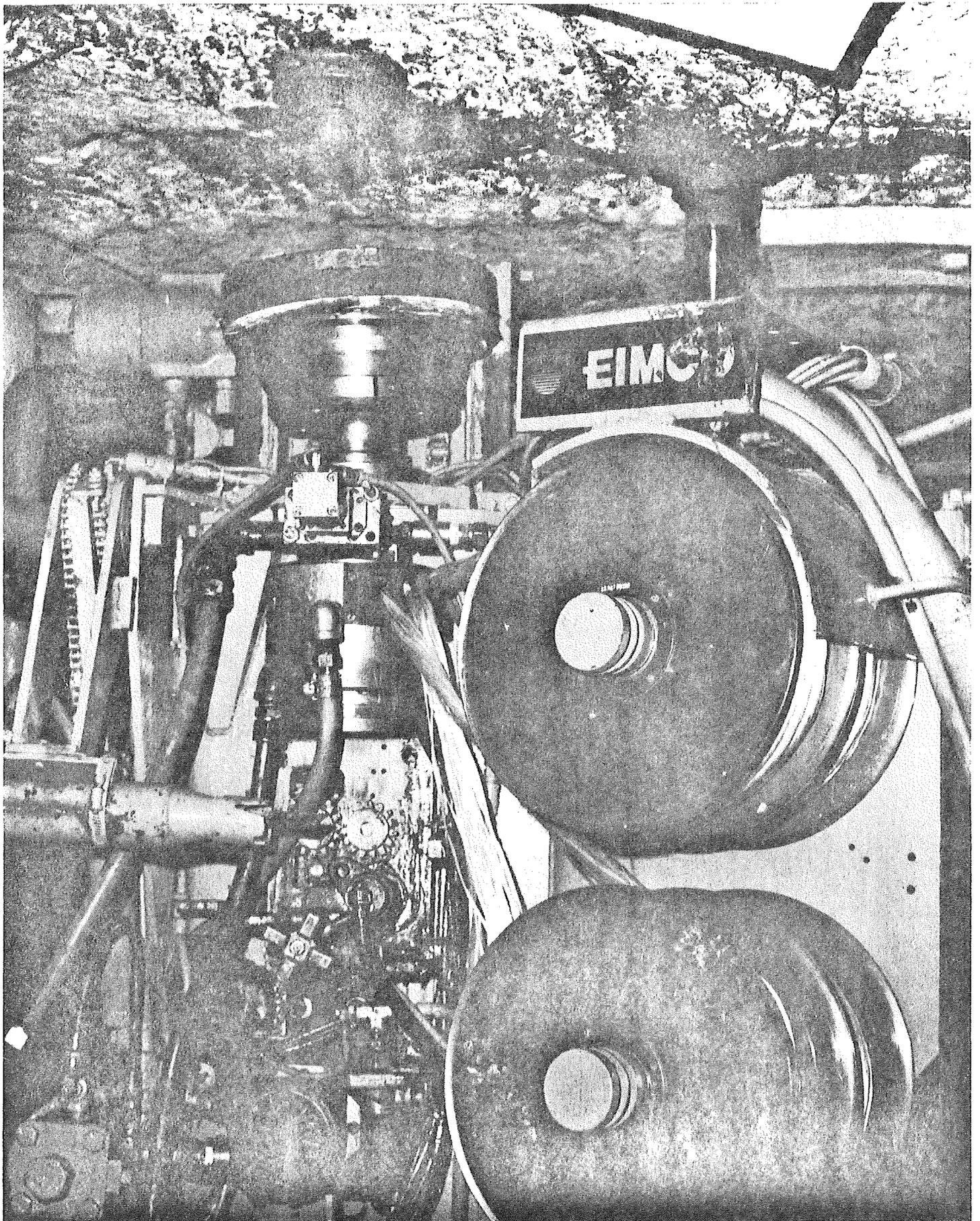
Vent Tube Drive

The vent tube drive is shown in Figure 31.

The vent tube is driven by rollers with teeth to grab the tube and drive it with a tooth action. The rollers are driven through a gear reduction by an air motor.

Roving/Vent Tube Seal

The roving/vent tube seal, as shown in Figure 34, is part of the roving bridge assembly inside the wetting chamber. When the seal is open, the vent tube and roving can be driven through the seal. When it is closed, the elastomer is crowded around the vent tube and the bundles of roving preventing activated polymer from leaking down around the roving and into the wetting chamber. The seal is actuated by a hydraulic cylinder.



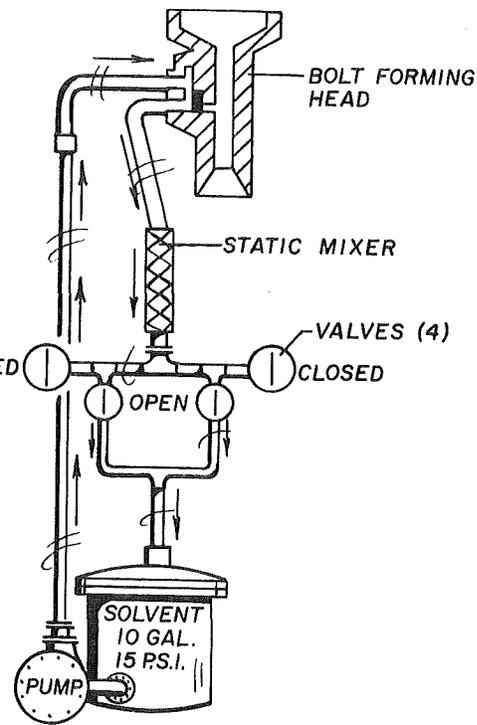
FIBERGLASS ROVING REELS

Figure 29

ed, the catalyzed and promoted resins must
idly to prevent solidification in the equip-

s trichloroethane, a cleaning solvent chosen
atmospheric pressure and room temperature no
tures will result.

is illustrated in Figure 32.



PURGE SYSTEM
Figure 32

circulated as long as the machine is running.
static mixer, and the six-way mixing valve
purged except when bolting.

ed as purge fluid, is stored in a 10 gallon
rainer at the outlet strains out any solids
ites.



VENT TUBE SUPPLY REEL
Figure 30

Solvent Pump

The solvent pump used is of the centrifugal type. To avoid vapor lock, this pump is primed by pressurizing the solvent tank.

Resin Heating System

Cold conditions during the field test required heating of the resin fluids in order to pump bolts satisfactorily. A system was improvised in the field as shown in Figure 33, to maintain the resin between 60 and 85°F.

The hydraulic oil return lines were used as a source of heat. Temperature was controlled by adjusting the oil flow using manual valves.

A coil of tubing was placed in the bottom of each resin supply tank and plumbed into the hydraulic return. A layer of fiberglass insulation was installed on the tanks.

The resin supply lines were heated by running hydraulic return lines in parallel and wrapping on insulation around the two lines.

The wetting resin pump was wrapped with a copper tube and hydraulic oil circulated through it.

Both pots on the injection pump were jacketed for hydraulic return fluid.

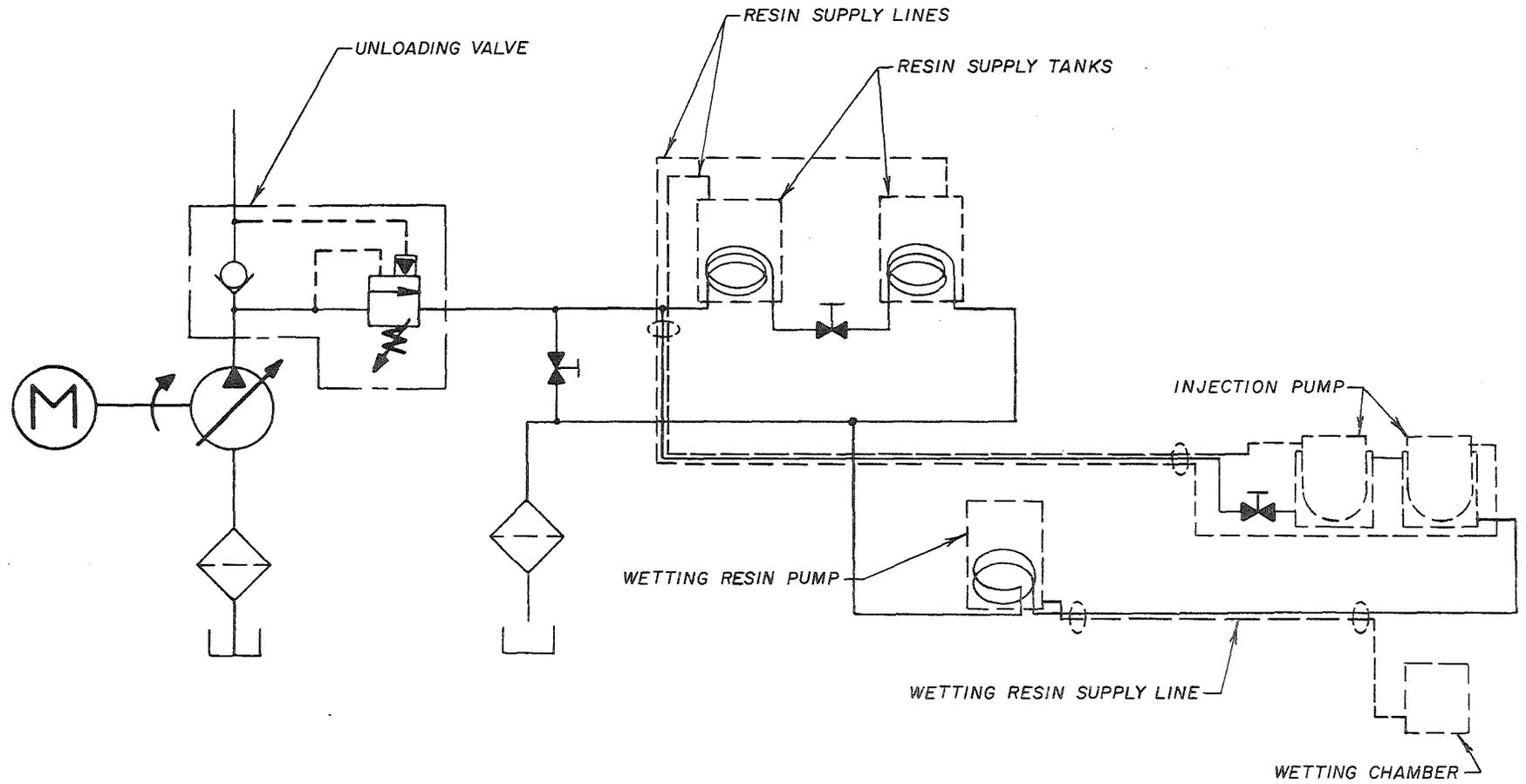
The catalyzed bolting resin proved very unstable at the elevated temperature. Therefore, heating of this resin component at the injection pump was discontinued.

Bolt Injection Head

This assembly is the tubular passage through which all bolt material passes into the roof and is shown in Figure 34. It makes contact with the mine roof through the Roof Seal. The mixed resin centers through the Head Valve and flows from there to the Roof Seal cavity and up into the hole drilled in the roof. The Vent Tube passes through the head driven by two toothed rollers and carrying roving along with it.

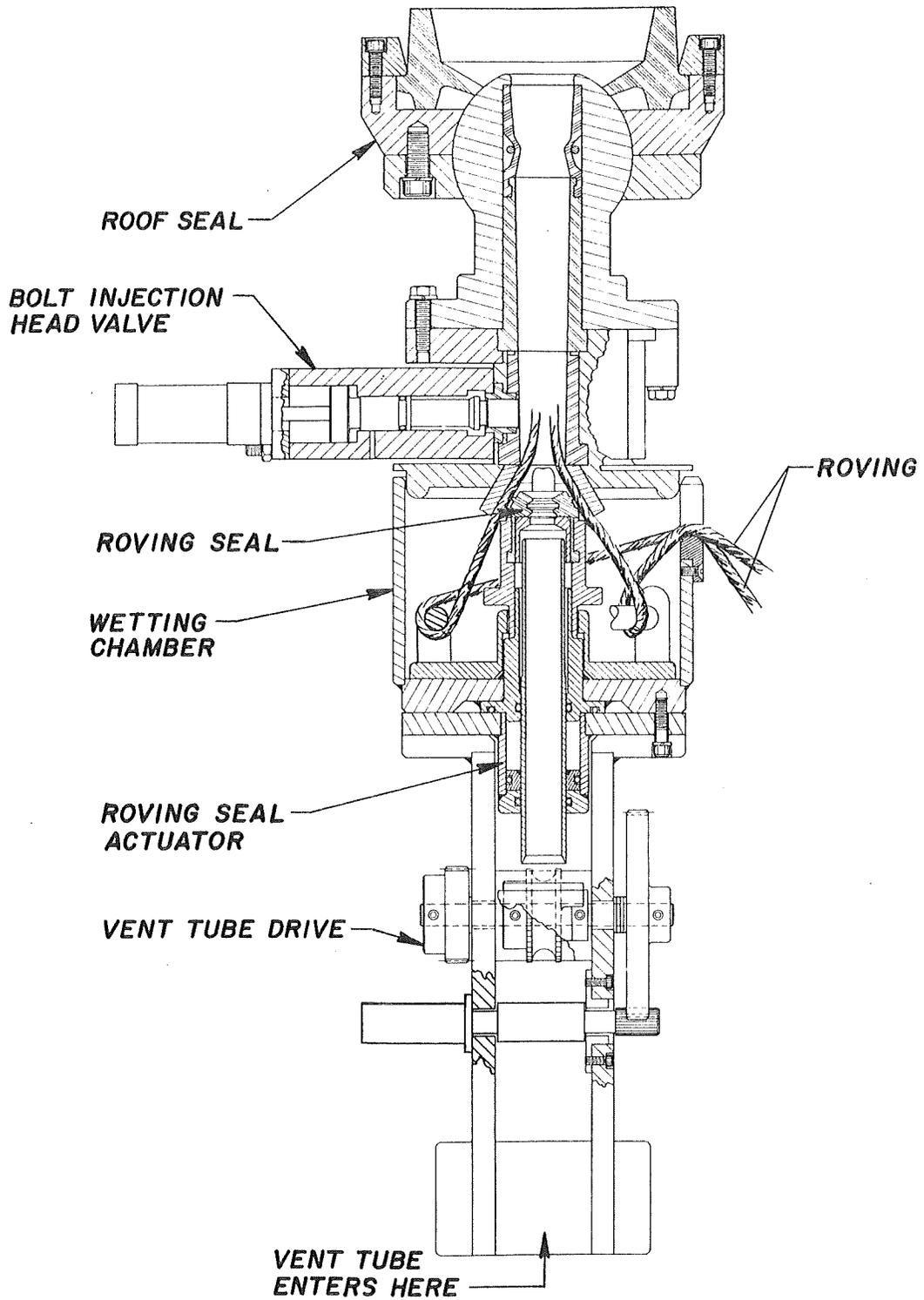
The head is mounted on the drill mast and is automatically positioned under the bolt hole following drilling.

This design is the result of extensive development and solves to a great extent the problem of mixed bolting fluid leaking through the roving seal down into the wetting chamber, a problem persisting through the first six months of machine test and operation. This was accomplished by:

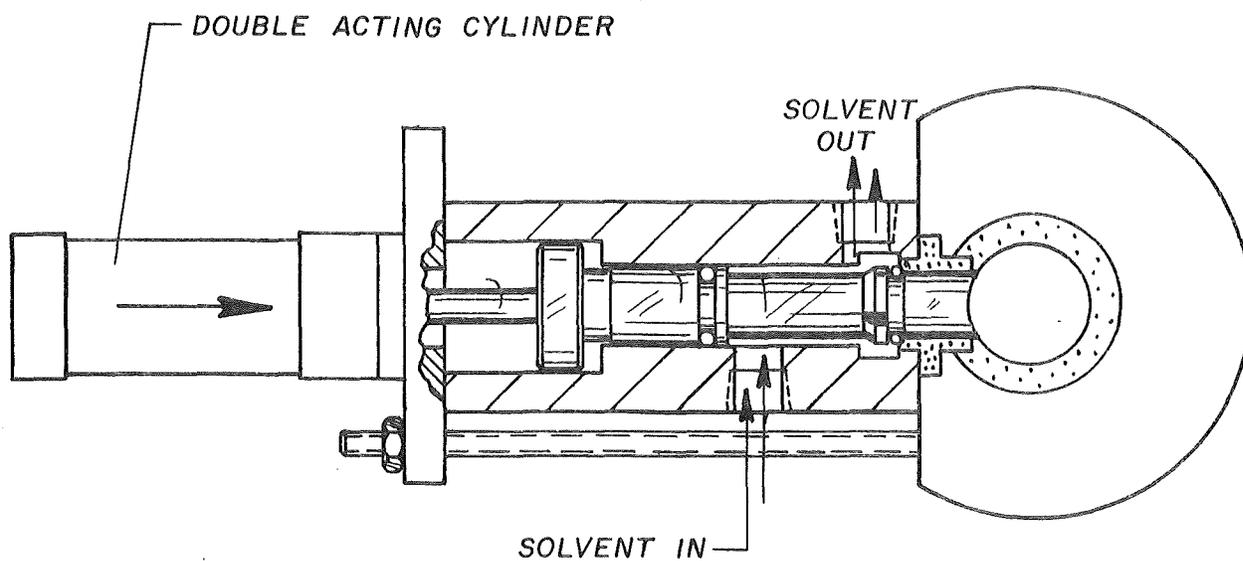


RESIN HEATING SYSTEM

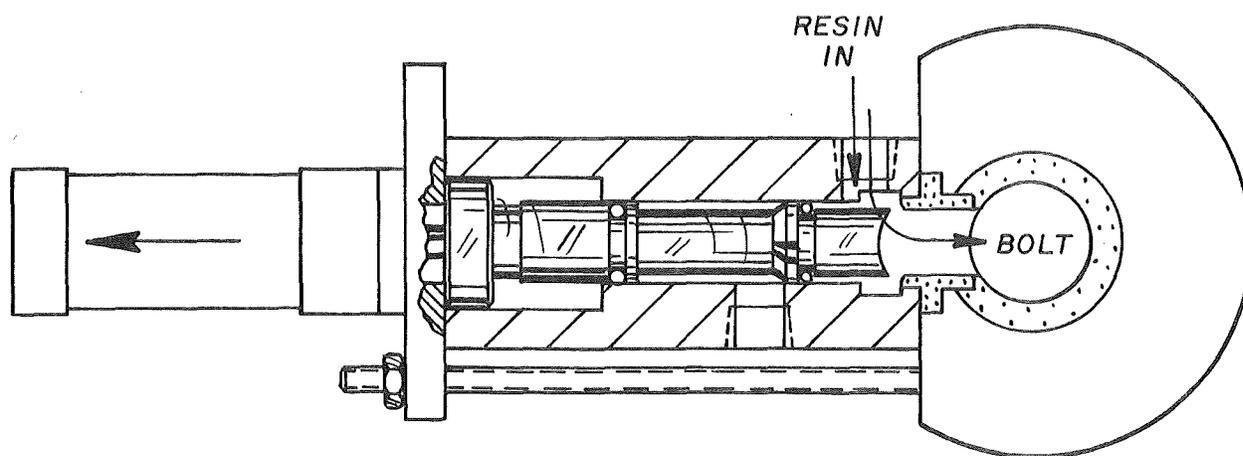
Figure 33



BOLT INJECTION HEAD
Figure 34



PURGE POSITION



INJECTION POSITION

HEAD VALVE
Figure 35

1. Improving the vent tube/roving seal. (This seal is shown in Figure 34.)
2. Changing the bolting sequence so that pumping occurs after vent tube and roving are fully inserted, rather than pumping during insertion.
3. Raising seal actuation force to 500 pounds.

Head Valve

The head valve is shown in Figure 35. It is a combination spool/poppet valve, hydraulically actuated. It admits the activated resin mix to the roof for the ultimate formation of a bolt.

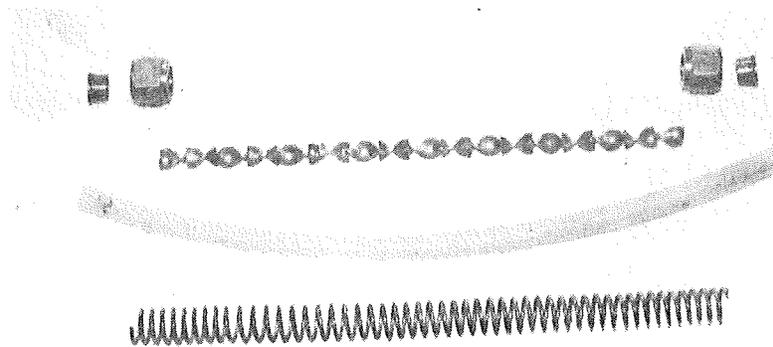
Roving Seal

The roving seal, shown in Figure 34, serves the very important function of, upon injection, closing off the opening through which the roving travels. It consists of an outer conical and ring-shaped seat, the guide cone and an inner conical silicone rubber seal. On closure, the rubber seal presses against inner conical surface of the cone actuated upwards by an air cylinder.

Static Mixer

The static mixer, Figure 36, consists of a series of vanes that split and mix the flow of fluid as it travels through a tube.

The tube is of transparent plastic material which is removed and replaced if and when mechanical cleaning of the mixing vanes is required. This is an important feature since the mixer by definition is subject to hardening and lodging of the mixed catalyzing resin.



STATIC MIXER
Figure 36

Roof Seal

The roof seal provides sealing to both smooth and rough roofs.

The hardness of the rubber and the depth of the seal ring must be matched to the degree of roughness in the roof encountered. The rougher the roof, the deeper and softer should be the seal.

On extremely rough surfaces or in conjunction with mesh, wood blocks, or mats a seal can be effected if a ring of crushable foam is placed on top of the mat or block as shown in Figure 37.

Cut Off Saw

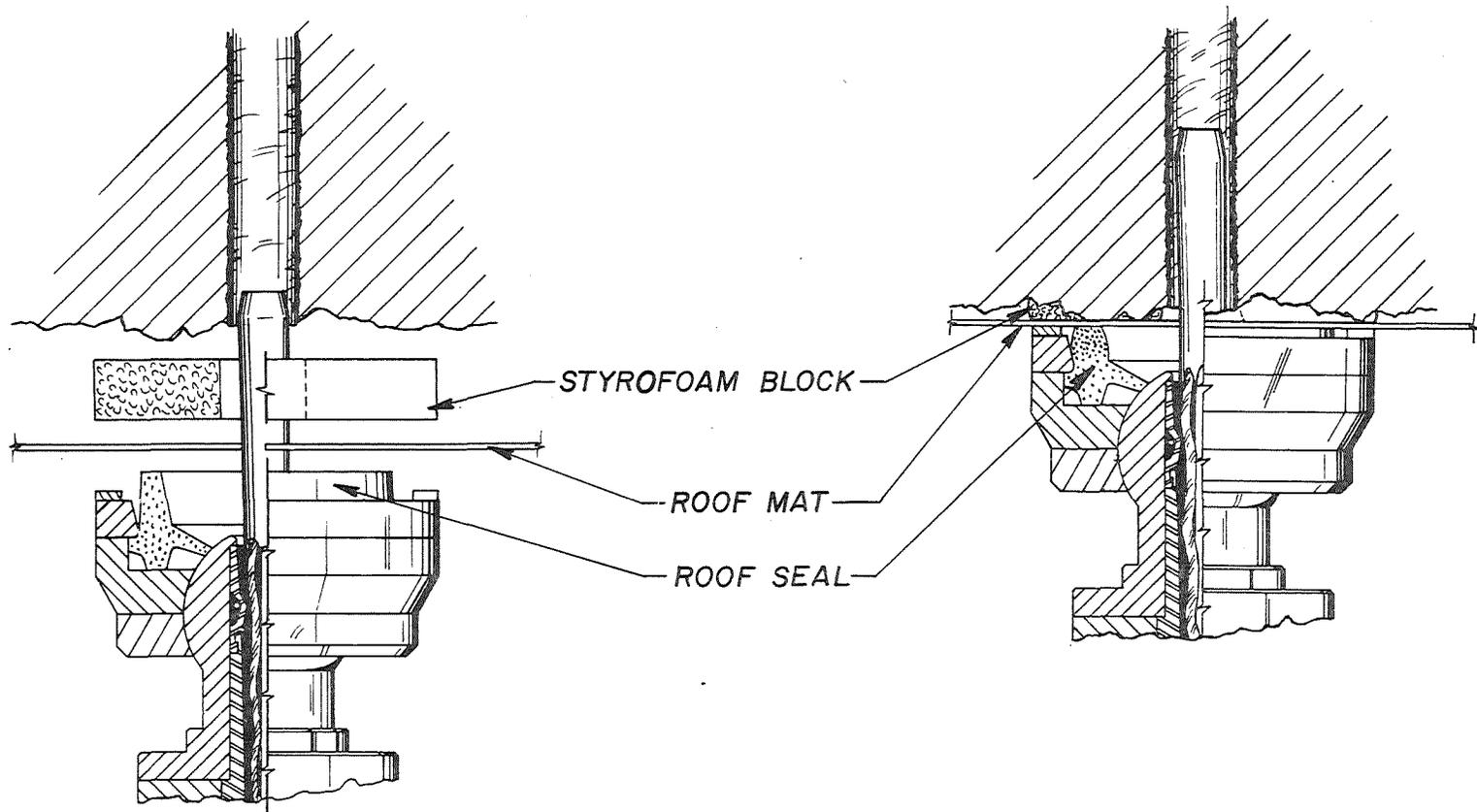
The Cut Off Saw is shown in Figure 38. It functions to cut the cured bolt from the stub remaining in the Bolt Injection Head. It consists of an air powered reciprocating commercial saw unit mounted on a swing arm hydraulically actuated and manually controlled from the operators cab.

Control System

Due to the necessity of maintaining exact sequences and time periods while injecting resin and also because of the large number of associated devices which must be controlled rapidly, a system was devised to automatically control the entire injection process. The control system, including limit switches, is entirely pneumatic and inherently safe for use in explosive atmospheres.

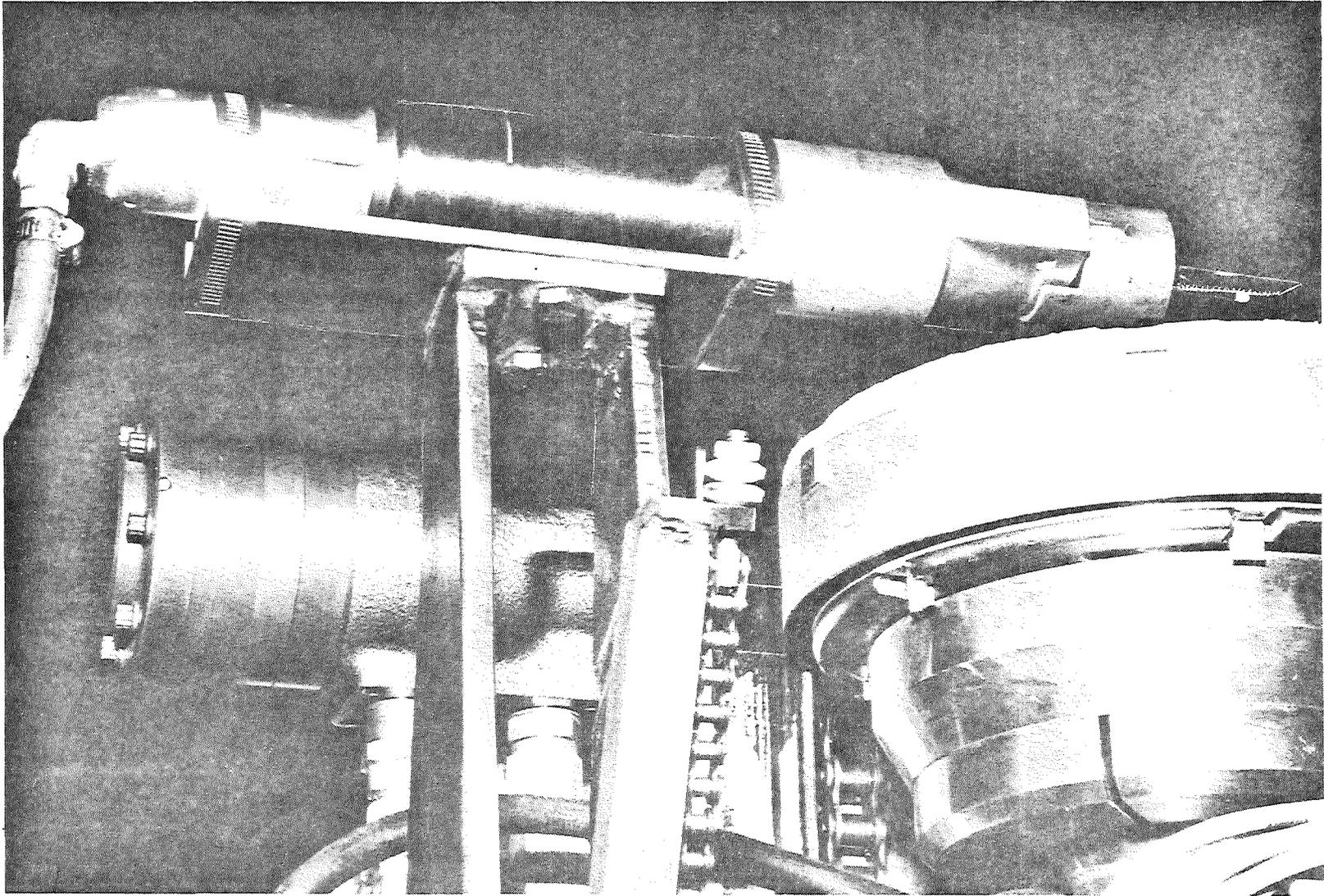
This system is shown in Figure 39. The following signals and control actions complete one bolt injection cycle:

1. Operator pushes start button, red "light" goes off.
2. Green "light" goes on - system has successfully initiated the cycle.
3. Green "light" goes off - injection complete.
4. Purging and curing continue automatically.
5. At the end of the cure cycle, the head of the machine drops automatically exposing the new bolt, which is still connected, umbilically, to the machine.
6. Operator pushes "cut" button which causes a saw to cut off the bolt.

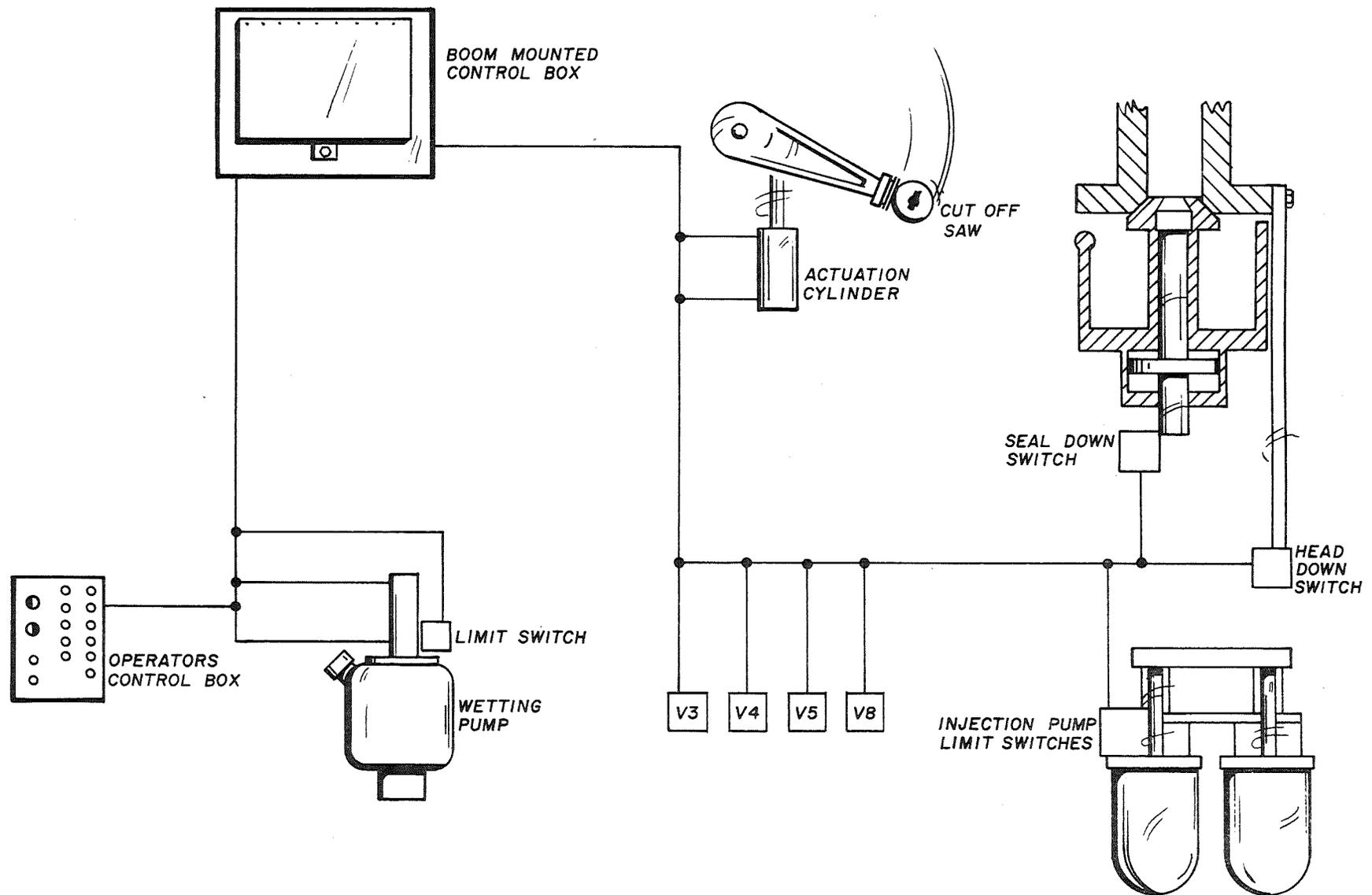


BOLT FORMING ROOF SEAL USED WITH MAT
(SHOWN), MESH OR COTTONWOOD BLOCK

Figure 37



BOLT CUT OFF SAW
Figure 38



CONTROL SYSTEM
Figure 39

7. Operator withdraws machine and presses "reset" button. Red light goes on.

The operator can terminate the cycle at any time by pressing the reset button.

The pneumatic control system is located as shown in Figure 40 and consists of:

1. Operator's control box mounted near operator station (see Figure 40).
2. Control logic circuitry, housed in a box mounted on the boom (see Figure 40).
3. Limit switches located on associated components:
 - Wetting fluid pump upswitch.
 - Wetting fluid pump downswitch.
 - Bolting head downswitch.
 - Roving seal downswitch.
 - Injection pump upswitch.
 - Injection pump downswitch

Operator's Control Box (See Figure 41)

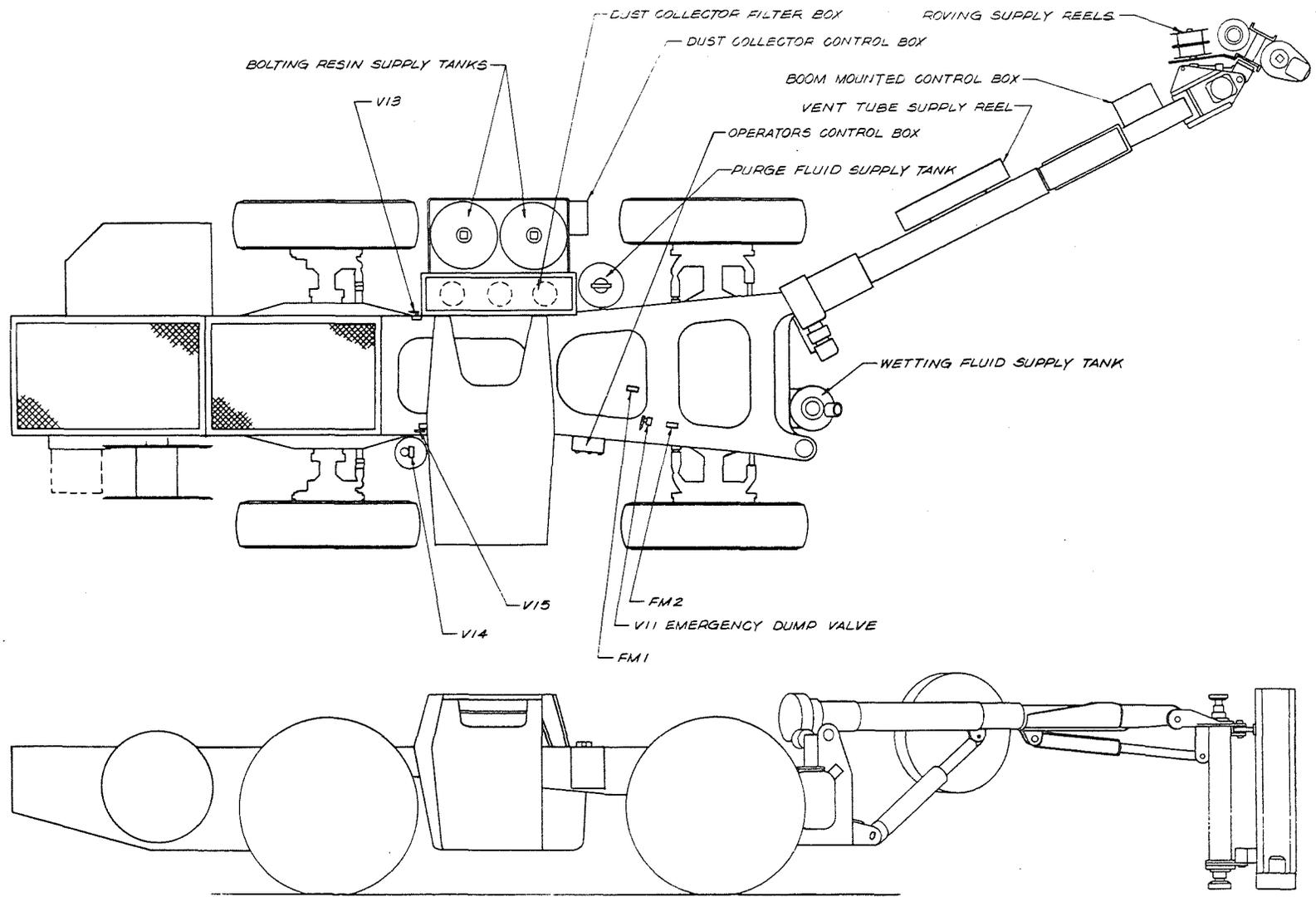
The machine can be operated either manually or automatically. In the automatic mode, the various machine functions occur in a controlled sequence. In the manual mode, each function can be individually controlled. The controls are as follows:

The purge push-buttons operate the purge shut-off valve to "on" or "off".

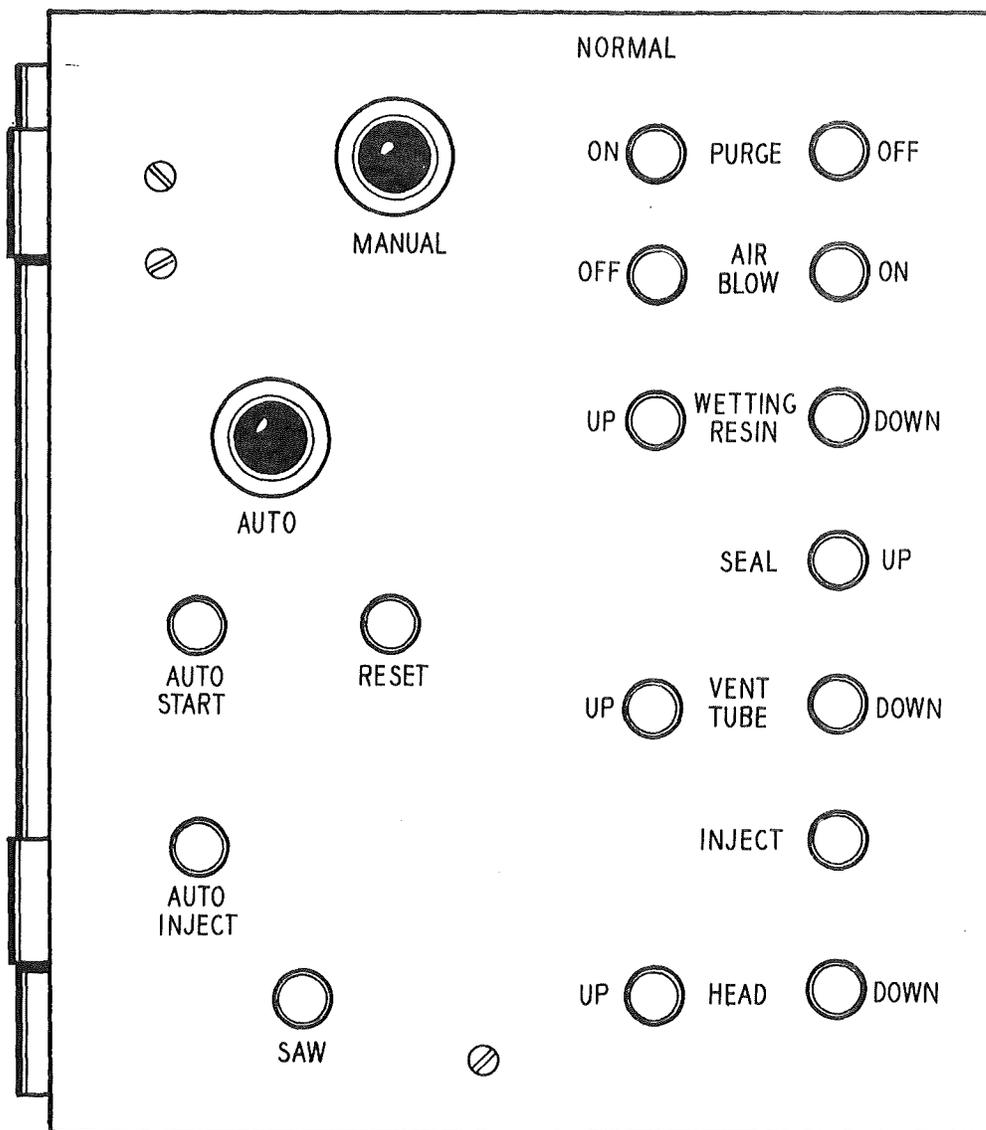
The airblow push buttons operate the airblow valve which blows purge fluid out of the mixed polymer circuit prior to injection. Positions are "on" or "off".

The wetting push-buttons operate the wetting resin pump, advancing wetting resin to the wetting chamber in "down" position or retrieving it to the storage tank in "up" position.

The seal push-button operates the roving seal, to set it for or to release it from closure around the roving.



CONTROL SYSTEM COMPONENT LOCATIONS
Figure 40



OPERATOR'S CONTROL BOX

Figure 41

The vent tube push-buttons operate the vent tube drive either up or down.

The manual inject button, shifts the six-way mixing valve to polymer inject position, the head valve to bolt position and actuates the injection pump.

The head push-buttons operate the bolting head up/down actuator. The head will stay in either position.

The reset button will return all functions to the normal position, i.e.,

Purge Valve	- open
Airblow Valve	- closed
Wetting Fluid Pump	- up

This button must be pressed before bolting operation is commenced. The red light comes on when the reset button is pressed.

The auto-start button initiates the automatic cycle. This isolates the individual function push-buttons, described above, so they are inoperative.

Before the auto-start button will function, three conditions have to be met. If these conditions are met the green light will come "on" and the automatic cycle will commence.

These conditions are:

1. Wetting fluid pump must be "up". This condition is met when the "up" limit switch on the wetting fluid pump is actuated.
2. Polymer injection pump must be "up" or "filled". This condition is met when the plunger plate on the injection pump is "up" and the limit switch is actuated.
3. Bolting head must be "up". This condition is met when the bolting head down limit switch is de-actuated.

The inject push button is inoperative except when the system is in automatic and then only during the period when the vent tube drive is on. It is used to complete the automatic cycle after the vent tube drive has driven the wetted roving to the end or top of the drilled hole. The proper time to push this button is determined by the operator. When the vent tube has

reached the end of the hole and the vent tube drive will either stop or run at a higher no-load speed. This condition is indicated by the sound of the vent tube drive motor.

The saw push-button actuates the cut-off saw. After the automatic cycle is complete and the bolting head has come down a stem of polymerized bolt is exposed below the bolt head. The saw push-button is then held down until the saw has cut through the exposed stem. This button is then released and the saw stops and retracts to its stowed position.

The functions that occur during the automatic cycle are as follows: (References are made to Figure 42):
Initial assumptions:

1. Polymer tanks are full.
2. Solvent tank is full.
3. Wetting fluid tank is filled.
4. Solvent is circulating as indicated by flow indicators FM1 and FM2.
5. Vent tube is in place.
6. Roving is treaded through wetting chamber and attached to vent tube.
7. Jack leg is set.
8. Hole has been drilled and the turret has been indexed to bolt position.
9. The head has been positioned "up" and the roof seal has been pressed against the roof.
10. Vent tube has been operated and is free to be driven up the hole.

A. Press Reset push button

1. Operation
 - a. Opens purge valve.
 - b. Closes air blow valve.
 - c. Raises wetting fluid pump.
 - d. Turns red light "on".

B. Press Auto Start push button.

1. Conditions for operation.

- a. Wetting pump "up".
- b. Polymer injection pump "up".
- c. Bolting head "up".

2. Operation.

- a. Starts wetting pump "down". The wetting pump is deliberately made to operate slowly (15-25 seconds) to give the air blow timer a chance to provide a good air blow. This is done by adjusting V19 (Figure 42) to achieve desired time.
- b. Closes Purge Valve (V3 Figure 42).
- c. Opens air blow valve (V4 Figure 42). This valve stays open until a timer turns it off. The timer for this is located in boom mounted control box.
- d. Air blow valve turns "off".
- e. Roving drive starts. This is initiated by the wetting fluid pump reaching the end of its stroke.
- f. Wetting fluid pump starts up. This is made to be deliberately slow by adjusting V18 (figure 42).

When the vent tube/roving reaches the end of the drilled hole, the drill motor either stops or changes to a fast speed which is noted by the operator. He then proceeds to the next step.

C. Press Inject push button.

1. Operation.

- a. Shuts off roving drive motor.
- b. Closes roving seal.
- c. V5 shifts which actuates V1, V2 and starts injection pump down.

- d. Injection pump then hits a limit switch in a preselected location which determines the length of bolt. This switch initiates the following events.
- e. V5 shifts returning V1, V2 to the purge positions.
- f. Purge valve (V3) opens allowing solvent to purge V2, V1, static mixer and connecting lines.
- g. Cure cycle timer starts, (located in boom mounted control box). When the timer runs out, the following events occur:
- h. The roving seal drops freeing the vent tube.
- i. After a short time delay to allow the roving seal to drop, the bolting head drops exposing the cured bolt stud which is ready for cut-off. This completes the automatic cycle.

Component Nomenclature (See Figure 42)

FM1 - An inline flow meter/sight gauge:

This one indicates flow in the primary solvent circuit, i.e., circulation between pump and tank.

FM2 - Same device as FM1. Indicates solvent circulation through head valve (V2), mixer, and mixing valve (V1).

R1 - This is a fixed restriction placed to insure flow in primary solvent circuit even when secondary solvent circuit is closed as in polymer injection mode.

V1 - Six way mixing valve. This valve is a minimum waste, sliding plate type valve. It has two hydraulic operators and is easily disassembled for cleaning.

V2 - This is the head valve, mounted on the bolt forming head.

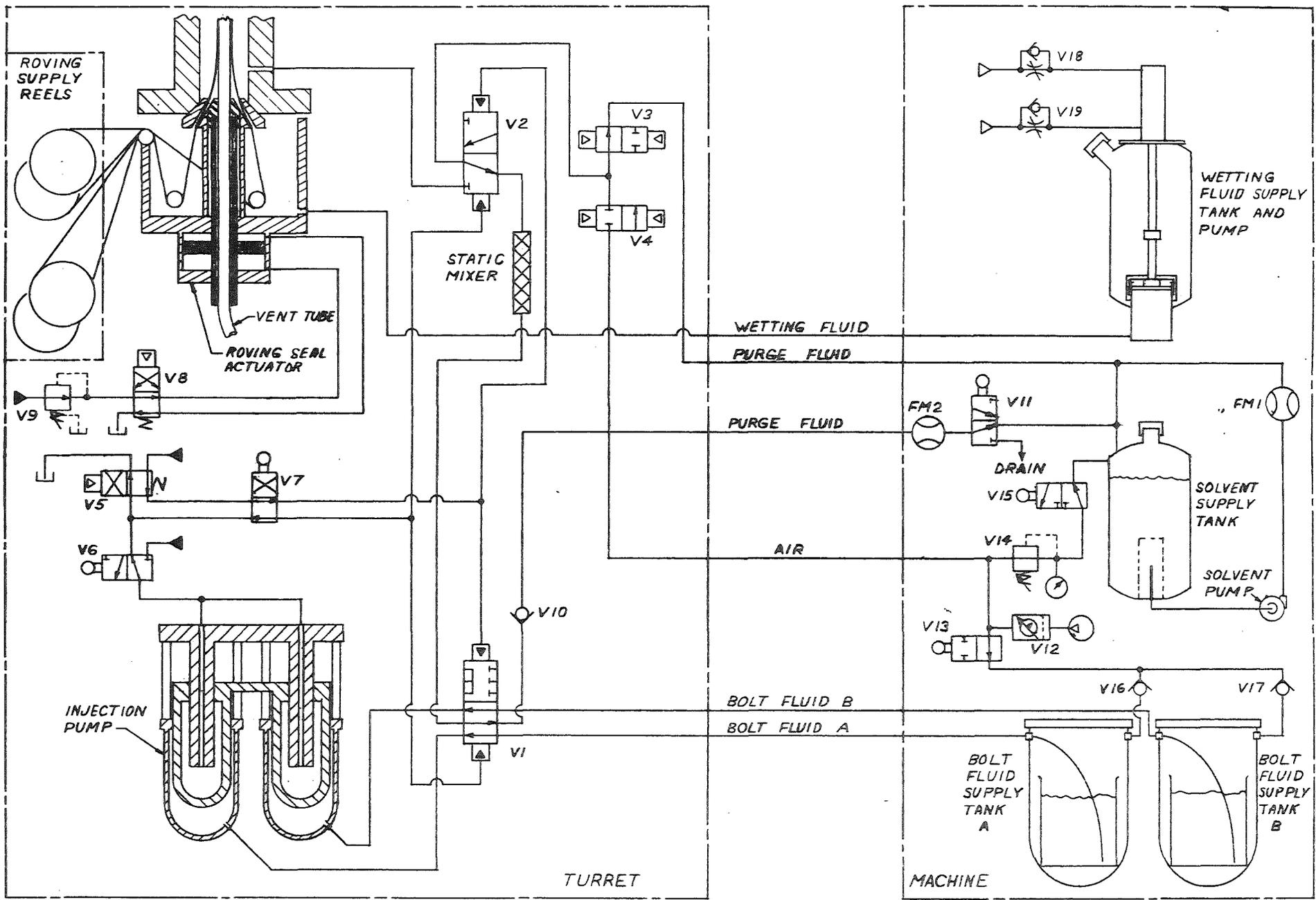
V3 - Solvent shut-off valve. This is a ball valve with a pneumatic actuator. It is controlled by the automatic control circuit.

V4 - Air-blow valve. Same type valve as V3.

V5 - This is a double acting four way pneumatically

operated, hydraulic valve. In the automatic mode this valve operates the injection pump; mixing valve (V1), and head valve (V2). It is operated by the automatic control circuit.

- V6 - This is a mechanically operated three way valve. It actuates the polymer injection pump for check-out and cleaning.
- V7 - This is a mechanically operated four way valve. It operates the mixing valve (V1) and head valve (V2) for check-out and trouble shooting purposes.
- V8 - Roving seal valve. This is a single acting, spring returned, three way, pneumatically operated, hydraulic valve. This valve operates a hollow shaft, double acting, hydraulic cylinder which closes the roving seal. The operator is controlled by the automatic control circuit.
- V9 - Pressure reducing valve. This valve controls the amount of force applied to the roving seal.
- V10 - Large capacity, gravity type, check valve to prevent solvent from flowing backwards.
- V11 - Emergency dump valve. Mechanically operated three way valve near operators station. In case of power failure during injection cycle this valve, opened, allows the remaining air pressure on the machine to purge the mixed polymer circuit.
- V12 - V12 indicates a filter, regulator, lubricator combination. This treats the air immediately after the compressor.
- V13 - A hand operated on/off valve shuts off air pressure to polymer supply tanks.
- V14 - This is a small pressure regulator controlling pressure to top of solvent supply tank.
- V15 - A mechanically operated three way valve. Turns air pressure on and off the solvent supply tank.
- V16, V17 - Check Valves to prevent vapors from mixing from polymer supply tank A and B.
- V18, V19 - These are flow control valves. They control the wetting fluid pumping rate.



PUMPABLE BOLT PROCESS FLOW DIAGRAM

Figure 42

Bolting Turret

The Bolting Turret facilitates proper alignment of the bolting head directly under the drilled hole. It will drill and then position the bolt injection head for installation of the pumpable bolt.

The rotary drill and the bolt injection head are mounted on colinear slides in one assembly with their thrust devices. This assembly is mounted on a pivot which is designed to allow the drill and bolting slides to be indexed or turreted from the drilling position (Figure 43) to the bolting position (Figure 44) thus providing accurate injection head alignment.

Drill

The drill design as a normal part of the Pumpable Bolt Machine is a conventional hydraulically powered rotary drill with chain feed.

Dust Suppression

The dust collection system is shown in Figure 45.

The drill on the Pumpable Bolt Machine does not allow evacuation through the drill steel. Instead, an auger type drill steel is used and drill chips and dust are collected at the roof or bottom of the drilled hole, by the relatively large air flow of 375 CFM. Because of this large air flow, a conventional roof bolter bag type collector cannot be used. Instead, a self-cleaning filter system was used consisting of a vacuum blower pulling air through a set of filters cleaned by a short blast of air which dislodges the cake of dust from the outside of the filter. This cake then falls to the bottom of the hopper. There are three filters and they are cleaned sequentially so there is no interruption of the dust suppression process.

The filter tank is emptied by opening the bottom of the hopper. This must be done while the vacuum system is turned off.

This system was tested and approved by MESA, #25B-214, for coal mine use, and given approval number 25B-214.

Resin System

The resin system initially used in this program was developed by Brookhaven National Laboratories. See Bibliography. (See Table 1)

Resin Formulation

The components of the bolt resin and their function are listed below:

Hetron 197 F Polyester
(Basic Resin, Contains Chlorine for Fire Retardancy)

Chlorostyrene Monomer
(Liquid Carrier for Resin)

Polystyrene Pellets
(To control shrinkage)

Glass Beads
(Filler to reduce cost, reduce creep and aid to transfer load from rock to roving)

Cabosil - Fumed Silica Thickener
(Controls viscosity and keeps glass in suspension)

Hydroquinone
(Inhibitor to improve shelf life)

Lupersol DSW
(Catalyst - to promote formation of free radicals, which in turn cause crosslinking)

Dimethyl Analine
(Promoter, used to adjust gel time at different temperatures and to improve pot life of catalyzed resin--less catalyst required)

Cobalt Naphthanate
(Promoter, see Dimethyl Analine)

Solvent Trichloroethane
For safety--No explosive mixtures at Std. Conditions

SP.G of Recipe originally 1.3 with 45% Glass Beads
1.45 to 1.50 Roving Weighs .25 lb. per ft. of bolt.

The so-called milled glass is fiberglass chopped into short pieces, about 1/32 inch in length. This type of filler improves the physical properties of the cured system but is difficult to pump, is abrasive and builds up in machine components such as valves. Since this caused repeated difficulties in machine operation during the shop tests, the chopped glass filler was discontinued and replaced with a glass filler in the form of micron sized spheres.

The pumping and flow qualities of the overall mixture improved so drastically with this change that it was possible to increase the amount of filler from its

original 16% to 35% of total mix, thereby substantially also reducing the cost of the mixture.

The bolting fluid formulated as previously described worked well in laboratory tests and while pumping test bolts in the shop. In the field difficulties were encountered, however, in producing high quality bolts.

Since the program described in this report was directed at proving the pumpable bolt concept, the bolting fluid chemistry was not investigated. Consequently, the following statements are generalizations only, drawn from observations and experiences in applying the bolting fluid.

In its present form, the bolting fluid cannot be pumped without addition of heat when ambient temperature is below 40°F.

Many factors appear to influence the behavior of the bolting fluid. Among them are age and storage temperature, contaminants (metals and metallic oxides primarily) mixing procedures as well as quality of the ingredients as delivered from the producer.

The presence of ground moisture slows or prevents complete cure of the resin.

During the contract, Hooker Chemical Corporation discontinued Hetron 197F and substituted Hetron 197G. According to Hooker, this is a change only in form and not formulation. Hetron 197F is a flake about 1/6 inch thick and about 1/2 inch irregular diameter. Hetron 197G is a ground granule. Mixing time was reduced considerably by this change.

The following then, is the basic bolting fluid formulation used in the mine installation.

Monochlorostyrene	28.5%
Hetron 197G	22.8%
Polystyrene Pellets	11.4%
Silane	1.5%
Glass Spheres - Size 3000	35.0%
Cabosil	0.8%
Hydroquinone	10 ppm

Promoted resin (Resin A) is obtained by adding 0.8% dimethyle analine and 0.8% cobalt naphthenate to a

quantity of basic bolting fluid. The catalyst used here is USP240.

The mixing procedure recommended by USBM for this formulation is as follows:

1. Add inhibitor to Monomer.
2. Split Monomer into two equal parts.
3. Add Hetron to one part.
 - a. Add slowly.
 - b. Mix with high shear mixer 1200-1800 RPM.
 - c. Do not exceed 120°F.
4. Add Polystyrene to other part of Monomer.
 - a. Add slowly.
 - b. Mix with high shear mixer 1200-1800 RPM.
 - c. Do not exceed 120°F.
5. Recombine and mix.
6. Add Silane.
7. Add glass slowly.
 - a. Do not exceed 120°F.
8. Add Cabosil slowly.
 - a. Do not exceed 120°F.

NOTE: High shear mixer to be approximately 1/3 the diameter of the container.

<u>Component "A" (Promoted resin)</u>	<u>Weight %</u>
Hetron 197F polyester flakes (Hooker Chemical)	29.0
Polystyrene pellets (expansion agent)	14.5
Chlorostyrene monomer	36.5
Milled glass (filler)	16.4
A-174 Silane (coupling agent by Union Carbide)	1.9
Cabosil (Fumed silica thickener)	0.5
Hydraquinone (inhibitor)	40 ppm
Dimethyl Aniline (promoter)	0.4
Cobalt Napthenate (promoter)	0.8
	<u>100.0</u>

<u>Component "B" (catalyzed resin)</u>	
Hetron 197F Polyester Flakes	29.0
Polystyrene Pellets	14.4 (1)
Chlorostyrene Monomer	36.5
Milled glass	16.3
A-174 Silane	1.9
Cabosil	0.5
Hydroquinone (2)	40 ppm
Lupersol DSW (Catalyst by Penwalt)	1.4
	<u>100.0</u>

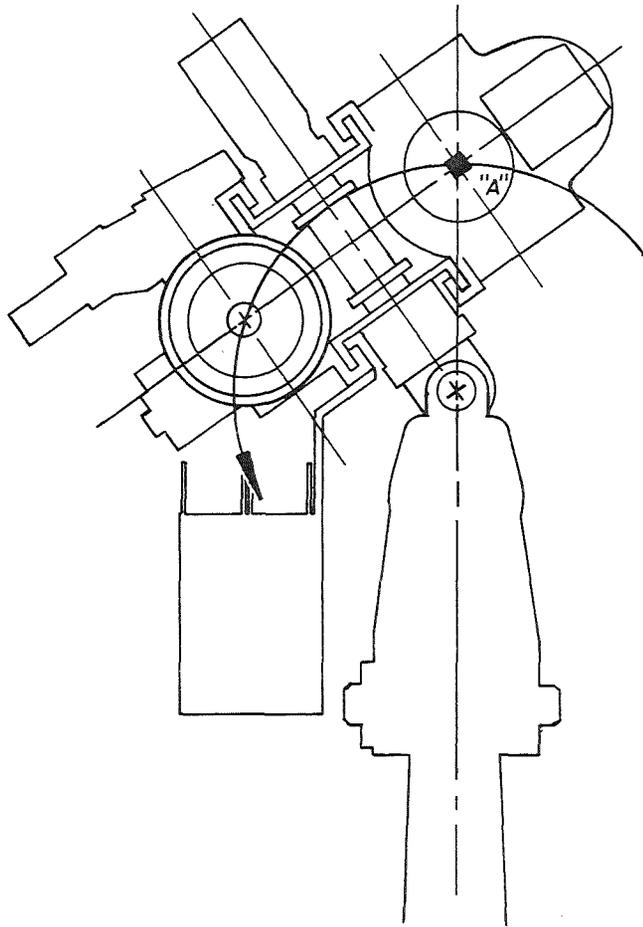
<u>Wetting Resin</u>	
Hetron 197F polyester flakes	48.3 (1)
Chlorostyrene monomer	48.3
A-174 Silane	1.9
Hydroquinone (2)	40 ppm
Lupersol	1.5
	<u>100.0</u>

¹Percentage may be varied 5% to adjust viscosity.

²Lupersol DSW should be added to resin batch as near as possible to the time of use.

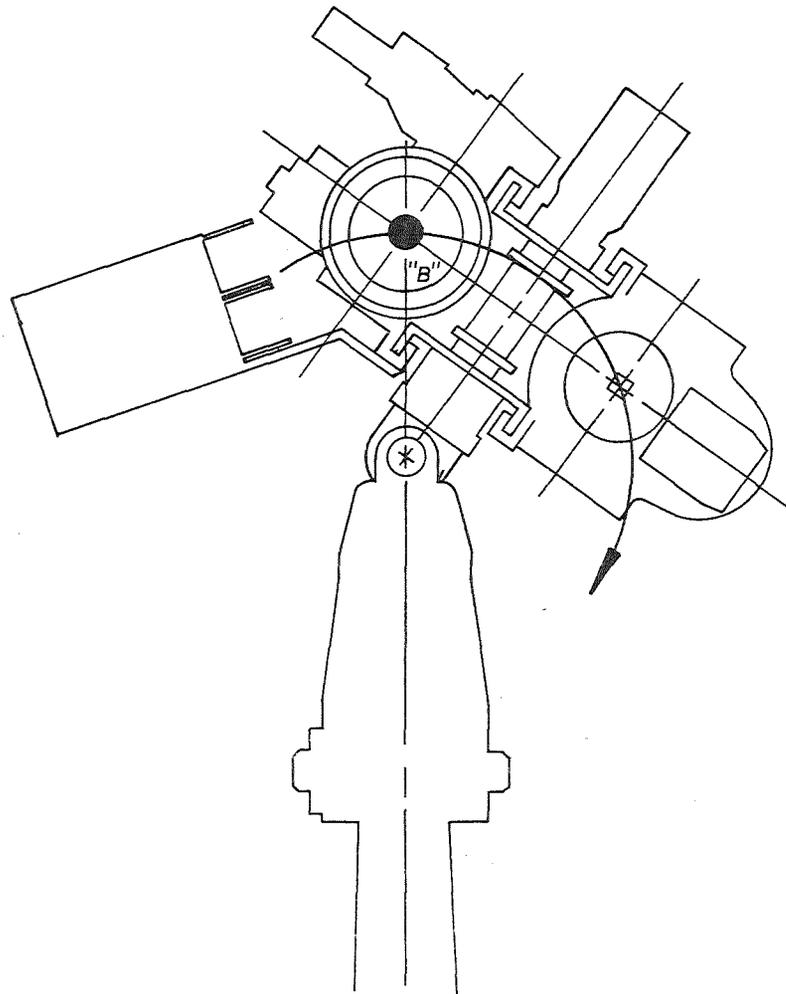
Pumpable Bolt Formulation

Table 1



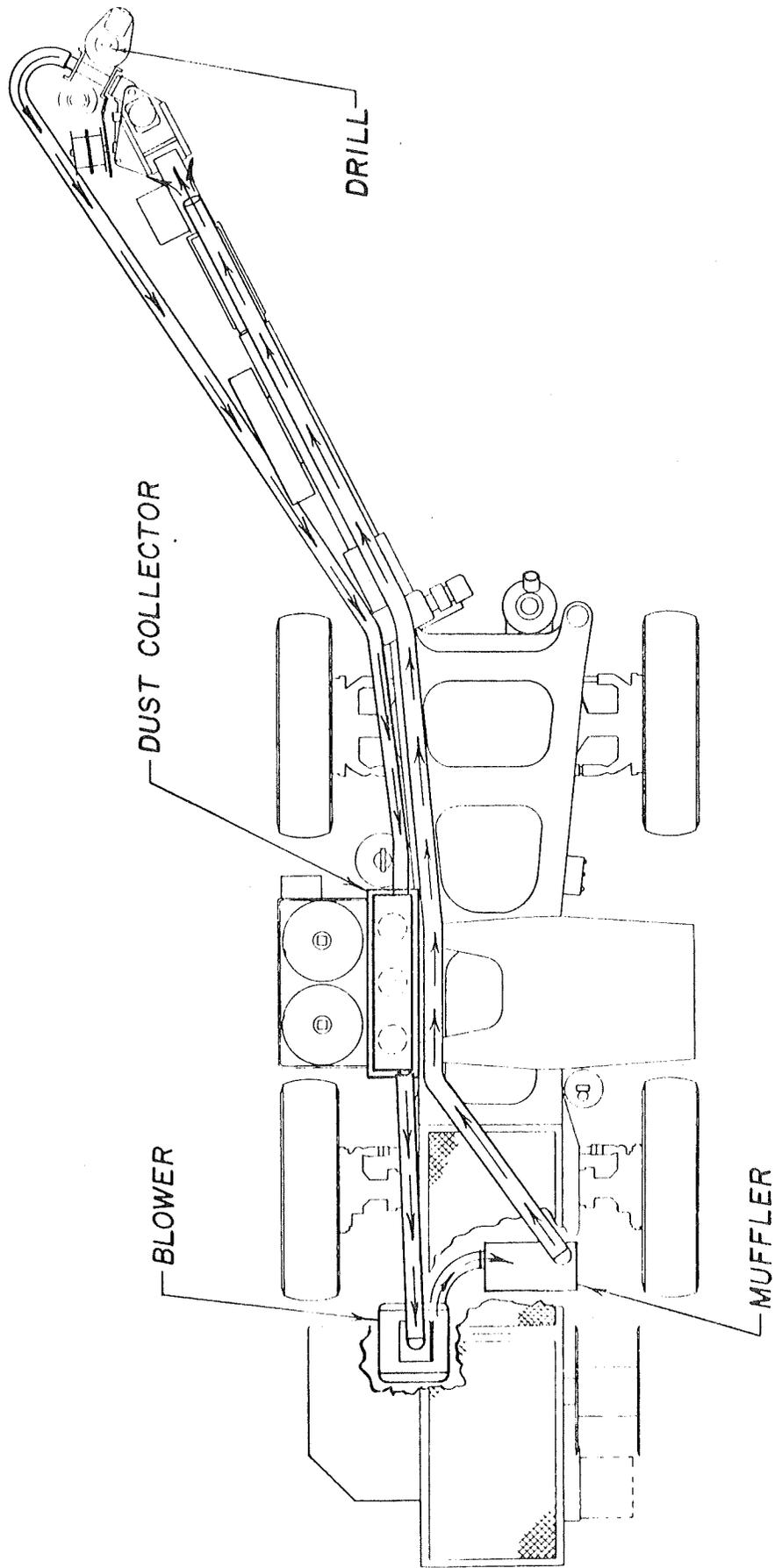
"A." DRILL IN DRILLING POSITION

Figure 43



"B." PUMPING HEAD IN BOLT INJECTION POSITION.

Figure 44



DUST COLLECTION SYSTEM

Figure 45

SHOP TESTS

Tests were conducted in the shop before taking the machine to the mine.

Water was used to check resin and control circuits and mechanisms. Following this initial functional check, resin was pumped into glass tubes to form complete simulated bolts. Drilling and dust collection system checks were performed in rock slab and finally bolts were pumped into the rock slab mounted on an overhead stand.

Results of Shop Tests

Control and Resin Circuits

Plumbing to dump purged resin into waste tanks was eliminated since the time required to wash out the main body of resin to be purged was found to be highly variable from bolt to bolt.

Valves

Most resin valves plugged frequently and were redesigned or replaced.

Valves must not have elastomeric seals or seats.

Stainless steel and polyethylene are particularly suitable materials.

Roving Seal

The development of a functional seal at the point where the roving and vent tube enters the resin filled bolt forming head continued through the shop test period and well into the mine installation period.

At this time attempts were made to make the roving seal work in a pumping sequence calling for simultaneous injection of roving and resin. This proved very difficult. In spite of many design refinements, a functional roving seal resulted only after "simultaneous" injection was abandoned in favor of insertion first of roving, complete closing of roving seal and pumping only after complete closure of this seal.

The roving seal is made of molded silicone rubber. During "simultaneous" injection, it is severely abraded and cut by

the roving since, under this system the seal has to squeeze the roving hard to form a seal against the resin pressure.

In its final form, the Roving Seal is shown in Figure 7. In this form and with "simultaneous" injection, it has an approximate life of 100 bolts.

Vent Tube

The vent tube is pictured in Figure 31. Chlorinated Polyvinyl Chloride was selected during the shop trials as the most suitable material after a lengthy process of selection in which most other commercially available plastics were tried.

In earlier tests, metal tubes were ruled out because of stiffness and difficulty in obtaining sufficient drive roller friction on metals.

Vent Tube Drive

The vent tube drive shown in Figure 31, was equipped with a torque limiting clutch designed to signal the completion of vent tube insertion as the leading section of the vent tube hits the end of the bolt hole in the roof. The torque limiting clutch proved to be unreliable as loads due to roving tension through the wetting system varied considerably. This torque reaction arm type of sensor likewise proved insufficiently reliable. This function was, therefore, returned to manual operator control.

The drive rollers of the vent tube drive have to grip and propel the vent tube against the resistance of the roving. A larger resistance develops in the case of "simultaneous" injection than if pushing of the roving takes place with an open roving seal, another argument against "simultaneous" injection.

During the shop trials, it was found necessary to provide the rollers with cut teeth and an increased spring load to increase the grip around the vent tube for a sufficient ultimate driving force.

Hose Material

The shop trials quickly pointed to the importance of proper selection of hose carrying resins and solvents.

Most commercial hose quickly softens under the influence of either resin or solvent and bursts under the influence of the respective operating pressures. The injection pump can deliver 300 psi and the supply system 100 psi.

Table 2, lists various hose types and their evaluation.

MATERIAL AND TYPE OF HOSE	EVALUATION
Teflon with braided covering	Too expensive to replace.
Clear unreinforced vinyl.	Swells and bursts under pressure. Incompatible with solvent.
Clear reinforced vinyl.	Swells and separates from braid. Incompatible with solvent.
Vinyl water hose.	Swells and bursts. Incompatible with solvent.
Braid reinforced vinyl water hose.	Swells and separates from braid then bursts.
Nylon pressure hose.	Swells slightly. Not flexible enough.
Neoprene hoses.	Swells and bursts.
Latex hoses.	Swells and bursts. Compatible with both resin and solvent.
Polyethylene and polypropylene.	Will burst under high temperature (120°C) and high pressure (100 PSI) but can be reinforced.

Table 2

In the course of the shop trials it became evident that premature polymerization of the resins must be expected from time to time. The hoses must then be replaced, therefore the cost of the hose used in this system should be low.

Braided Teflon hose is satisfactory but should be used only in lines where replacement is infrequent. Unreinforced polyethylene hose is compatible with resin and solvents and is inexpensive, but cannot resist system pressures.

This type of hose was chosen as major hose material after reinforcement was accomplished by the external application of a spiral wire.

Only metal suitable as a conduit for the resin is Stainless Steel. Copper, brass, mild steel, cadmium or zinc plated tubing or fittings promote resin polymerization and are unsuitable.

Material Selection

The following summarizes what was learned in relation to material compatibility during the course of shop testing period.

Stainless Steel is the best metal for use in contact with the resins and solvents.

Carbon Steel is good but the oxides appear to have a catalytic effect on the bolting resin.

Brass, Copper, Cadmium, and Zinc all appear to have a catalytic effect on the bolting resins.

Teflon^R is a good material for liquid resins and solvent and was used as hose liners in the solvent and bolting resin circuits. However, if the resins were allowed to polymerize in contact with teflon, severe sticking resulted. Therefore, it became necessary to abandon its use in the bolt forming head.

Vinyl - (Flexible polyvinyl-chloride) - swells badly in contact with solvent or bolting fluid.

Urethane, Buna-N, Neoprene is unsatisfactory because of swelling.

Polyethylene and Polypropylene both have excellent resistance to solvent and bolting fluid. Used in the bolt forming head and where a semi-rigid plastic can be used in components. The polymer supply lines are polyethylene reinforced with a wire coil applied to the outside of the hose.

FIELD INSTALLATION OF PUMPABLE BOLTS

Introduction

Under this program, 6-700 bolts were to be installed in each of two mines. The installation was to proceed in parallel with two adjacent entries bolted conventionally. By instrumenting each entry for convergence, roof sag and separation, the effectiveness of the pumpable bolt was to be compared with that of conventional bolts. The planned test installation is shown in Figure 46.

A total of about 200 Pumpable Bolts were actually installed in two mines in the western United States. The number of bolts installed was limited by the extremely difficult roof conditions which developed in both mines during the pumpable bolt installation.

A total of sixteen mines were visited in an attempt to select mines suited for a meaningful evaluation of the pumpable bolt. Two mines were selected. They are:

Carbon Fuel Company (Now Braztah Corp.)
No. 3 Mine
Martin, Utah

Energy Development Company
Vanguard No. 3 Mine
Hanna, Wyoming

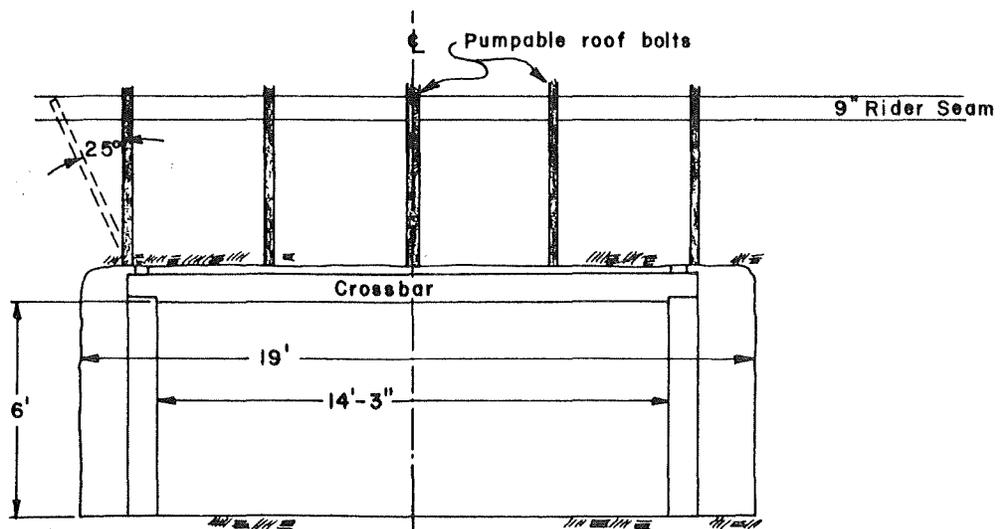
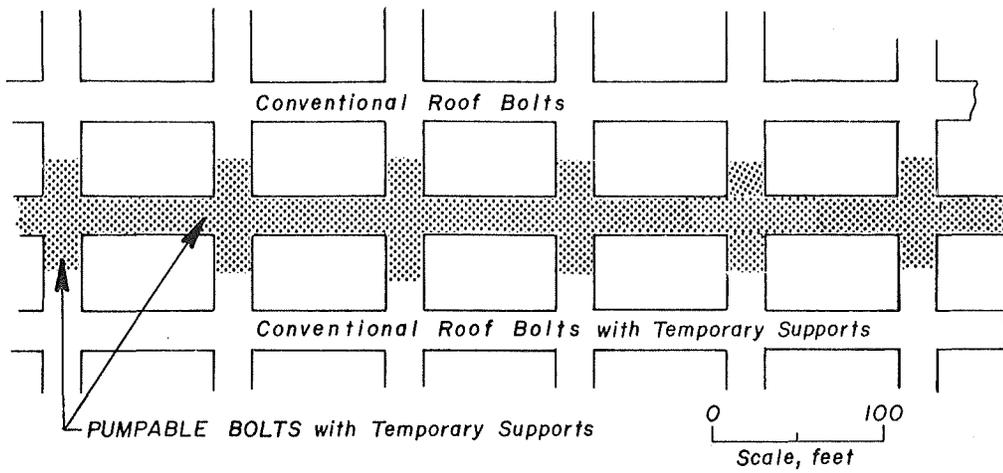
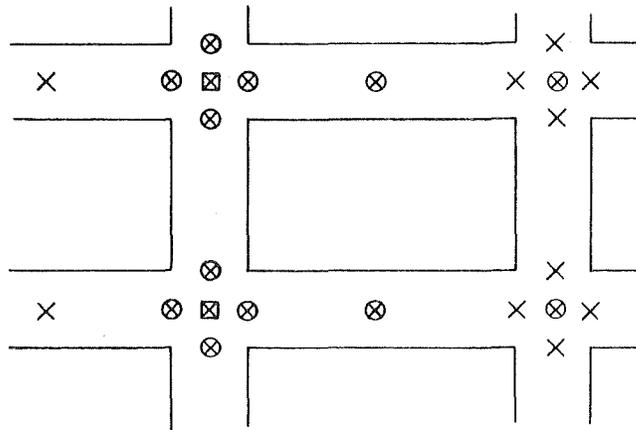
Installation at Carbon Fuel

Mine Description

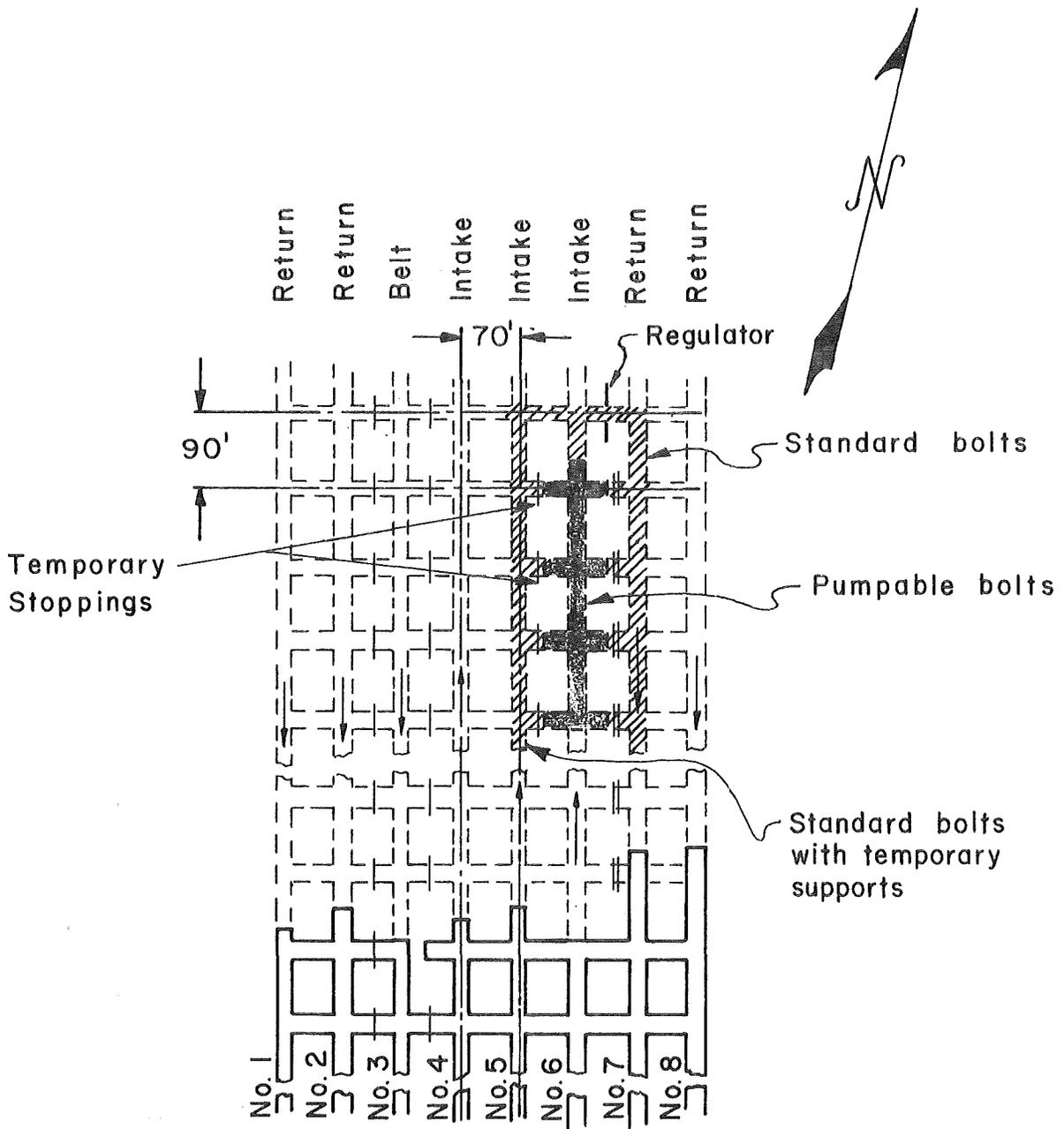
The coal seam has a limestone shale roof, a sandstone floor and dips about 8 degrees. Seam is 4 to 7 feet thick and is dry in most areas. Mining is by room and pillar method with continuous miners. Standard roof support consists of roof bolts on 4 to 5 foot centers and a row of props on one side spaced on 5 foot centers. Roof bolts are 4 to 6 feet in length. Roof rock is hard, requiring percussive drilling. Air and rock temperatures range between 15 and 21 degrees C.

The test site was the Main North Entry #7 near the 85th cross-cut and is shown in Figure 47.

- × Sag and convergence
- ⊗ Air test 60
- ⊠ Bed separation test



PUMPABLE BOLT TEST INSTALLATION PLAN
Figure 46



MAIN NORTH ENTRIES
Scale 1" = 200'

CARBON FUEL COMPANY No. 3 MINE
BRAZTAH CORP.

PUMPABLE BOLT TEST SITE

Figure 47

Results at Carbon Fuel

Thirty-seven bolts were installed at the active face, in both fairly good and badly fractured roof rock. All bolts are sound and solidly anchored as shown in Figures 48 and 49 although, in the badly fractured zone, rock slabs peeling away from the roof broke some boltheads.

Because of severe and rapid deterioration of roof conditions in this mining district, the test installation of pumpable bolts at Carbon Fuel was terminated after 37 bolts were installed. Figure 50 illustrates the severe fracturing of the roof being supported.

Six fourteen inch long bolts were installed to determine any difference in pullout strength between bolts pumped into holes made with dry and with wet drilling. No difference was discernable. These six bolts resisted a pull of 10,000 lbs.

The Pumpable Bolt Machine functioned well except that at the beginning of this test phase, severe leakage occurred at the Roving Seal. The pumping sequence was then simultaneous injection of roving, vent tube and bolt fluid. When this sequence was changed to first insertion of roving and vent tube, then closing the roving seal fully and finally pumping bolt fluid, no further leakage occurred.

Because of the severity of the roof conditions during this installation, more time was spent on incidentals such as scaling the roof and placing temporary supports than on actual bolting. Therefore, no measurement was made of machine productivity.

Installation at Energy Development

Mine Description

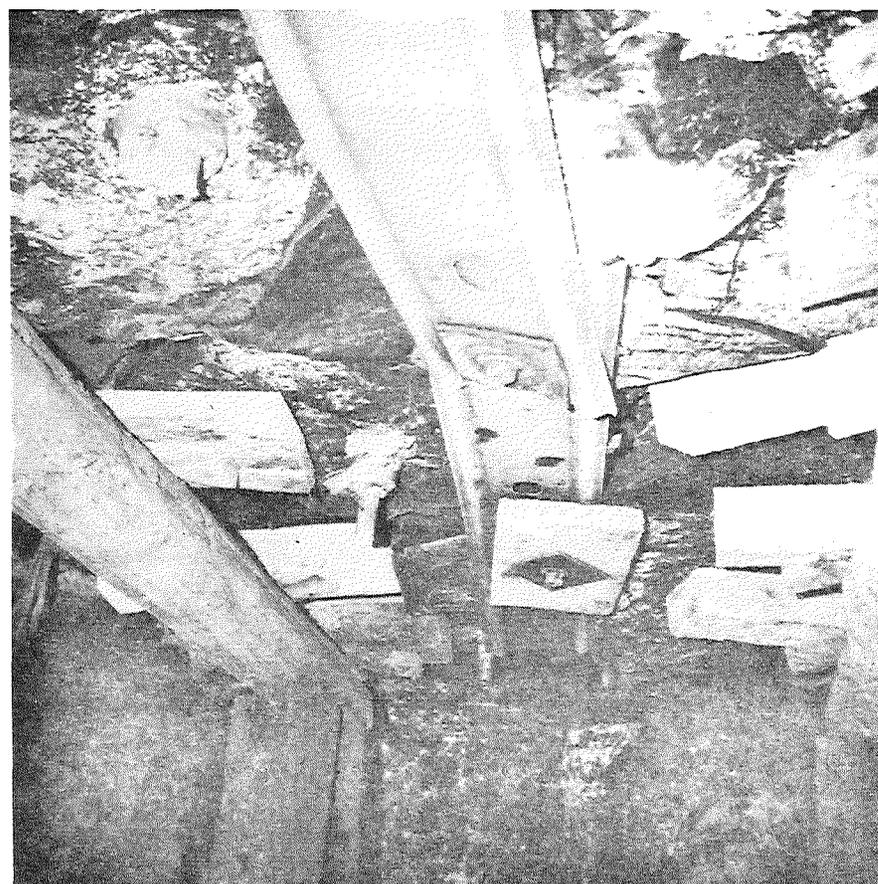
This mine was opened in 1974. The seam is 10 feet thick splitting 500 feet from portal. The lower split, 6 1/2 feet thick, is mined. Dip is approximately 12 degrees. The roof in by the split is silt stone and the roof is wet. Mining is by room and pillar method using continuous miners. Roof support was achieved by installing 5 foot bolts on 4 foot centers using landing mats and some wood blocks. Drilling was rotary, dry. Air temperatures vary seasonally from -3°C to 18°C.

The Pumpable Bolt Test Installation in this mine was to have comparison entries using standard bolts as well as temporary supports in the pumpable bolt entry are similar to that shown for Carbon Fuel as shown in Figure 47. Test site locations are shown in Figure 51.



PUMPABLE ROOF BOLTS AT FACE IN CARBON FUEL CO. MINE

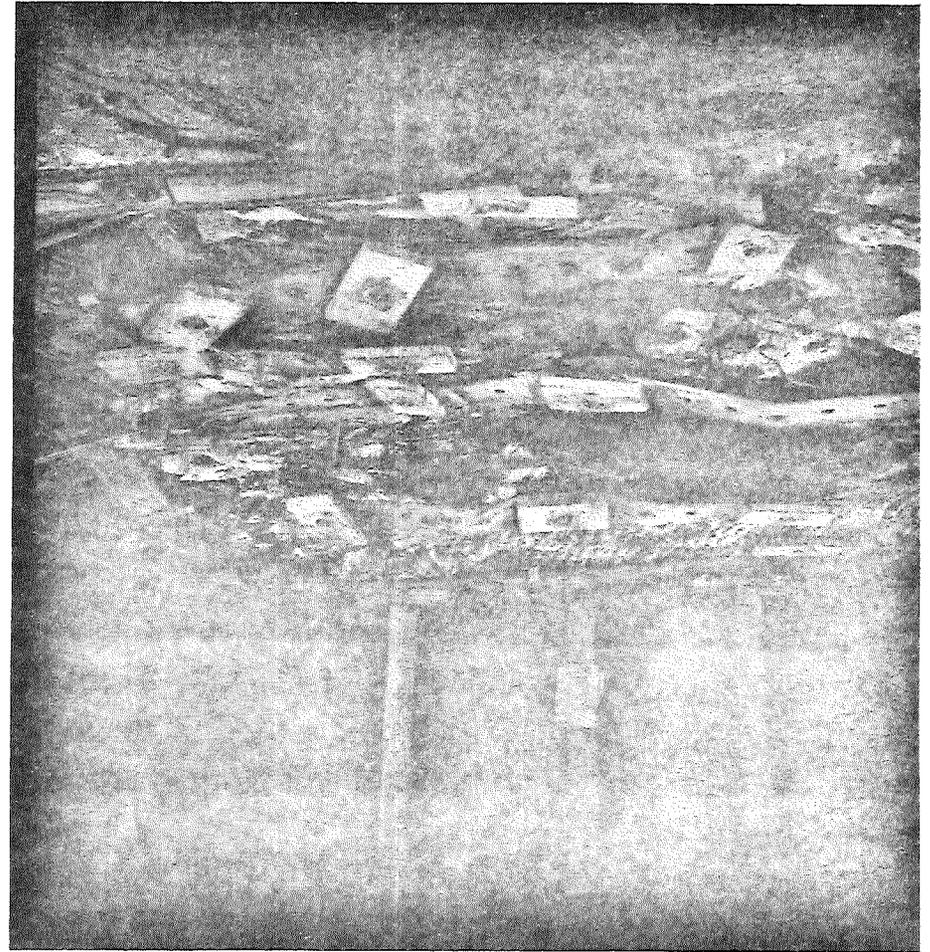
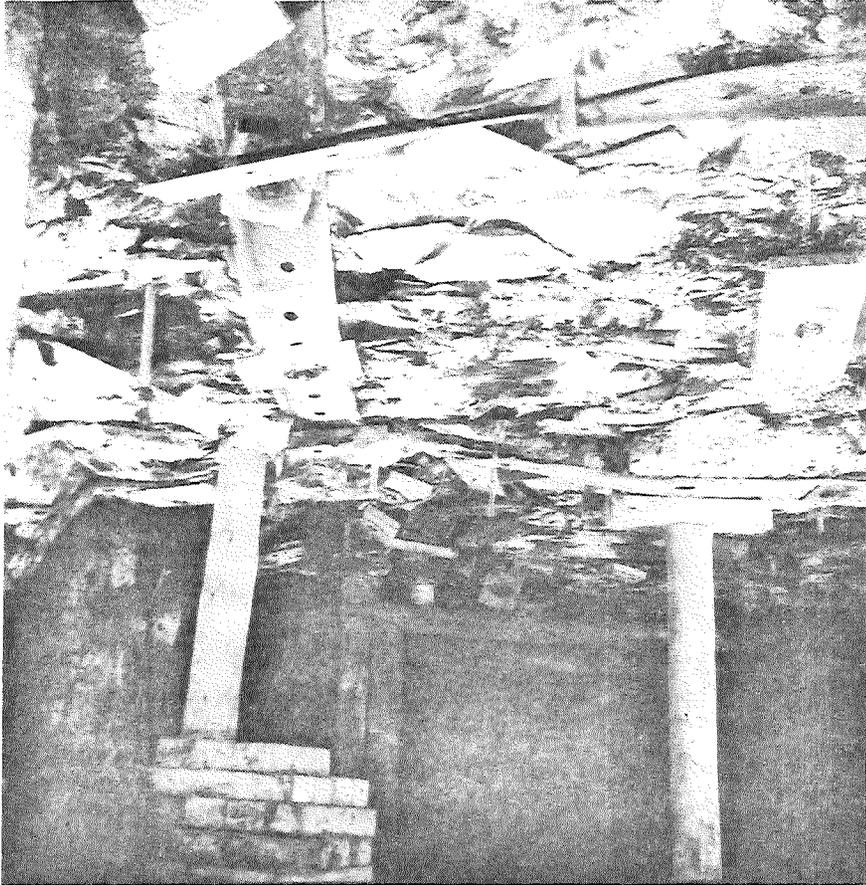
Figure 48



PUMPABLE ROOF BOLTS AT CARBON FUEL

Figure 49

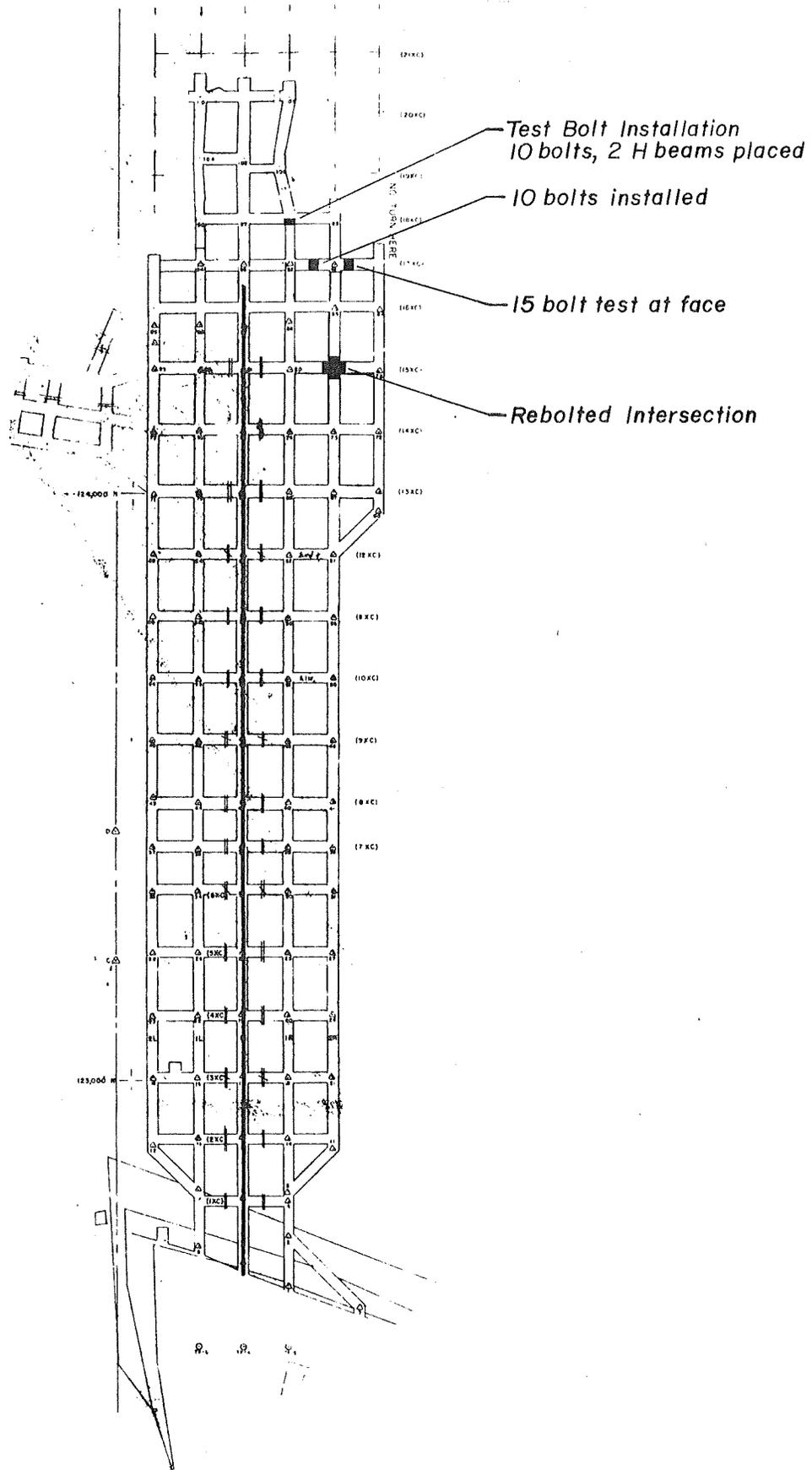
NOTE: Double end props put in
as safety precaution.
Steel mats installed after
test terminated.



BADLY FRACTURED ROCK AT THE 85TH CROSSCUT OF CARBON FUEL CO.

Figure 50

NOTE: Mine used steel mats and Cottonwood blocks with resin grouted steel bolts as well as props to hold up the intersection after test terminated.



TEST SITE
 ENERGY DEVELOPMENT CO.
 VANGUARD #3 MINE

Figure 51

Pre-Test Installation Check Out

A test area was established to check machine operations before installation of test bolts. The following difficulties were encountered:

Resin would not move through the lines. Temperature in the crosscut during the first attempt was between +4 and +7 degrees C. Heating of the tanks, lines and pots did not improve fluidity. To increase flow, larger lines were installed to reduce line friction. Wetting resin was added to the bolting resin and resins mixed with glass content reduced by 10% to lower viscosity. No improvement in fluidity resulted.

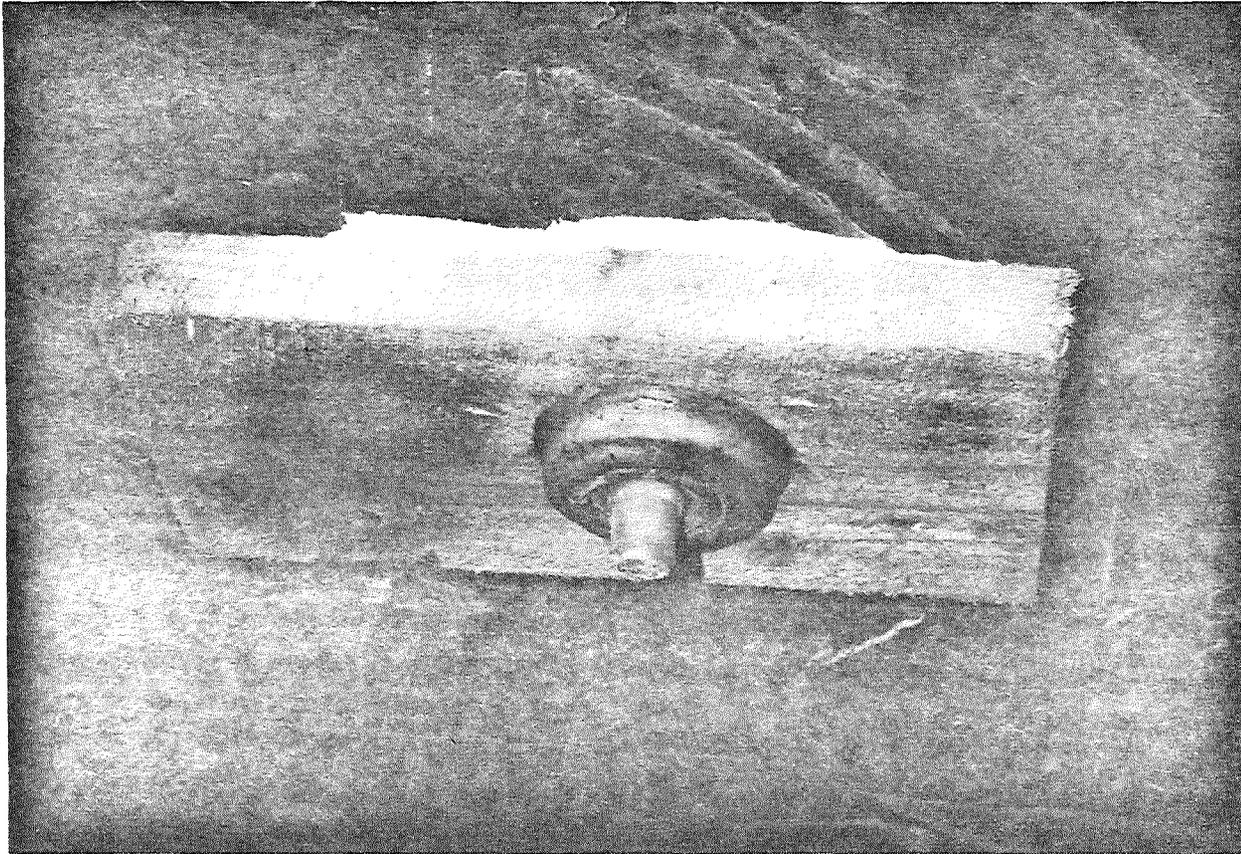
Mixing of the resins took longer than previously experienced. The extended mixing time made the resin frothy and thicker.

It was surmised that the resulting lack of fluidity was due to the monochlorostyrene used in the resin formulae having exceeded its shelf life, or the resin having become too warm during mixing.

Fresh batches of resins were brought in and tanks, pots and lines heated. This new resin supply could be pumped satisfactorily. However, at mine temperatures between +3°C and -3°C the resin would not cure after injection. At +7°C, cure took place in a satisfactory time period.

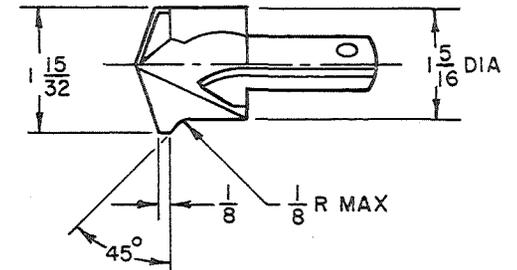
Deterioration of the mine roof occurred as the face advanced and it became necessary to use cottonwood blocks and/or steel mats even in the pumpable bolt test area. Several materials were tried between the roof and the blocks and mats as seals against the bolting fluid. Styrofoam proved best. Figure 52 illustrates the bolt installation using styrofoam at the roof.

As the face advanced, water was encountered in both roof and bottom. The water in the siltstone roof created a coating of mud in the drilled hole. Under this condition, no chemical bond was attained between the pumpable roof bolts and the roof rock. To attain a mechanical bond, a drill bit was devised as shown in Figure 53 that, when run up and down the already drilled hole, produced a spiral groove or rifling effect in the drilled hole. Holes were then cleaned out by brushing with a steel flue brush and blowing with air. This procedure improved bond sufficiently to allow installation to proceed.



Bolt with styrofoam as seal between wood block and roof at Energy Development.

Figure 52



RIFLING BIT

Figure 53

Test Bolt Installation

Ten bolts were installed at the face, Figures 54 and 55, using Steel mats, wood blocks and styrofoam seals.

Severe caving at the active face started after installation of these ten bolts.

The roof conditions then continually deteriorated and there was no possibility of testing the pumpable roof bolts at the face as planned. The decision was made to rebolt an intersection previously bolted with mechanically anchored roof bolts. The site selected was intersection second right at the 15th cross-cut (Figure 51).

The mechanically anchored bolts in the intersection and twenty feet in each direction were torqued. The Bureau of Mines attempted determination of bolt torque but the bolts were so heavily loaded that torque could not be determined.

Instrumentation holes were drilled, all in excess of 12 feet, and points placed at 12 feet, 6 feet, 4 feet and 2 feet depths. No convergence points were placed in floor because the floor was very soft and muddy.

The Pumpable Bolts were installed between the existing mechanically anchored bolts, with steel mat supports and cottonwood blocks using styrofoam as a seal between the block and the roof.

A total of 101 pumpable bolts were installed in the intersection. Photos of some of these bolts are shown in Figures 56 and 57. These bolts were installed in eight shifts averaging just under 13 bolts per shift including all preparations, installation, cleanup and maintenance.

Results at Energy Development

174 pumpable bolts were installed under conditions and with results as shown in Table 3.

In addition, 12 mechanically anchored steel bolts and 5 resin grouted bolts of 5 ft. lengths were installed and tested. Typical yield values were:

Mechanical anchors: 10,000 lbs.

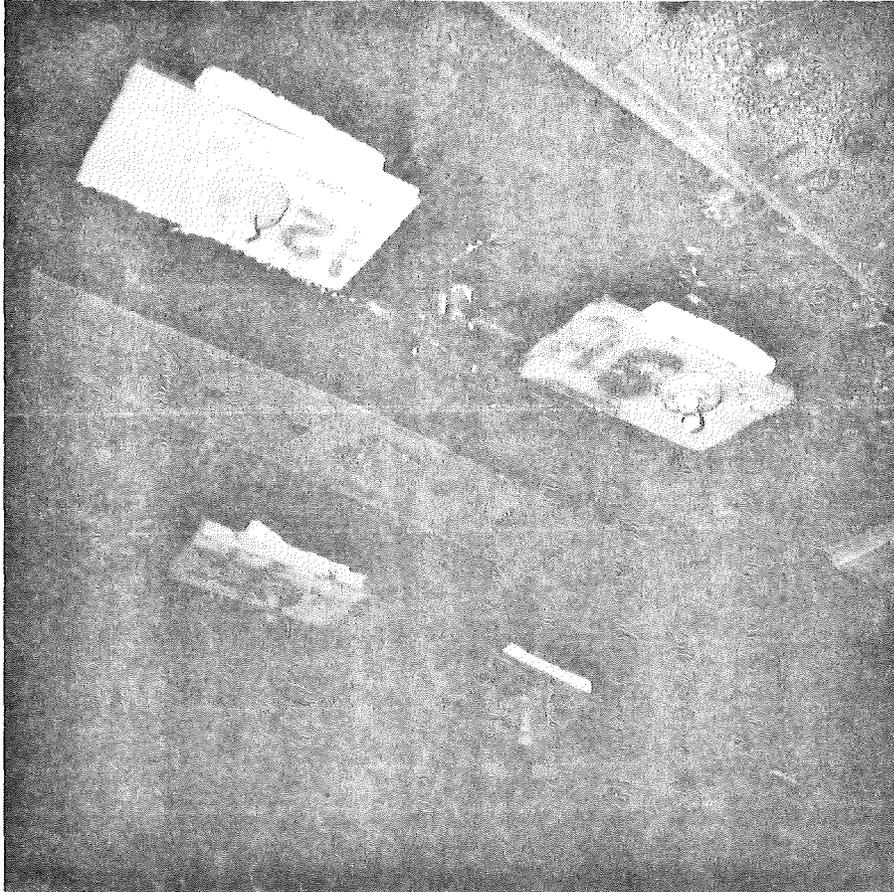
Resin grouted bolts: 28,000 lbs.

For the pumpable bolts, yield values could not be determined if they exceeded the point at which the bolt head broke off which typically occurs at 10,000 lbs.



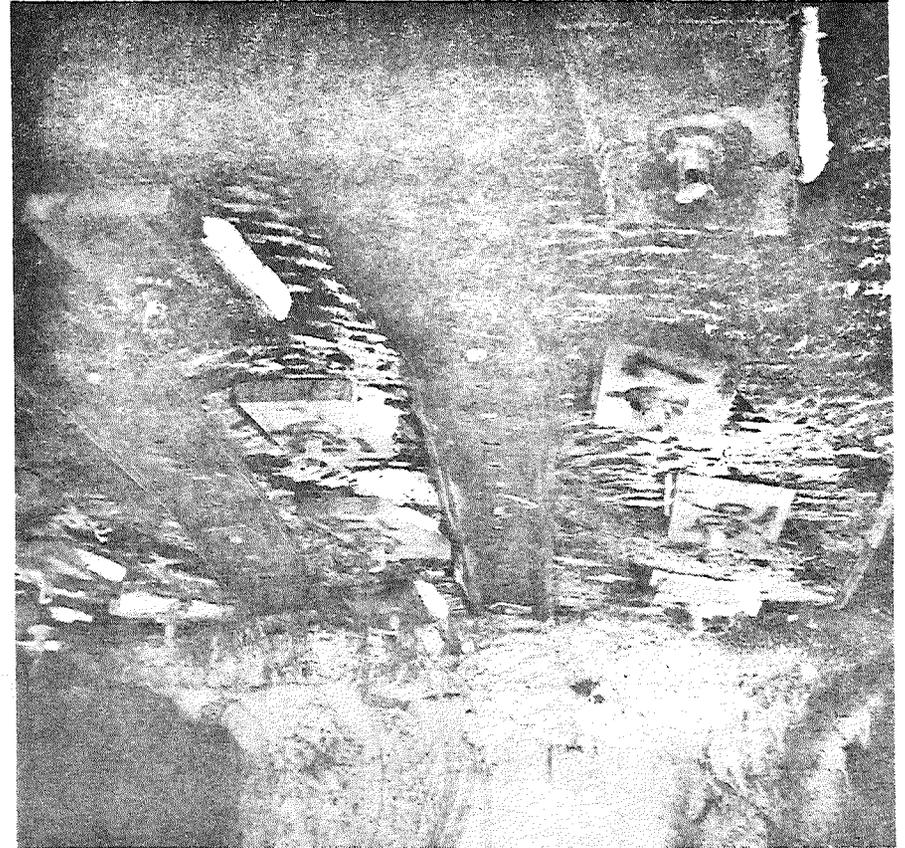
Pumpable roof bolts installed with steel mats
and styrofoam seals between roof and mats.
Energy Development.

Figure 54



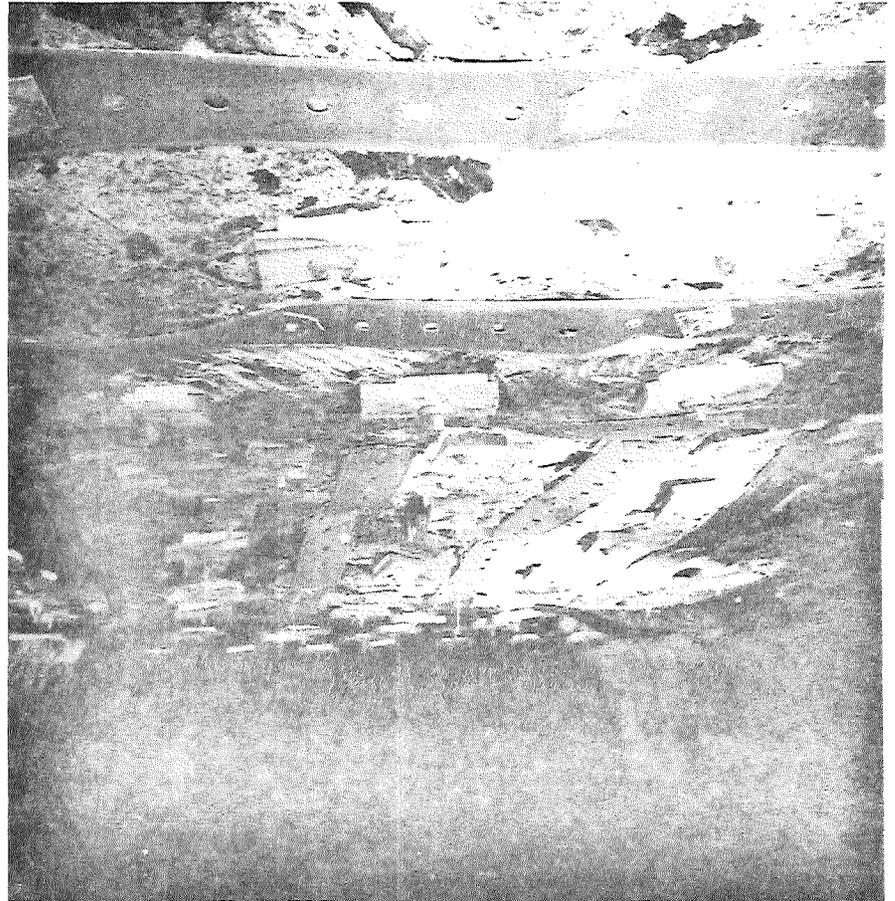
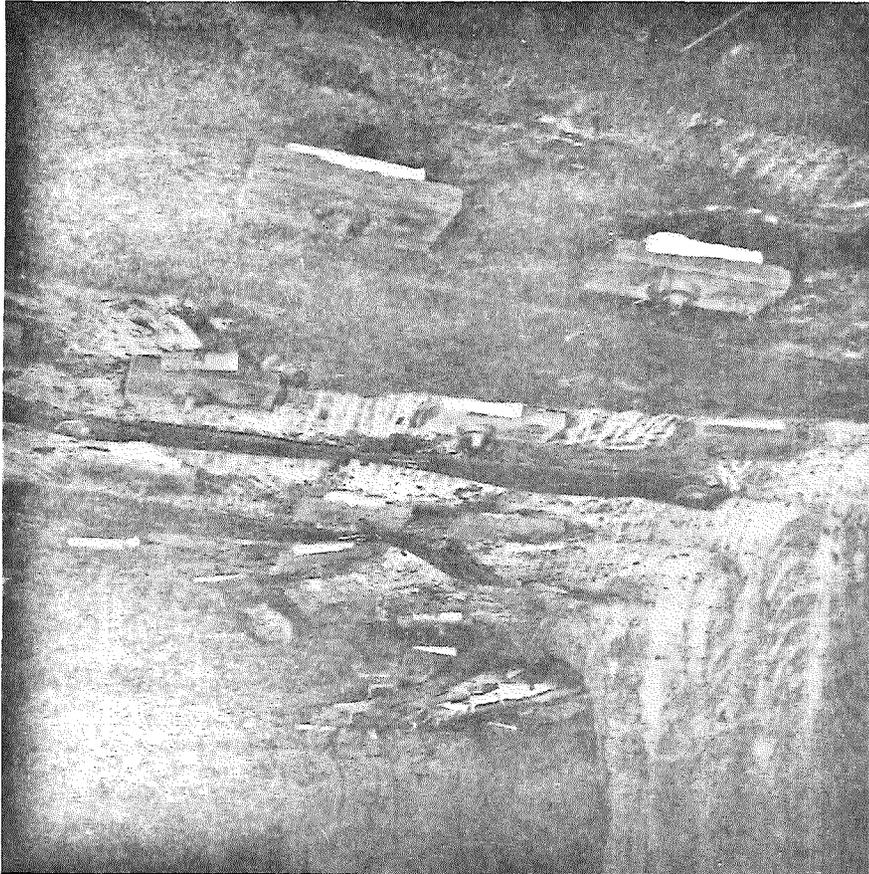
Pumpable roof bolts (and instrumentation point No. 5),
Energy Development.

Figure 55



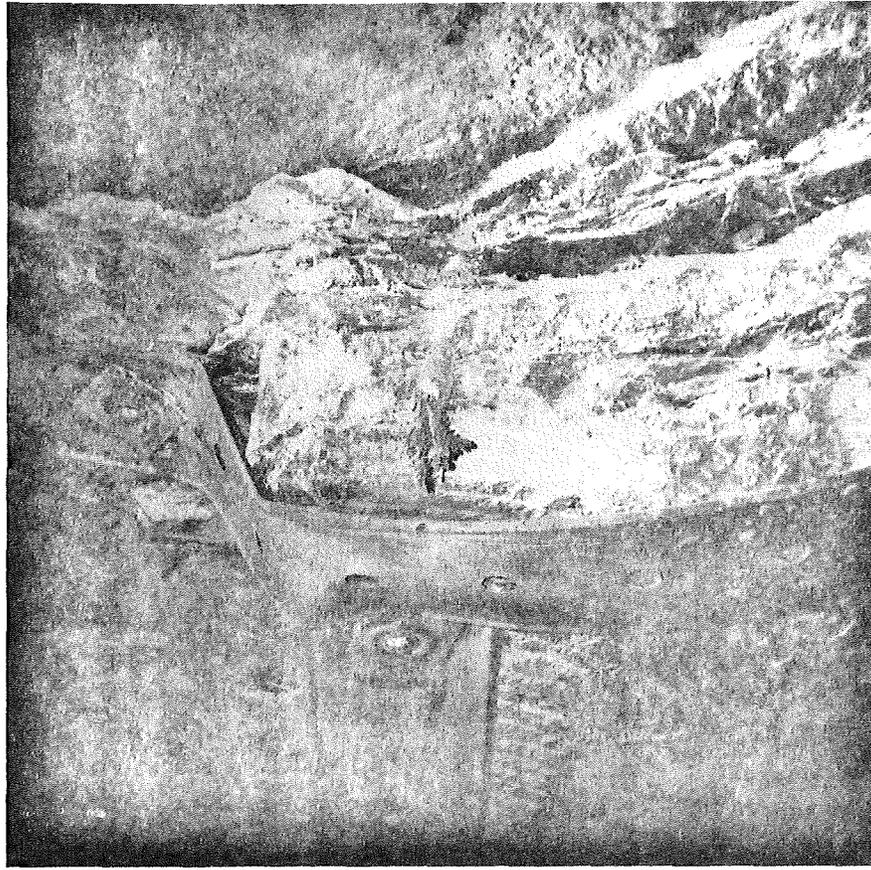
Pumpable roof bolts installed between existing mats at intersection, Energy Development.

Figure 56



Pumpable Roof Bolts at Intersection, Energy Development

Figure 57



When the slab in foreground fell out, the mats bent at the adjacent pumpable bolts, breaking the heads off. Resin grouted steel bolts installed through the same mats after test was terminated.

Figure 58

	Approx. Ambient Temp.	Number Failing 7000 lbs Pull Test	Number Passing 7000 lbs Pull Test	Hole Treatment
Bolts placed in production cycle.	10°C	0	10	Rifled, brushed
Bolts placed outside production cycle.	3°C	15	17	No Treatment
	5°C	0	10 Untested Apparently Good 14	Rifled, brushed
		0	1	No Treatment
	12°C	6 (Note: These were redone and sub sequently included under the 101 pass- ing)	101 Untested Apparently Good	Rifled, brushed
TOTALS		21	153	

Note: Resin system was heated for all of the bolts reported here.

SUMMARY OF BOLT TESTS AT ENERGY DEVELOPMENT

Table 3

In almost every case, the ultimate shear at which the head failed was approximately 3000 psi, which is in rough correspondence with published typical values for Hetron 197, a very low strength polyester. It should be noted that Hetron was selected on the basis of its fire retardant rather than its physical properties.

Typical cycle time, including positioning, drilling, bolt pumping and cure was 20 minutes per bolt. This does not include shift clean-up.

The machine operated well during this installation phase with the only exception that the head valve required cleaning for every 7 to 8 bolts installed.

Conclusions From Mine Installations

The present resin system will produce a good bolt if rock temperatures exceed +7°C.

Below +7°C, the cure of the pumpable bolt is slow and uncertain.

Below +7°C, improvement in the cure time and completeness of cure can be achieved if the resin is heated. Maximum operating temperature for the present resin system appears to be 35°C.

In the present machine design, heating of the resin system becomes necessary below +7°C in order to achieve flowrates commensurate with an acceptable bolt installation time (a time approximating that of a conventional bolt installation).

Indications are that the pumpable bolt will function and provide support similar to that of resin grouted bolts.

It is possible to effectively install pumpable bolts in conjunction with auxiliary support means such as mesh or landing mats.

Where mats are used and become subject to heavy loads, the head of the pumpable bolt is of insufficient strength to assuredly hold the mats in place.

Under normal mining conditions, bolts can be installed in 15 minutes or less using a two men crew.

OPERATING PROCEDURES

In a separate volume, a detailed description is given of operating procedures and routine machine maintenance. The following brief description is intended only as an illustration of the relative complexity of the pumpable bolt installation procedures, including mixing of bolt material, actual bolting and the clean up work which by necessity must follow after each finished bolting operation.

Resin Mixing Procedures

1. For amounts and formulations of resin and chemicals see Table 4.
2. Materials required:
 - A. Two containers containing equal amounts of bolting resin.
 - B. Appropriate amounts of the following:
 1. Wetting resin.
 2. Catalyst - Methyl - ethylketone peroxide
 3. Promoter - Dimethyl Aniline.
 - CAUTION: Do not allow the catalyst and promoters to come in contact with each other.
 - C. Mixing Motor.
 - D. Mixing propellers and shaft.
 - E. Spatula or putty knife.
 - F. Solvent (at least one gallon of Trichloroethane for cleaning purposes).
3. Thoroughly mix bolting resins. The glass settles to the bottom and may have to be scraped off the bottom of the container. Mix until the resin is smooth and homogeneous.
4. Pour measured amounts of promoters into one container of bolting resin and thoroughly mix.

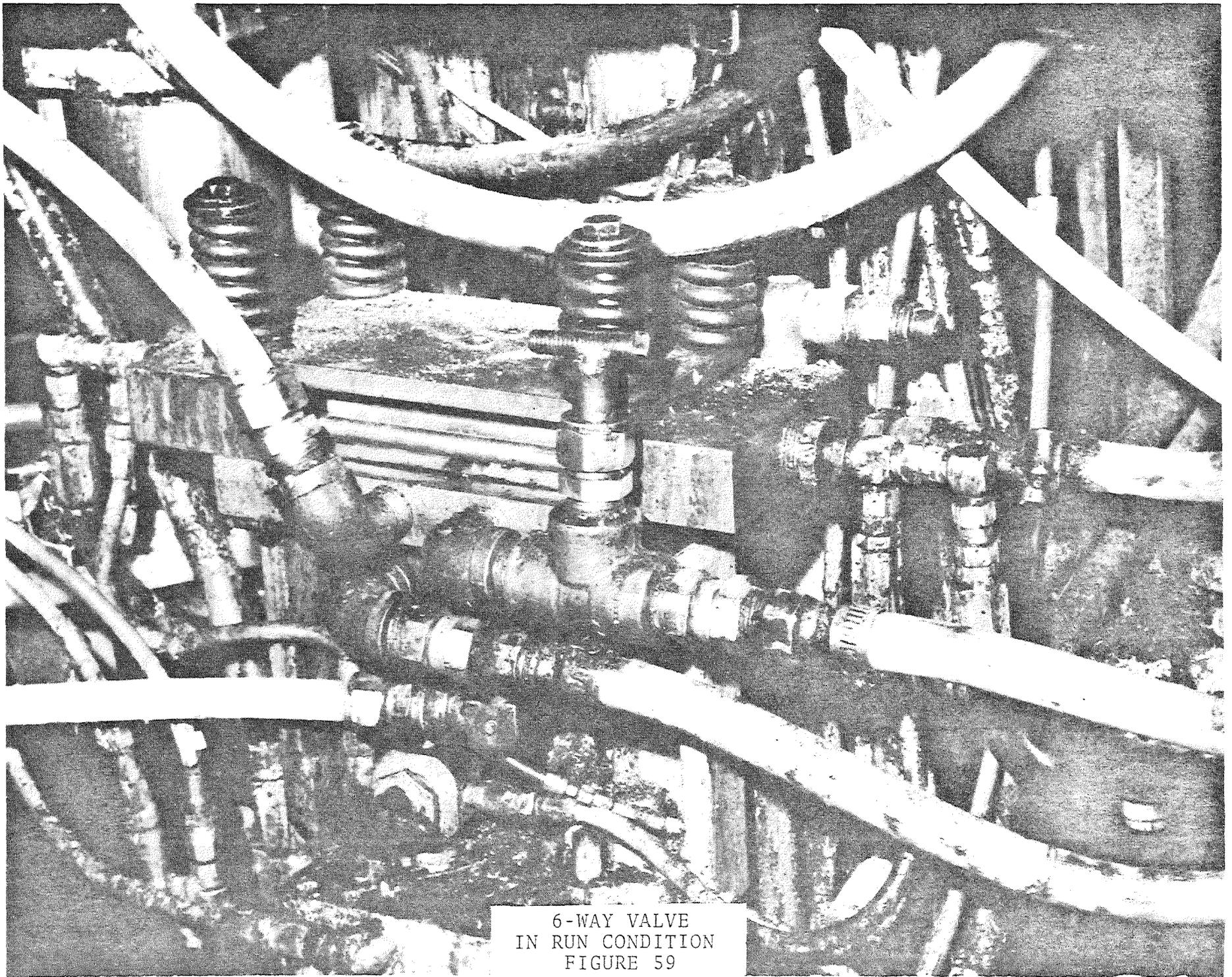
BOLTING FLUID		PROMOTERS		CATALYST	WETTING RESIN CATALYST
LBS	GRAMS	DMA (.8%)	CNG (.8%)	VSP-240 1.6%	224 (1.5%)
1	453.6	3.66	3.66	7.26	6.91
2	907.2	7.32	7.32	14.51	13.82
3	1360.8	10.97	10.97	21.77	20.72
4	1814.4	14.63	14.63	29.03	27.63
5	2268	18.29	18.29	36.29	34.54
6	2721.6	21.95	21.95	43.54	41.44
7	3175.2	25.61	25.61	50.8	48.35
8	3628.8	29.26	29.26	58.06	55.26
9	4082.4	32.92	32.92	65.32	62.17
10	4536.0	36.58	36.58	72.58	69.08
15	6804	54.87	54.87	108.9	103.6
20	9072	73.16	73.16	145.1	138.2
25	11340	91.45	91.45	181.4	172.7
30	13,608	109.7	109.7	217.7	207.2
35	15,876	128.0	128.0	254.0	241.8
40	18,144	146.3	146.3	290.3	276.3
60	27,216	219.5	218.5	435.4	414.4
70	31,752	256.1	256.1	508	
80	36,288	292.6	292.6	580.6	
90	40,824	329.2	329.2	653.2	
100	45,360	365.8	365.8	725.8	
121	54,885	442.6	442.6	878.2	

TABLE 4

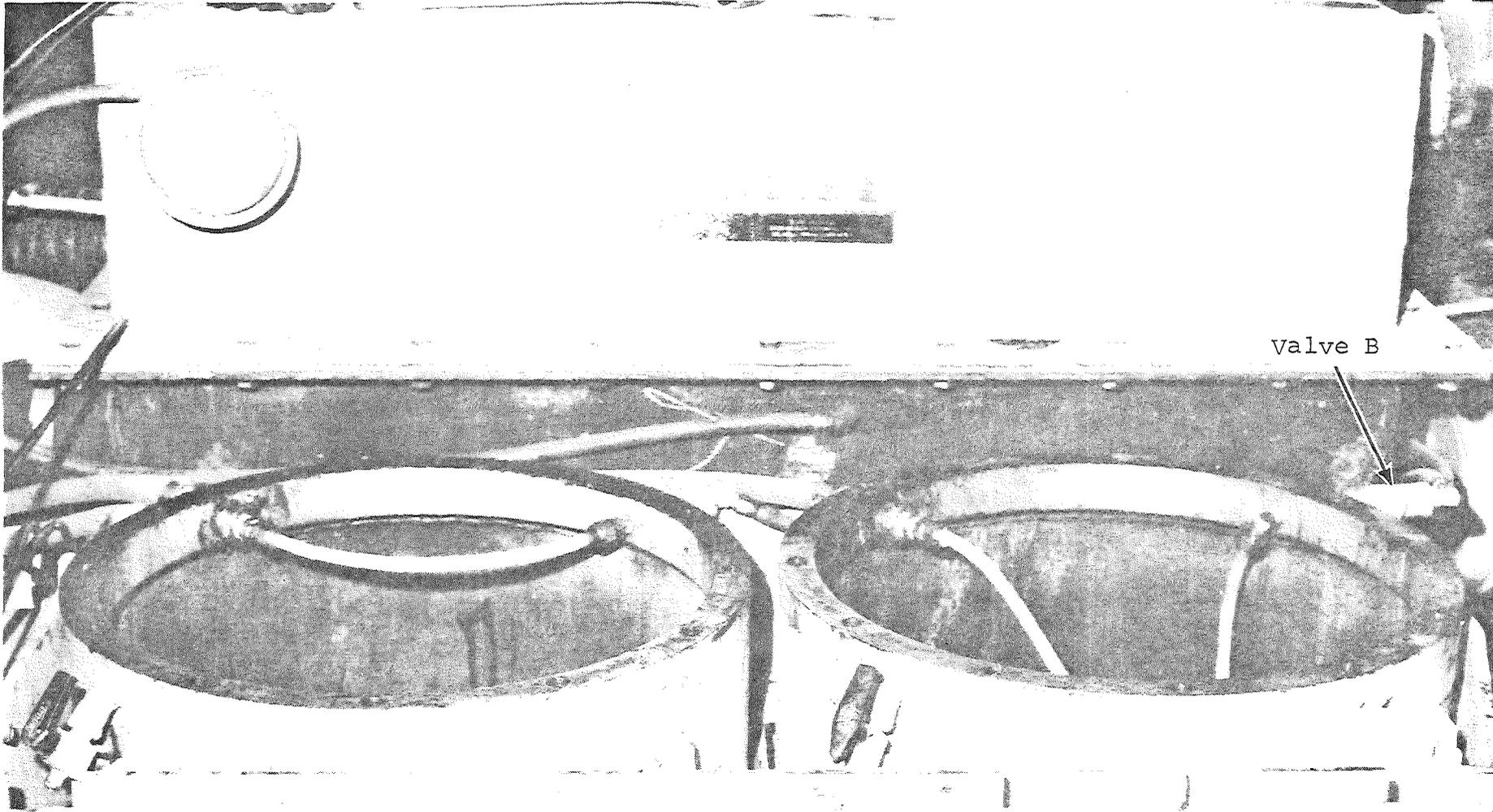
5. Clean mixer.
6. Add catalyst to wetting resin and mix.
7. Add catalyst to other container of bolting resin and thoroughly mix.
8. Clean mixer and tools.
9. If resins are not to be used immediately, cover the containers. Mixed chemicals should be used within 6 hours.

Preparation for Bolting

1. Change lines at 6-way valve to run condition as shown in Figure 59.
2. Grease O-rings in injection pump pots.
3. Apply some grease around bottom of injection pump plungers.
4. Install injection pump pots; connect lines and install plugs in bottom.
5. Install dry-run lines in resin supply tanks as shown in Figure 60.
6. Check solvent tank and fill if necessary.
7. Install wetting pump piston and bell in tank.
 - A. Grease O-ring in wetting pump bell.
 - B. Grease wetting pump cylinder in bottom of tank. Grease I.D. and O.D. of top portion (inside tank).
 - C. Install pump assembly in tank.
8. Turn machine on.
9. Check for solvent circulation through both sight gauges.
 - A. Reset auto controls.
 - B. Air supply to solvent tank - on.
 - C. Circulation in BOTH sight gauges.
10. Air supply to solvent tank - on. (Valve A, Figure 61)
Set air pressure to 10-20 PSI. (Regulator, Figure 61)
11. Check for solvent or air leaks.
12. Check operation of all functions with manual buttons.



6-WAY VALVE
IN RUN CONDITION
FIGURE 59

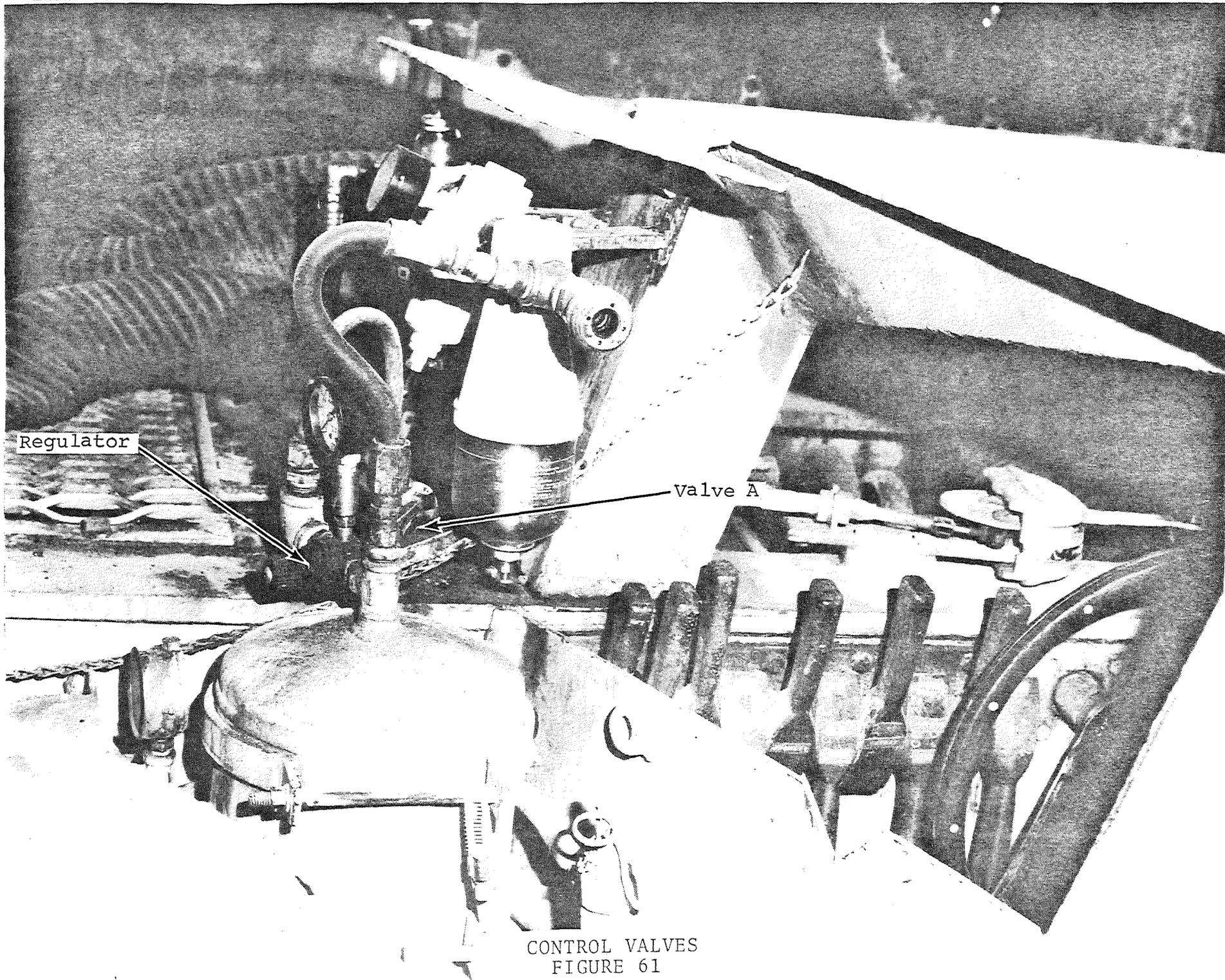


ENVIROTECH



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RESIN SUPPLY TANKS
WITH DRY-RUN LINES
FIGURE 60

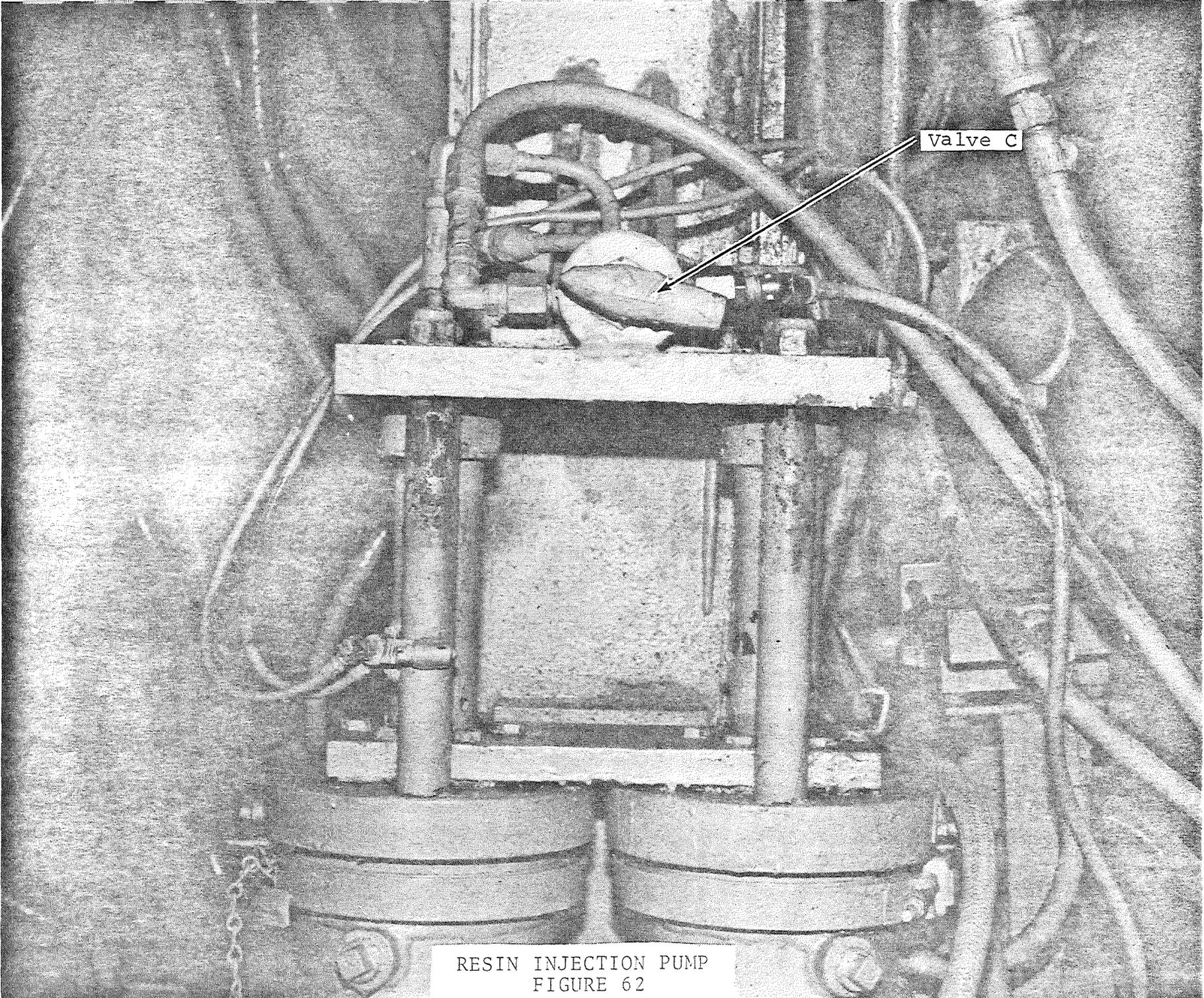


Regulator

Valve A

CONTROL VALVES
FIGURE 61

13. Push RESET button.
14. Push AUTO START button.
15. After roving drive starts, push INJ. START button.
16. Check cure cycle timer.
17. Perform dry run (steps 13 to 16) at least twice.
18. Turn air supply to resin tanks - OFF. (Valve B, Figure 60)
19. Remove plugs from bottom of injection pump pots and allow air and solvent to escape.
20. Remove dry-run lines from resin supply tanks.
21. Install open-top containers of resin in resin supply tanks.
 - A. Catalyzed resin in rear tank (Boom end is front).
 - B. Promoted resin in forward tank. (Purple)
22. Install resin supply line fittings in tanks with teflon tape or pipe dope to insure an airtight seal.
23. Cut 3/4" polyethylene supply lines long enough to reach bottom of resin containers.
24. Tighten supply line fittings on tube hand tight.
25. Install lids on resin supply tanks.
26. Close vent valves on resin supply tanks.
27. Open air supply valve to resin supply tanks. (Valve B, Figure 60)
28. Turn Valve C, Figure 62 to manual position.
29. Turn machine - ON
(Check for solvent circulation - both sight gauges.)
30. Check for bubbles in resin supply lines coming from supply tanks.
 - A. If there are bubbles immediately turn air supply to resin tanks off and drain air.
 - B. Remove tank lid and tighten fittings and check for proper assembly of O-ring and back-up ring in fittings.
31. When resin starts to come out of injection pump pots install plugs.



Valve C

RESIN INJECTION PUMP
FIGURE 62

32. When both plugs have been installed in injection pump pots, turn Valve C, Figure 62 to automatic position.
33. Pour wetting resin into wetting resin supply tank.
34. With wetting resin supply line (going to wetting chamber) removed from wetting chamber, operate the wetting pump through one cycle to push any old solvent in lines out into waste container.
35. Thread roving through roving bridge.
36. Run vent tube up into roving and tape securely.
37. Close wetting chamber.
38. Run vent tube drive up until it is one or two inches above roof seal.
39. When resin injection pump plungers are all the way up, the machine is ready to pump bolts.

Bolting Procedure

When the preceding "Preparation for Bolting" procedures have been complied with, the machine is ready to install bolts. The following are standard operating procedures for drilling holes and pumping bolts. These operations are controlled from the operator's compartment.

1. Locate and drill hole (bolting head must be "down").
 - A. Index the turret to drill position.
 - B. Locate turret under position where bolt is to be installed.
 - C. Using "advance" and "jackleg" levers set jacklegs against floor and roof.
 - D. Advance turret up until rubber cushion on dust collector is no more than two inches from roof. It may touch the roof.
 - E. Drill hole.
 1. Turn drill "on".
 2. Feed drill into roof. Use maximum rate at which drill still turns.
 3. Drill steel may have to be changed depending on depth of hole required.

2. Clean hole.

NOTE: The amount of cleaning required will depend on the rock conditions. The cleaning will range from no cleaning effort at all to blowing air up the hole and brushing.

3. Install bolt.

- A. Index turret to bolt position.

- B. Raise bolting head.

1. Make sure stub of previous bolt enters new hole.

- C. Advance turret until roof seal rubber is compressed against roof.

- D. Run roving drive momentarily to determine that the stub will not hang up in the hole.

- E. Press reset button.

- F. Check for flow in both flow meters (FM1, FM2, see Figure 63).

- G. Press auto start button. (Green light should come "on".)

- H. Press "inject" button.

1. Injection pump will go down until it trips the end of bolt switch.

2. Cure cycle then starts.

3. At end of cure cycle, the head will drop.

4. Cut bolt off stub.

- A. Press cut-off saw button.

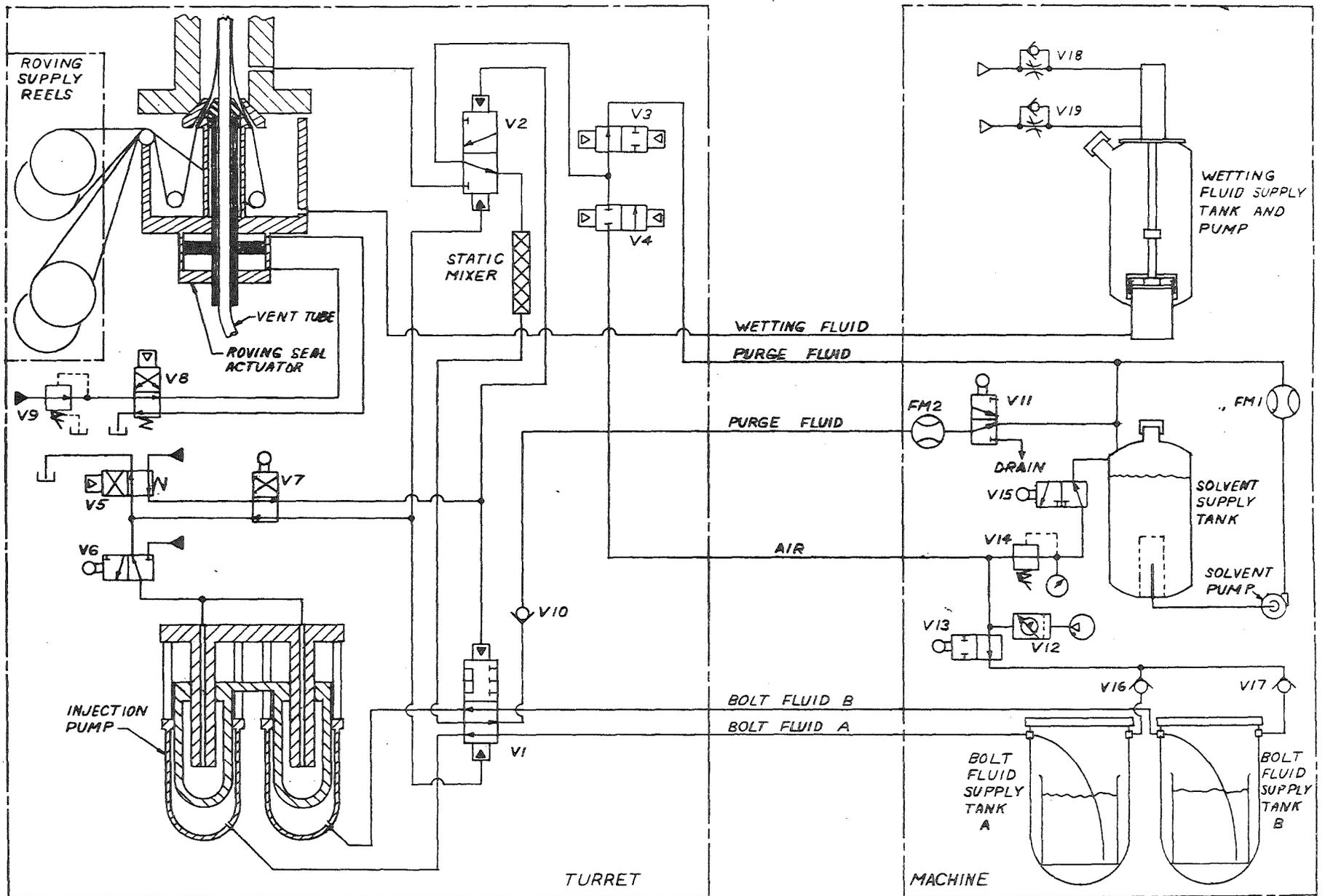
1. Button must remain depressed until saw has cut through stub.

- B. Release cut-off saw button.

1. Saw will return to stowed position.

Clean Up Procedure

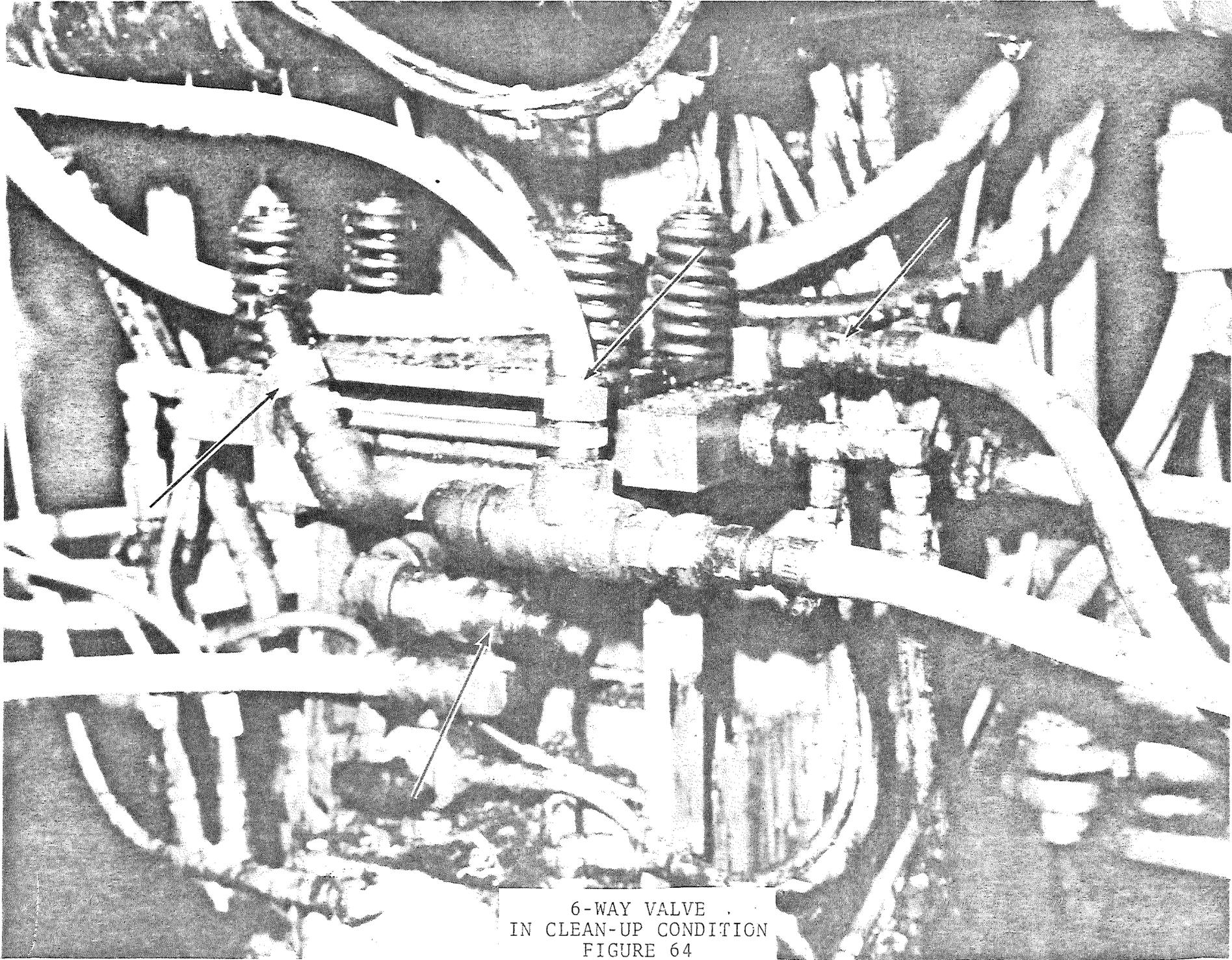
1. Remove plugs from bottom of injection pump pots and allow any remaining resin in lines to be blown out.



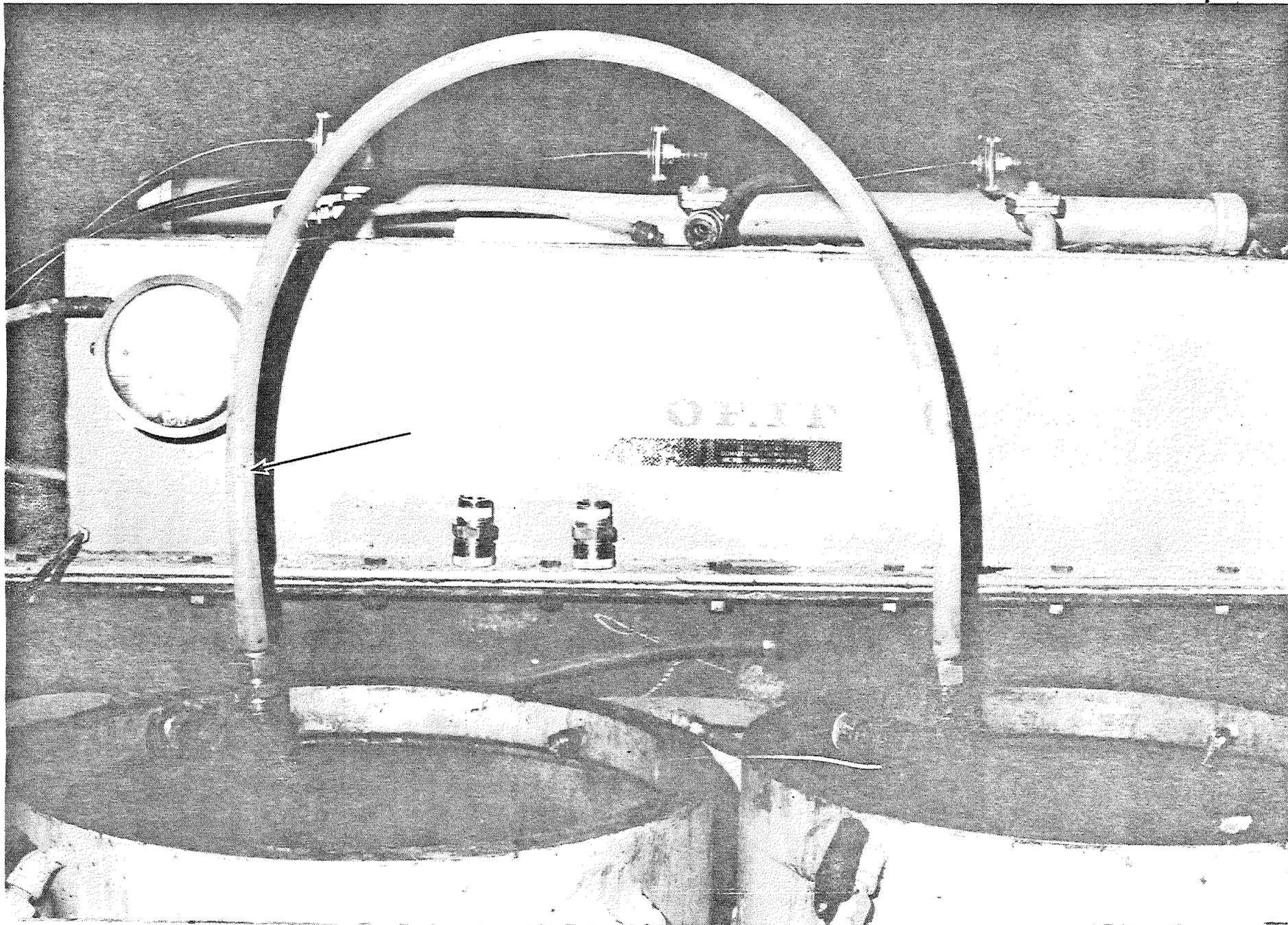
PUMPABLE BOLT PROCESS FLOW DIAGRAM

Figure 63

- NOTE: If there is a substantial amount of resin remaining in supply tanks (two gallons or more) the following procedure saves time:
- A. Shut off air supply to resin supply tanks and drain air.
 - B. Remove tank lids.
 - C. Remove supply hoses from resin containers.
 - D. Connect dry-run lines as shown in Figure 60.
 - E. Turn on air supply to resin tanks.
 - F. Proceed with step one above.
2. Turn Valve C, Figure 62, to manual position to push resin from injection pumps.
 3. When plastic is blown out of lines and injection pumps, turn off air supply to resin supply tanks.
 4. Reinstall plugs in bottom of injection pump pots.
 5. Air blow solvent lines and turn machine off:
 - A. Purge Valve - Close.
 - B. Air Blow - On.
 - C. Air Blow - Off.
 - D. Turn Machine- Off.
 6. Drain pressure from solvent tank with Valve A, Figure 61.
 7. Connect lines on 6-way mixing valve as shown in Figure 64.
 8. Install connecting line between resin supply tanks as shown in Figure 65.
 9. Check solvent supply--not lower than 8 inches from top of tank.
 10. Turn machine on.
 11. Air blow - off.
 12. Purge valve - open.
 13. Turn on air supply to solvent tank.
 14. Check for solvent circulation and allow to circulate for at least five minutes.



6-WAY VALVE
IN CLEAN-UP CONDITION
FIGURE 64



RESIN SUPPLY TANKS
IN CLEAN-UP CONDITION
FIGURE 65

NOTE: If solvent does not circulate readily within one minute after starting machine, proceed as follows:

- A. Increase pressure on solvent tank up to 60 PSI maximum (regulator, Figure 61). This may start the circulation. If not, proceed with B.
 - B. Open emergency dump valve until circulation starts. If circulation still does not start, there is likely a solid plug in the circuit.
15. During circulation, cycle injection pump slowly at least six times with valve C, Figure 62.
 16. Purge valve - off.
 17. Air blow - on.
 18. Wait for lines to clear.
 19. Air blow - off.
 20. Turn machine - off.
 21. Drain air from solvent tank.
 22. Remove injection pump pots and clean pots and pistons by hand.
 23. Clean resin supply hose fittings.

Clean Wetting Resin System:

1. Drain wetting resin tank into a waste container.
2. Reinstall plug and pour approximately two gallons of solvent (trichloroethane) into wetting resin supply tank.
3. Remove wetting resin supply hose from wetting chamber. Direct end into waste container or back into wetting resin tank.
4. Cycle wetting resin pump with manual controls three to six times.
5. Drain remaining solvent from wetting resin supply tank.
6. Remove wetting resin pump and piston from tank and rinse all parts by hand.
7. Clean wetting chamber and bridge by hand.

SUBJECT INVENTIONS

Fluid Injection Pump

This invention describes a device for transferring a measured quantity of fluid to a different location and then returning all of the fluid to its point of origin.

Vent Tube Polymer Synchronizer

This invention describes a system for synchronizing the amount of polymer injected to the length of vent tube inserted in the bolt hole. It may also be stated, that this system will remember the length of tubing used, and at a later time meter a proportional quantity of fluid.

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