

A mining research contract report
SEPTEMBER 1983

FABRICATION AND TEST OF AN ARTICULATED REMOTE MANUAL ROOF BOLTER

Contract H0202036
The Bendix Corporation

Bureau of Mines Open File Report 18-84

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BUREAU OF MINES
UNITED STATES DEPARTMENT OF THE INTERIOR



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FOREWORD

This report was prepared by the Bendix Corporation, Energy, Environment and Technology Office, under USBM contract number H0202036. This contract was initiated under the Advanced Coal Mining Technology program. It was administered under the technical direction of the Spokane Research Center with Mr. Richard P. Curtin as the Technical Project Officer. Mr. Howard Cole was the Contract Administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period from 9/17/80 to 7/1/83. This report was submitted by the authors on September 30, 1983.

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1. INTRODUCTION

1.1 Summary - This contract implemented the fabrication and testing of the semi-automatic roof bolter design conceived in Phase II of USBM contract H0272044 entitled "Evaluation of Mine Roof Bolter Components". This earlier contract qualitatively surveyed bolting components and recommended an articulated scoop-like chassis, with a roof bolter module on the front end. The articulated chassis was chosen for its maneuverability and adaptability to the incorporation of an operator's cab relatively close to the bolting position for visibility of the bolting operation but far enough away to place him safely under supported roof during the bolting operation.

The tool module consists of a flexible drill, a roof bolt inserter, a thrust/torque assembly, and a plate storage, feed and receiver mechanism. These devices collectively allow the operator to drill, insert anchor bolts into the roof with appropriate bearing plates in place, push the bolts to the roof and rotate them to preset torque levels while sitting approximately seven feet from the drill station. (Since the operator is seated in a modified supine position, his head is some eight-feet from the drill station while his feet are about four-feet from the drill station.) The bolter design evolved under USBM contract H0272044 was fabricated and tested in the Bendix laboratory and in a West Virginia coal mine. Approximately one-hundred eighty-eight bolts were installed during the underground testing.

2. SYSTEM DESCRIPTION AND OPERATION

2.1 System Description - The semi-automatic roof bolter consists of an articulated chassis and a bolter component assembly which primarily interface at the front end of the chassis. The operator performs the entire bolting cycle from under protected roof positioned approximately seven feet behind the drilling and bolting location. The machine is capable of operating in 37 to 60 inch high coal seams and can install four to eight foot bolts into the roof. It was designed to be used in 16 to 20 foot wide entries. The machine is shown in Figures 1 and 2.

The Bolter Component Assembly (BCA) consists of a flexible drill, roof bolt inserter, thrust/torque assembly, plate magazine, feed and receive mechanisms, and a carriage assembly, all mounted in a frame. The BCA is mounted to the vehicle by two elevation assemblies each located on either side of the BCA. These elevation assemblies allow the BCA to be raised against the roof.

The vehicle chassis contains the following major components and sub-systems: bolt storage, hydraulic control system, electric motor, high and low pressure pumps, dust blower, electrical cable reel and controller, hydraulic wheel motors with drive reducers and brakes, 70 gal hydraulic reservoir, fire suppression, duct collection, area lighting and methane monitoring system.

The operator's cab, Figure 3, contains all the controls and displays required for tramming, drilling, bolting and system monitoring. The two system function/monitoring panels are shown in Figures 4 and 5.

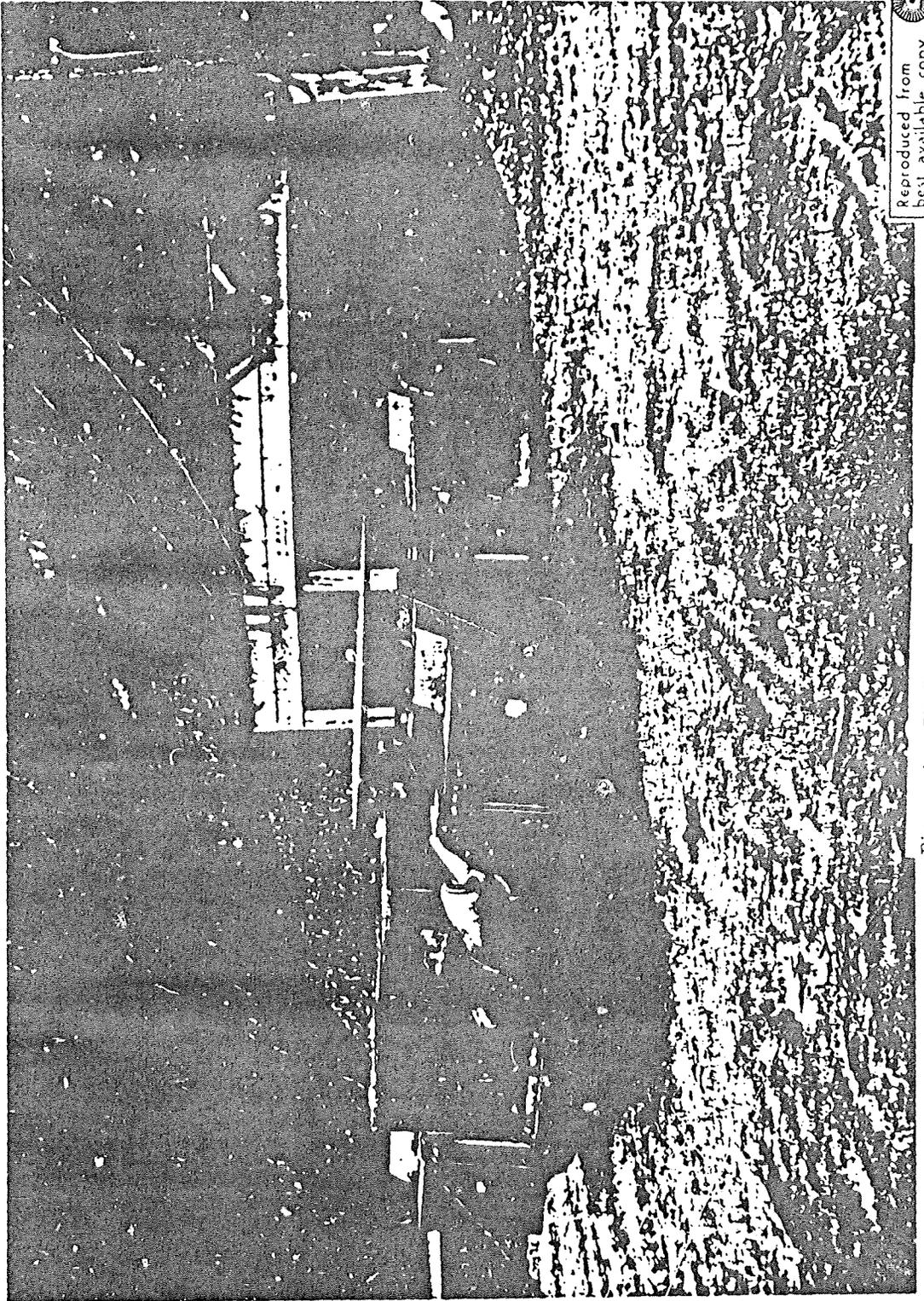


Figure 1. ARM Bolter at Cari Eagle #1 Mine

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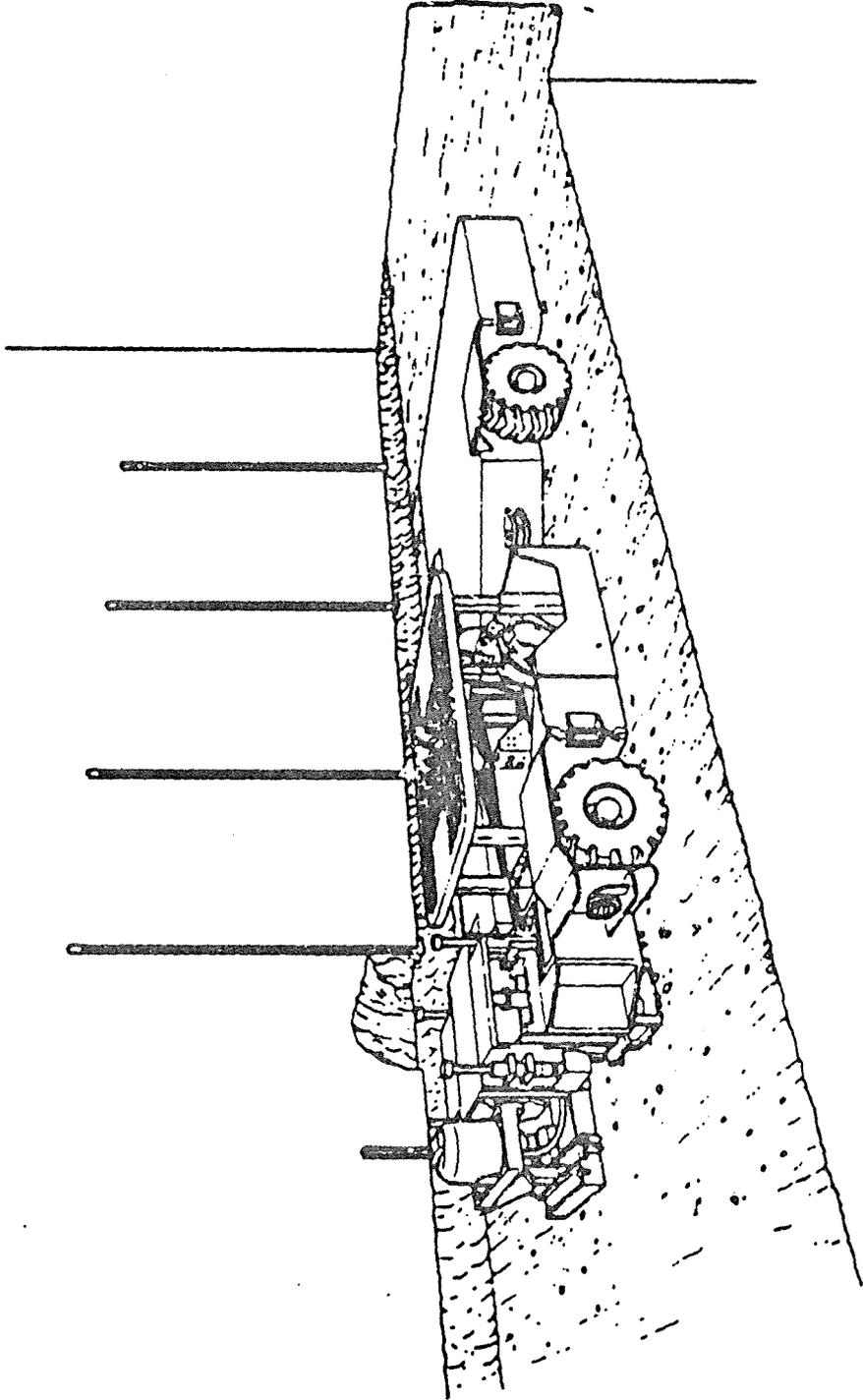


Figure 2. Artist Concept, Articulated Remote Manual Bolter

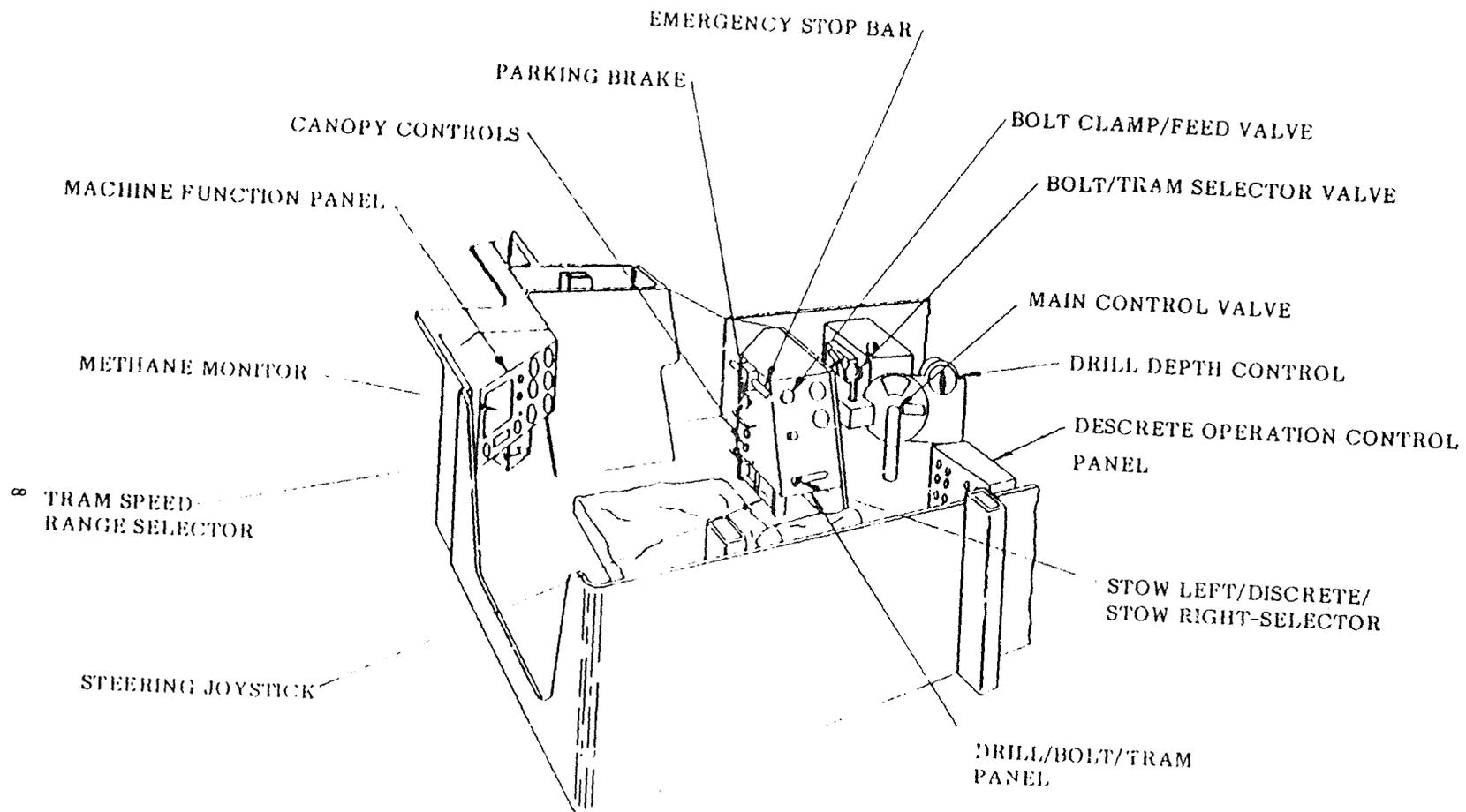


Figure 3. Operator Cab/Controls

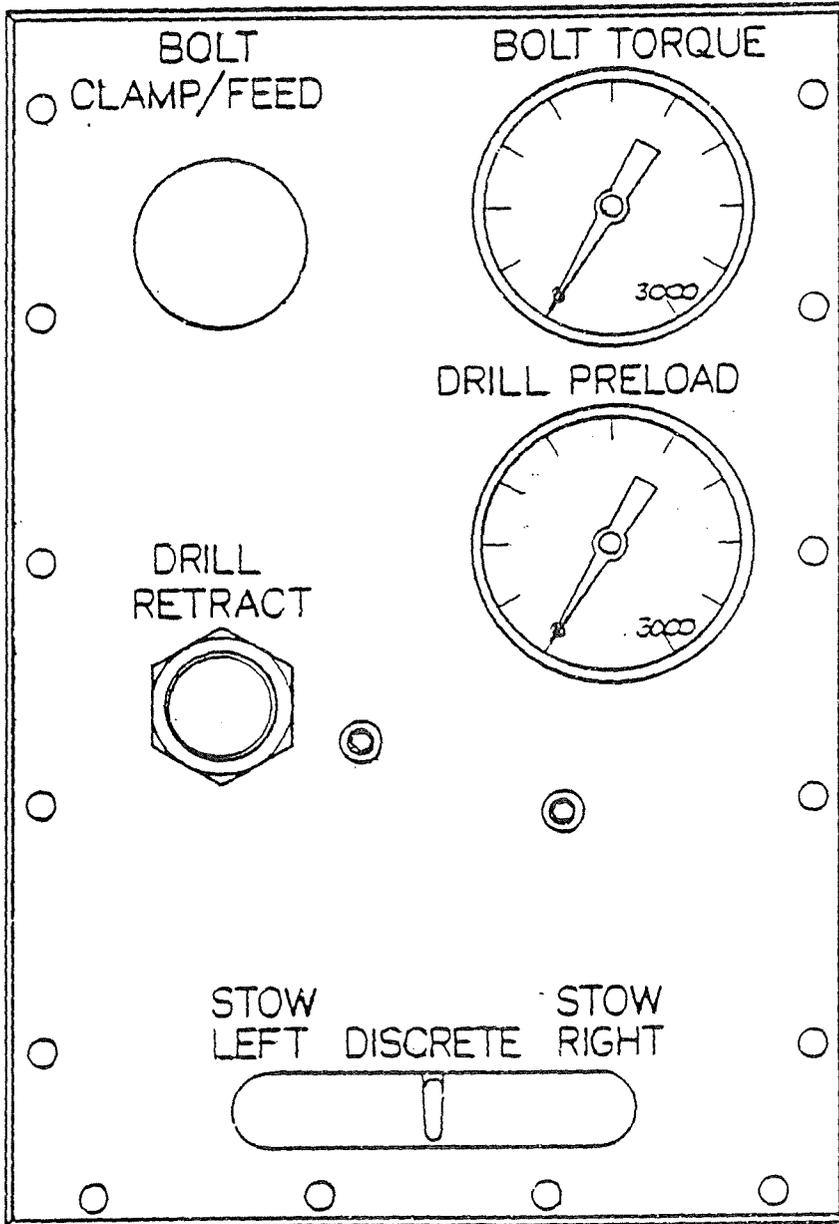


Figure 4. Drill/Bolt/Tram Panel

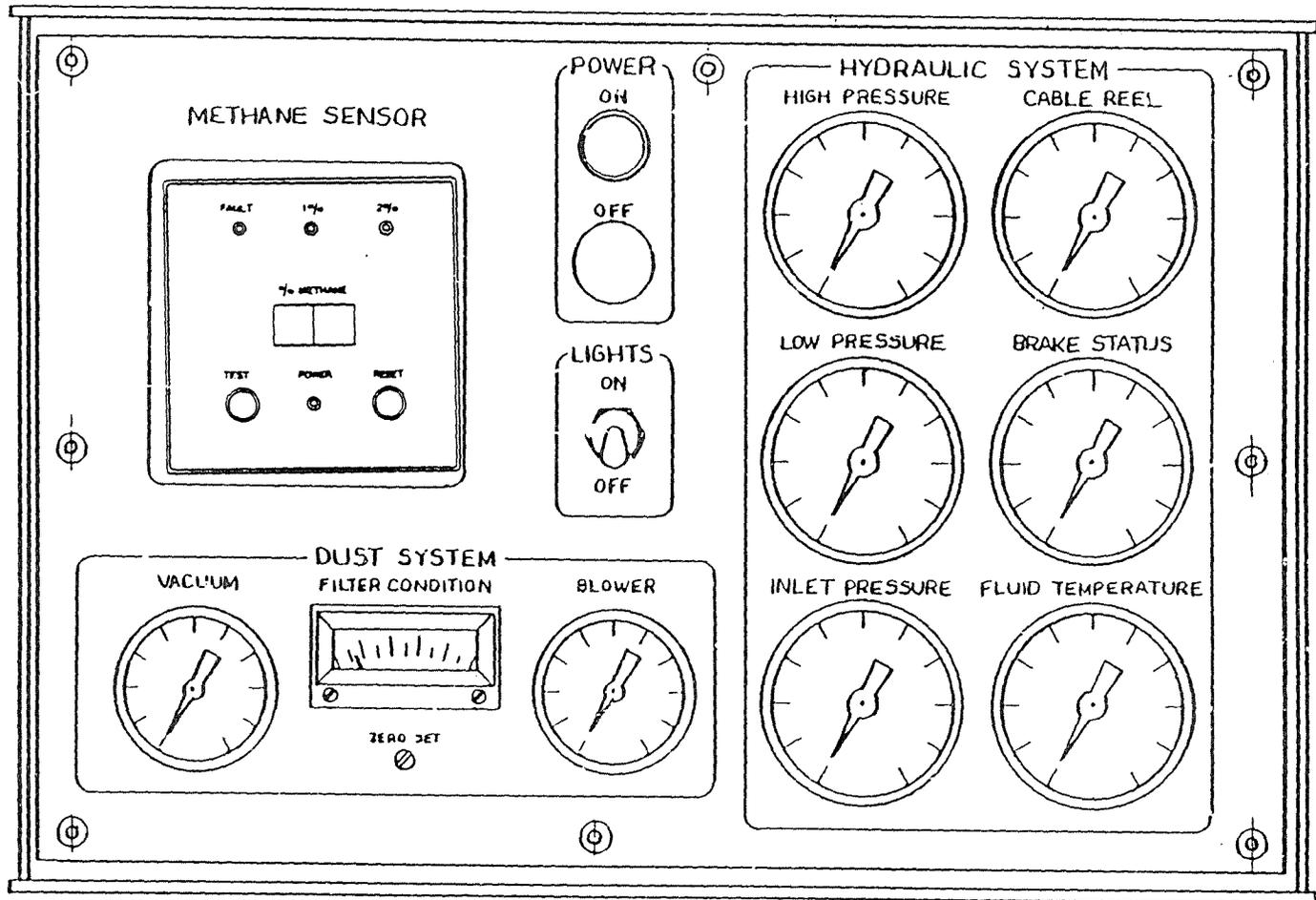


Figure 5. Machine Function Panel

The flexible drill is mounted on the front end of the frame in a support structure. The drill support is rotated about a horizontal axis by a rotary actuator. The drill has three positions - stow left, stow right and vertical for drilling. The drill string is 1-3/8 inch diameter and is made up of short links connected by universal joints to accomplish the greater than seam height drilling. The roof bolt inserter, thrust/torque assembly and the plate mechanisms are all mounted in a carriage assembly which moves in the frame to properly position the bolt at the hole centerline. The roof bolt inserter bends, straightens and inserts the bolt into the hole by means of a swing arm, drive roller and clamping cylinder. When the bending and straightening functions are completed the bolt head extends approximately twelve inches from the roof.

The thrust/torque assembly is mounted under the RBI when stowed and is deployed to its operating position on the bolt centerline by a hydraulic cylinder and linkage. The thrust cylinder is extended to push the bolt to the roof and the torque assembly rotates the bolt to a preset torque level via a hydraulically driven gear train. Bearing plates, stowed in a magazine, move forward with a deployment mechanism and are captured in the plate receiver. The plate magazine and deployment mechanism are located at the top of the carriage assembly and the plate receiver is mounted to the RBI swing arm.

The frame, which carries the drill and carriage assembly, also interfaces with the elevation assemblies. These elevation assemblies raise and lower the entire frame from tram height to operating height which varies depending on the coal seam thickness. The elevation assemblies contain foot jack hydraulic cylinders which when extended place the innermost elevation track to the floor. The main mast hydraulic cylinder is used for raising/lowering the elevation assembly track sections and the bolter component assembly frame. In addition, each elevation assembly also contains two roof support cylinders for locking the entire elevation assembly between the roof and the floor. This locking action not only stabilizes the tool module, but also is used to react drilling and bolting loads into the roof and floor respectively, rather than through the chassis' tires. The elevation assembly also contains indexing cylinders for moving the frame two inches down/up to facilitate swinging the drill from its operate to stow position without loss of hole centerline alignment.

Tram and bolting controls and displays are mounted in the operator's cab. Proportional control for tramming and steering the chassis is provided by a joy stick. The bolting functions are hydraulically controlled by an operator-initiated multiposition sequence valve. From the cab the operator is able to hand feed bolts into the RBI. He has two seating positions, one facing fore to drill and bolt and the other facing aft for tramming from place to place. The cab also contains a panel which enables the operator to actuate every machine function individually. A machine function panel has displays of vehicle system status, such as hydraulic pressure, fluid temperature and methane level.

The articulated chassis is a further development of an Innovative Industries Model 82 Scoop frame with modifications to convert it to a roof bolter and to accommodate the BCA. The chassis height is 26 inches, width is 96 inches and the length is 23.1 feet including the BCA. Steering is accomplished by dual

cylinders mounted symmetrically between the frame sections and angled to the pivot. The machine is driven by four hydraulic motors. The rear frame section has fail-safe brakes built into the drive system. The tires are 28 x 12.5 - 15 and have footprint pressures of 38 to 42 psi. The tram speed is variable to 2.0 mph.

The rear frame section also includes a seventy gallon capacity fluid reservoir with appropriate filters, 75 hp electrical motor, a 2,500 psi high pressure 30 gpm pump, a 460 psi low pressure 5 gpm pump, dust system and its necessary vacuum blower, a starter box and cable reel assembly. The front section of the chassis contains the operators cab, the BCA hydraulic components, the bolt tray and the BCA.

The entire machine is lighted by incandescent area luminaries and incandescent head lamps.

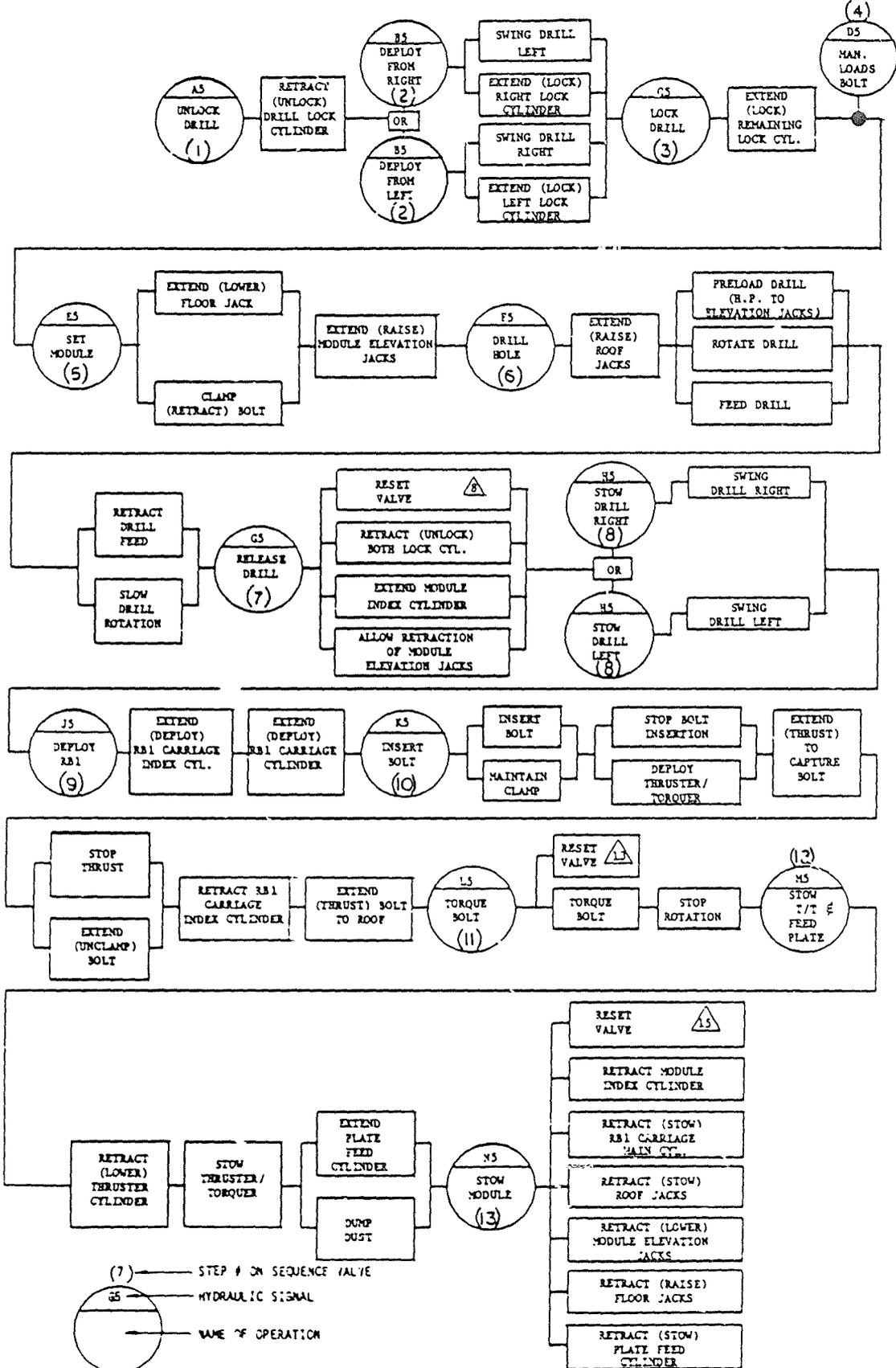
2.2 Systems Operation - The machine may be operated by a single miner. The operation is as follows: Bolts and plates are loaded at an off-site location. The machine is driven from place to place by tramping in an aft direction to the last crosscut. For the final tram to the place to be bolted the operator will change to the drill bolt seat and tram with the BCA forward to the first hole location. The machine will tram with all BCA components in the stowed position. That is, the drill will be left or right, the carriage will be back, the thrust/torque assembly will be beneath the RBI and the elevation assembly cylinders will all be contracted.

When the machine arrives at the first hole the operator will perform the drilling and bolting functions using the main control valve, Figure 3. He will unlock the drill and swing it to the vertical. He then hand feeds the bolt by lifting it from the tray and placing it on rollers which will align it with the RBI rollers. He pushes the bolt forward until it goes through a bearing plate on the swing arm and comes to rest against a stop on the drill support frame. He locks the drill, the bolt is clamped by the swing arm and the BCA is raised with the elevation assembly foot section going to the floor followed by the main cylinder extending until the drill is preloaded against the roof. The locating pads are placed against the roof and the hole is drilled. The drill string is retracted, the locating pad indexing cylinders are extended to lower the drill from the roof and the drill is unlocked. The drill is swung to the left or right stow position (away from the rib) and locked. The module is raised back to the roof and the carriage is simultaneously moved to its operate position. The bolt is bent and fed by the RBI into the hole until the head is approximately twelve inches from the roof. The thrust/torque assembly is deployed and the thrust cylinder is extended until the chuck engages the bolt head. The swing arm is unclamped and the RBI is moved backward enough to allow the thruster cylinder to pass as the bolt is thrust to the roof. The bolt is torqued by the chuck through a motor driven gear train, then the thruster is retracted and stowed. The plate for the next cycle is then pushed forward by extending the plate feed cylinder and locked in the receiver by locking jaws. The plate feed is stowed, the elevation assembly is returned to the stow position and the machine is ready to tram to the next hole. The process is repeated until the entire place is bolted.

2.3 Detailed Operations - The following is a detailed step by step operational sequence required for roof bolting assuming the bolt tray and plate magazine are loaded. In addition, a plate must be in both the receiver and the intermediate position. A flow diagram which depicts the bolt installation process is shown in Figure 6. The circles correspond to operator initiated steps and the squares indicate the actuator operations.

In order to complete a single bolting cycle, the operator will:

1. Tram the machine forward by pushing the joy stick forward until some convenient point on the chassis is aligned to an existing bolt. When arriving at the hole location he will set the joy stick to the vertical (or intermediate) position to stop the machine. The spring loaded joy stick returns to neutral and the brakes automatically set. The operator then engages the emergency brake and raises the canopy.
2. Move the Bolt/Tram selector lever to the forward (Bolt) position.
3. Cycle the main control valve (Figure 3) to the UNLOCK DRILL position. This position will retract both drill lock cylinders.
4. Cycle the main control valve to the DEPLOY position. As the drill swings to the vertical, a locking pin which rides in the slot on the drill frame is extended to stop the drill motion at the vertical position.
5. Remove a bolt from the bolt tray and set it into the feed tray and rollers and push it forward until it comes to a stop. The bolt will go through the bearing plate hole and stop when it contacts a stop plate on the drill frame.
6. Cycle the main control valve to the LOCK DRILL position. This action will extend the one retracted drill lock cylinder.
7. Cycle the main control valve to EXTEND MASTS position. This action will simultaneously disengage the tram circuit and the steering circuit and extend the floor cylinders placing each foot on the floor. The RBI swing arm clamps the bolt at this point. While performing this operation, two hands are required to insure that the operator is not near the bolt head. When the swing arm clamps, the bolt head will move down. The main elevation cylinders are then extended until the drill contacts the roof. The BOLT CLAMP/FEED knob must be depressed in order to allow the RBI to clamp the bolt.
8. Cycle the main control valve to DRILL HOLE position. This action extends the four locating pad cylinders to the roof, preloads the main elevation cylinders and engages the clutch for the dust system's blowers. The drill string is next rotated and fed to drill the hole. The bit is fed to a preselected depth, stopped and retracted automatically.



(7) — STEP # ON SEQUENCE VALVE
 GS — HYDRAULIC SIGNAL
 NAME OF OPERATION

Figure 6. Operations Sequence

LEGEND

9. Cycle the main control valve to RELEASE DRILL. This motion will reset the drill feed valve for the next cycle, retract both drill lock cylinders to allow the drill to be free to swing to stow, extend the locating pad index cylinders which will lower the BCA and retract the main cylinders of the elevation assembly approximately two inches. These functions will enable the drill to be swung to the stow position without striking the roof.
10. Cycle the main control valve to STOW. This action stows the drill to the preselected side position (either left or right) provide clearance for the subsequent steps involving the RBI and thrust/torque assembly. As the drill is moving to one side the lock cylinder on that side is extended to lock the drill in the stow position.
11. Cycle the main control valve to the DEPLOY RBI position. The RBI main cylinders and indexing cylinders will extend, as the RBI moves forward and up to place it so the bolt will center on the drilled hole. The main mast will extend and the locating pad indexing cylinders will retract approximately two inches, thus returning the BCA to the roof.
12. Cycle the main control valve to INSERT BOLT. The swing arm clamp will remain closed and the drive wheel and rollers will bend and restraighten the bolt, which will be driven into the hole until the head actuates the drive wheel motor stop. The thrust/torque assembly is deployed until the thruster cylinder is vertical and in line with the bolt. The thruster cylinder extends until the chuck engages the bolt head. Thrusting is ceased and the swing arm is opened. The opening between the swing arm and the RBI is sufficient to enable the thruster cylinder to fit through when thrusting, but this opening isn't on line to allow the cylinder through. Therefore, the RBI is retracted half the distance that the swing arm had just opened thus aligning the RBI/swing arm opening with the thrust cylinder. The thrust cylinder is extended and the bolt is pushed to the roof. The Bolt Clamp/Feed knob must be depressed in order to allow the RBI to feed the bolt.
13. Cycle the main control valve to the TORQUE BOLT position. The torquer motor is actuated and rotates the chuck/bolt via a gear transmission until a preset torque level is reached, and rotation ceases.
14. Cycle the main control valve to the STOW T/T position. The thruster cylinder is retracted, followed by retraction of the thrust/torque deployment cylinder. This places the thrust/torque assembly in the stow location. The next action extends the plate feed cylinders which push a plate from the magazine to an intermediate position and concurrently move the plate that was in the intermediate position to the plate receiver. The dust box cylinder is also extended to open the door for dumping.

15. Cycle the main control valve to RETRACT MASTS position. This action will retract the RBI main cylinders moving it down the ramp to its stowed location. Also the elevation assembly cylinders will be retracted to prepare for tram. After these events have occurred the tram and steering systems inhibits are removed.

3. CONCLUSIONS AND RECOMMENDATIONS

3.1 Conclusions - The results of this project demonstrate that roof bolting with an articulated chassis with the operator located approximately five feet from the bolting operation is a workable concept. The use of the operator's visual and auditory senses to provide feedback for the status of the bolting operation also proved feasible. The all-hydraulic control system performed well during the testing but is bulky and contains a large number of components and hydraulic connections. The ARM Bolter was able to bolt the test site in bolting patterns for either conventional or continuous miner operations. Both the operation and maintenance of the Bolter were within the capabilities of the mine personnel.

3.2 Recommendations - The complexity of the control system, the effectiveness of the dust collection system and the ability to accommodate uneven roof conditions need to be addressed in subsequent projects.

3.2.1 Control System - The ARM Bolter Hydraulic Control System was designed using discrete valve components interconnected with tubing. This followed the module concept used in the mechanical design. This approach allows the control system to be fabricated with off-the-shelf components and provides the maximum flexibility during the control system development. The operation sequence and control linkage operation have been verified by the testing so that an integrated hydraulic system or microprocessor control system could be utilized to reduce the control system bulk and improve the maintainability.

3.2.2 Dust Collection System - The Bendix Flexible Drill utilized in the ARM Bolter requires a good dust collection system. The Donaldson system used on the bolter suffered from poor fabrication and a need for rather frequent servicing of the third (paper element) stage. The failures of the dust system were directly responsible for packing and breakage of the drill head. The fabrication problems were poor fits of the dump valves and access doors which caused vacuum leaks. The paper filter seems to fill rapidly due to the fine particle size created by the drill and may be resolved by working with the dust box vendor or changing to a different style of dust box.

3.2.3 Roof Condition Tolerance - The present BCA design allows for roof unevenness of up to approximately two inches. In order to allow wider usage of the ARM Bolter, a greater roof unevenness should be accommodated. This would require redesign of the tool carriage.

4. SYSTEM DESIGN

4.1 Mechanical Design

4.1.1 Performance Criteria - Figure 7 outlines the primary parameters and requirements to which Bendix designed the bolting system. Bendix has been able to reduce the machine tram height from the maximum 43" requirement to 38" overall height. The gradeability has been increased to 15% and the bolt proximity to face and rib has been reduced to less than 16".

4.1.2 Design Goals - The design goals which are depicted in Figure 8 have been adhered to throughout the design evolution process. The relationship between system complexity and operator convenience was continually evaluated and optimized. Functional design, maintenance, fabrication and operation were primary design criteria. It is firmly believed that industry acceptance is predicated upon system reliability as well as performance. Previous USBM contracts were reviewed and certain results implemented in the following areas: Drill, RBI, Illumination System, Cable Reel Take-Up, Canopy and many human factors aspects.

The control system and function actuators are entirely hydraulic. There are no electronic or pneumatic sensors. The troubleshooting and maintenance skills required avoid technical skill mixing. The operator feedback is visual and is discussed in the human factors section.

The modular component design enables the mechanic to change out system elements quickly and perform sensitive maintenance in the more suitable shop environment.

4.1.3 Dust Collection System - The dust collection system, shown schematically in Figure 9, is required for the removal of the drill debris. The system consists of a blower, dust collector box, vacuum/blower, muffler and supporting controls and gauges.

The system operates when pilot pressure during the drilling cycle engages the clutch for each blower. Ambient air is drawn in through a filter on the inlet side of the ROOTS 2504J blower. The outlet of the blower is connected to a flexible hose which goes through the center of the drill string to an outlet port beneath the drill bit. As the drill is retracted, debris which clings to the drill string sections is evacuated via a manifold at the top of the drill into a vacuum hose and passes through the Donaldson XYXOO-5109 Roof Drill Dust collector. This system has three filter stages. The first stage contains a tangential cyclone which removes approximately 95% of the dust. The second stage has reverse flow cyclone tubes which remove an additional 4% of the dust. The third stage contains a cartridge type heavy duty pleated paper filter encased in a perforated metal housing. Most of the remaining dust is collected in this 5 micron pore size filter. The clean air passes through the second ROOTS 2504J unit, used in this case as a blower, or through a muffler for silencing and out to the atmosphere. The system is automatically turned off by disengaging the blower clutch when the drill string is stowed at the completion of the drilling cycle. After the bearing plates are fed forward in the STOW T/T step of the sequence the dust dump cylinder is extended and the first two stages are emptied.

OPERATOR REMOTE FROM TOOLS

ENTRY 16 TO 20 FT

BOLT LENGTH 4 TO 8 FT

MACHINE HEIGHT (MINIMUM POSSIBLE) ≤ 43 "

MINIMUM GROUND CLEARANCE 6" (DRILL STRING MAY GO BELOW 6")

BOLT TORQUE VARIABLE 0 TO 225 LB-FT/ $\pm 10\%$ PRESET VALUE

MSHA DESIGN COMPLIANCE

SPEEDS COMPARABLE TO STD ROOF BOLTERS/NEGOTIATE 10% GRADE

**APPROVED LIGHTING, METHANE, WARNING AND SHUTDOWN,
DUST COLLECTION SYSTEMS**

BOLT WITHIN 18 INCHES OF FACE/18 INCHES OF RIB

EASE OF MAINTENANCE AND OPERATION

**CONTROLS SHALL UTILIZE RESULTS OF PREVIOUS/CURRENT
USBM PROJECTS**

**OPTIMIZE COMPLEXITY/RELIABILITY/OPERATOR SKILL/
MAINTAINABILITY TRADE OFFS**

MINIMIZE MODULE PROFILE

DESIGN SAFETY FACTOR OF 3

ACCEPTANCE BY INDUSTRY

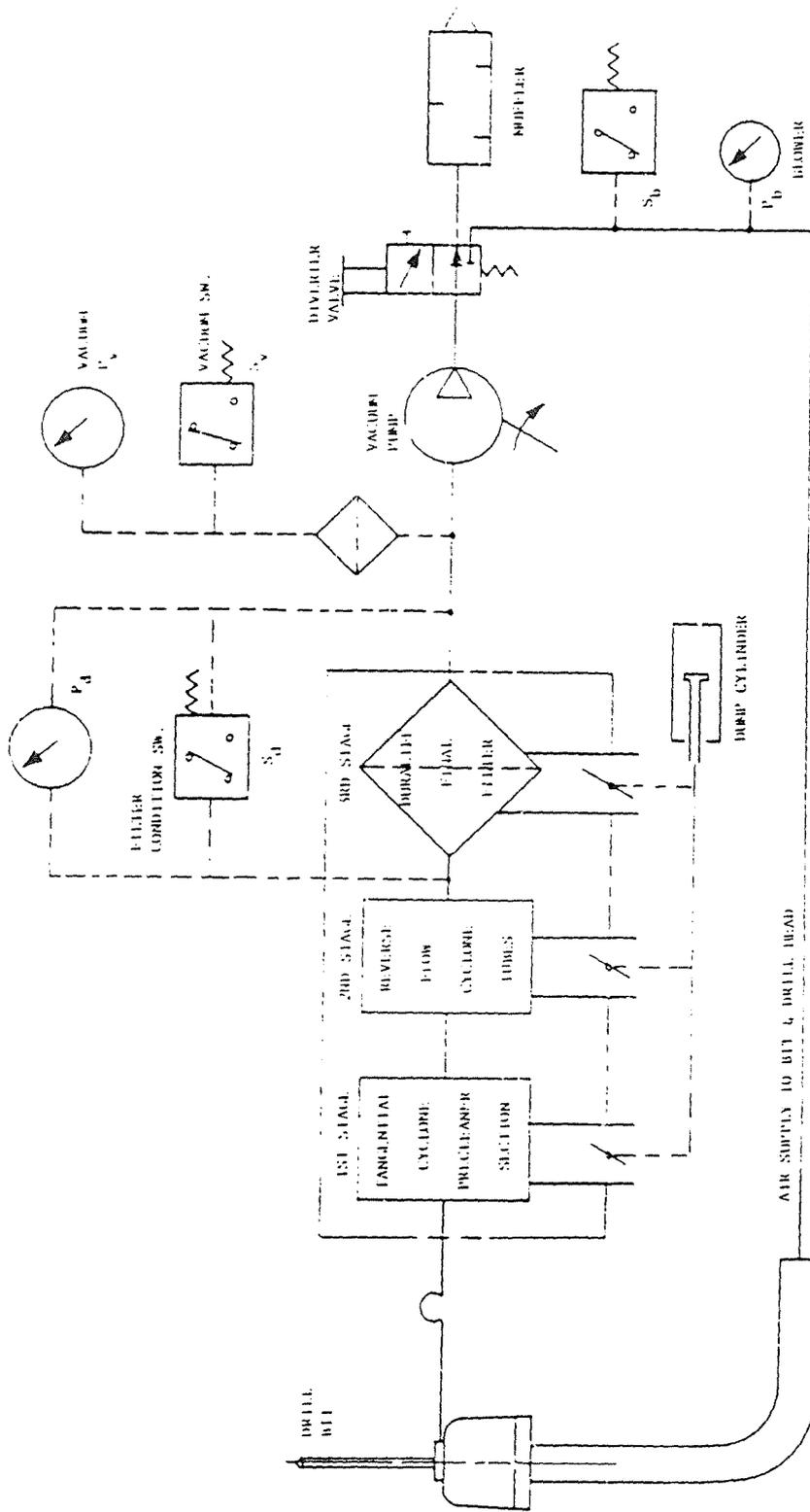
UTILIZE PREVIOUS USBM CONTRACTS

OPERATOR COMFORT & SAFETY

ALL HYDRAULIC CONTROL & ACTUATION

USE OF MODULAR DESIGN

Figure 8. Design Goal



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Figure 9. Roof Bolter Dust Collection System

Three pressure monitors are mounted in the operator's cab to enable him to evaluate the system's performance. In addition, the system has automatic shutoffs built in to protect the system. Absolute pressure is monitored at the output side of the Roots Blower which pressurizes the drill string. This pressure nominally operates at 10 psig and has a back pressure relief vent set to 15 psig and an automatic shutoff to protect the blower and drill. Another pressure gage monitors the input side of the vacuum blower. This pressure nominally operates at 8"Hg and contains a vacuum relief valve to protect the vacuum blower and drill. If the vacuum increases to 15"Hg the machine will be automatically shutdown for servicing. A third gage reads differential pressure across the filter element. If this pressure rises above 25"H₂O the system should be shut down at the end of the cycle and the filter element should be replaced. An automatic shut down is built into the system that will be activated at 40"H₂O. At this point the blowers and the drill will be shut down.

4.1.4 Methane Detection System - The methane detection system is an Appalachian Electronic Instruments, Inc., Ronceverte, West Virginia, model 102A. The system consists of three components: an Amplifier Readout Unit, a power supply and a detector sensing head. (see Figure 10).

The power supply, model PN7163, is mounted in a permissible box. It converts the incoming 440 ac voltage to 12 volts dc. The Amplifier Readout Unit is mounted on the large panel, Figure 5, and is readily visible to the operator. This unit contains digital LED readouts which indicate percent methane. The detector sensing head is mounted on the front end of the chassis. It contains a detector connector and a removable sensor, whose resistance changes in the presence of methane. The methane monitor power supply is energized whenever there is power to the Bolter.

If methane is present the signal from the sensor is amplified, converted to percent methane, and displayed numerically on the readout unit. The tenth percent digit is displayed in yellow and the unit percent digit is red. If the concentration reaches 1% the yellow LED starts flashing and continues as long as the concentration remains 1% or more. If the concentration reaches 2% the red LED is lighted and the machine is simultaneously shut down. The machine can not be restarted until the concentration drops below 2% and a reset button on the readout unit is operated. The readout unit contains a test button which simulates a methane signal from the sensor, checks the displays and shuts down the machine. The detector must be checked independently with a calibrated sample of gas.

4.1.5 Traction Drive System - The standard Innovative Products scoop (In-Pro) employs a mechanical drive system with drive shafts, differentials, and transfer case. The USBM/Bendix system requirement for an open machine center (for bolt clearance) rules out the mechanical drive because the axle and differential take up needed center space. The Sundstrand hydrostatic drive replaces the mechanical drive system and provides additional advantages as well. Proportional speed control, less weight and space, and dual pump utilization are benefits of the hydrostatic system.

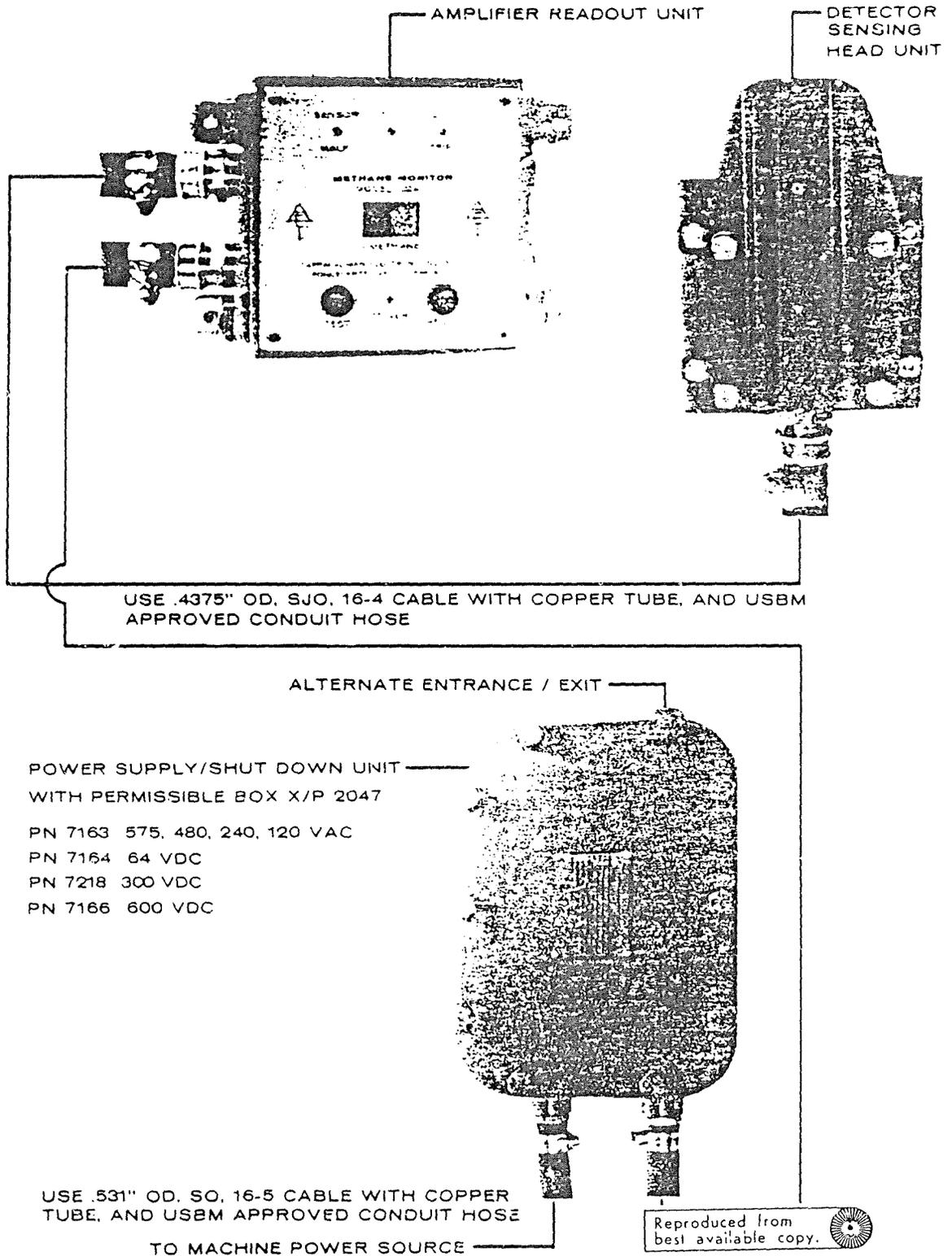


Figure 10. Complete Methane Monitor Model 102A

The traction system is basically comprised of the following: Sundstrand 22 series, variable displacement, pressure compensated, pump; four Sundstrand fixed displacement, axial piston, wheel motors, four Fairfield wheel drive reducers; two AUSCO fail safe, inline brakes, and a joystick speed/steering control. The wheel reducers may be disengaged by reversing the cap which provides for convenient vehicle towing.

The fail safe brakes require hydraulic pressure to disengage and are engaged as follows: during the bolting cycle when the emergency brake is applied, whenever the joystick is in neutral, and whenever there is a loss in hydraulic pressure or electrical power. The brake system meets the requirements of part 18 of title 30, Code of Federal Regulations.

The vehicle is designed to accelerate to 2 mph on a 15% grade in 3 seconds.

4.1.6 Power System - The 75hp AC electric motor and appropriate controller is part of the In-Pro supplied vehicle. The above, along with the cable reel, are off-the-shelf components. This facilitated and simplified the certification process.

The voltage requirements are as follows: motor, 440 VAC; illumination system, 110 VAC; methane monitor, 12 VDC; and operator's station 12 VDC. The methane monitor system power supply (P.N. 7103) will provide the 12 VDC from 440 VAC.

4.1.7 Hydraulic System - The hydraulic configuration consists of two pressure compensated, variable displacement systems. A high pressure pump (2500 psi @ 30 gpm) supplies the drill, roof bolt inserter, bolt torquer, main mast, floor supports, drill swing, locating pads and cable reel. A low pressure pump (450 psi @ 5 gpm) supplies the canopy, drill lock locators, carriage deploy, thrust/torque deploy, thruster, plate feed, dust box dump, blower clutch and pilot control pressures. The reservoir is two 35 gallon units with filtered filler pump.

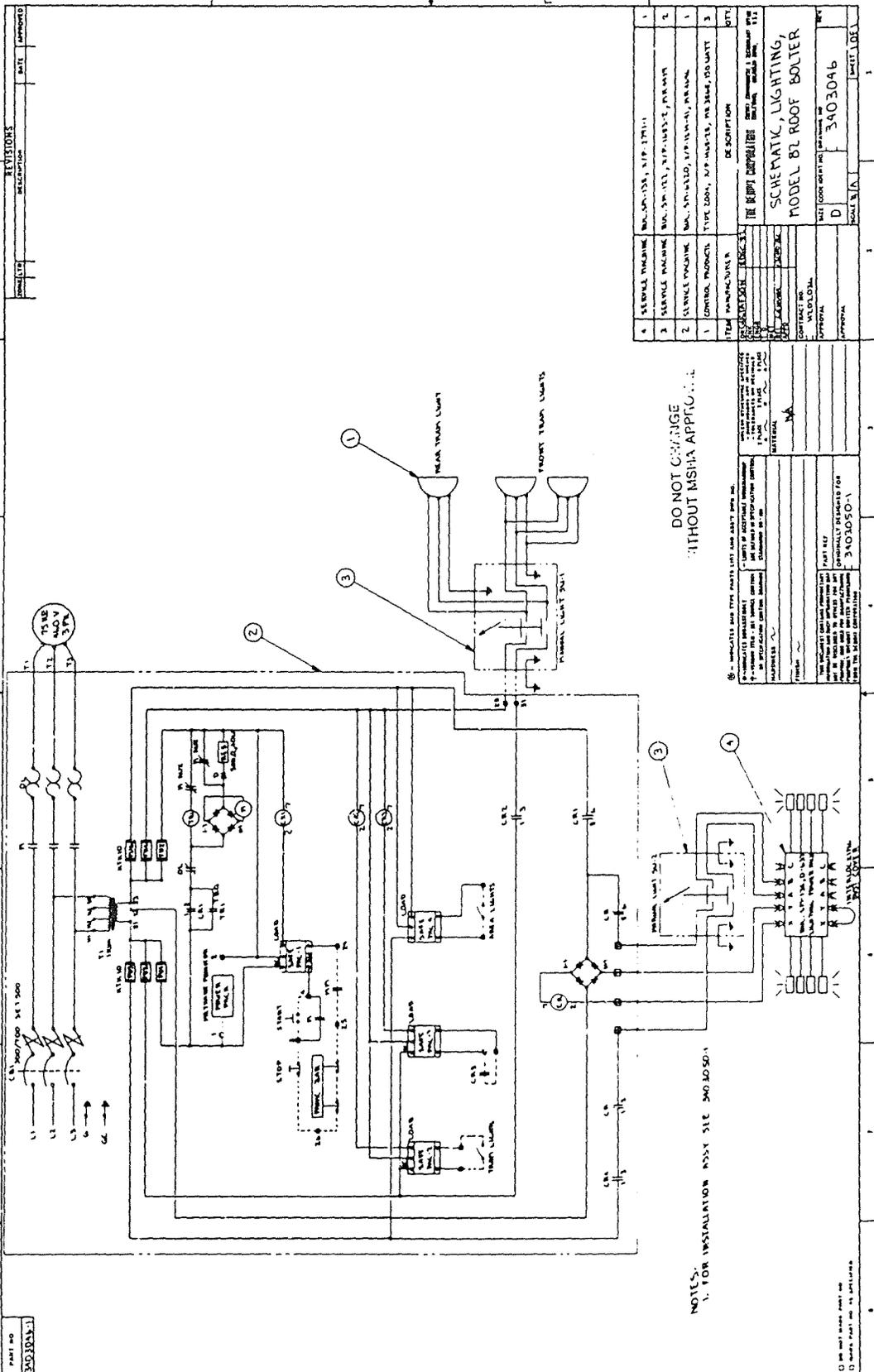
4.1.8 Illumination System - The bolter is equipped with an incandescent area lighting system supplied by Service Machine Company. This system utilized a Service Machine power supply mounted just ahead of the cable reel. One incandescent tube is mounted at each of the four wheels, one tube is mounted vertically at each side of the Bolter Components Assembly (BCA). One tube is mounted vertically on the rear of the machine and an eighth unit is located on the top of the machine just behind the articulated joint. The lighting system consists of standard components mounted according to the manufacturers recommendations. The lighting during the underground testing was adequate and application was made to the Beckley Electrical Testing Laboratory for approval. The application was shelved because of time funding constraints. The configuration is shown on Figure 11 and 12.

4.1.9 Fire Suppression System - The Ansul LT-A-101-20 Dual Mine Fire Control System is placed on the machine for fire protection. The system contains manual actuators located on either side of the front end of the machine,

REVISIONS
REVISION NO. DESCRIPTION DATE APPROVED

3403046

3403046



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NOTES:
1. FOR INSTALLATION SEE 3403050-1

ITEM NO.	DESCRIPTION	QUANTITY
1	SERVICE MACHINE	1
2	SERVICE MACHINE	2
3	SERVICE MACHINE	1
4	CONTROL PANEL	1
5	TRAMP LIGHTS	3

THE MSHA APPROVAL

SCHEMATIC, LIGHTING,
MODEL 82 ROOF BOLTER

3403046

DATE: 11/15/81

BY: [Signature]

APPROVED: [Signature]

PROJECT NO. 3403046

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Figure 12. Lighting Schematic

hoses for distribution, two cylinders which contain the dry chemical for fire extinguishing and a series of carefully placed fixed nozzles to spray the chemical.

Should the operator see a fire on the machine he would pull a safety clip and push a button to manually puncture the CO₂ cartridge which will pressurize the dry chemical in each of the cylinders. This dry monoammonium phosphate based chemical will be distributed to the fixed nozzles and sprayed in a fan shaped pattern on the flames. Nozzles are located in the rear section of the chassis and provide coverage of the electrical starter box, 75 hp ac motor, cable reel, wheel brakes and blower clutch.

4.1.10 Operator Cab - The operator's cab consists of a structure integral with the chassis, controls and displays, and a protective canopy. The various controls and displays, their layout and configuration are shown in Figure 3, 4 and 5.

4.1.10.1 Cab Structure - The cab is made up of a $\frac{1}{2}$ " plate enclosure measuring 65" in length and varying in width from 44" at the pivot end to 29" at the Tool Module end. The operator cab has been laid out to facilitate operator access to all controls and was designed after a human factor study of the operator requirements. The cab is exceptionally roomy and provides space for stowage of tools and the self contained breathing apparatus.

4.1.10.2 Protective Canopy - The canopy is as small as possible yet protects the operator even as he reaches to manually feed a bolt. The canopy height is adjustable and is raised to the roof during bolting to provide maximum visibility. However, the 13" canopy stroke restricts roof contact in seam heights in excess of 46".

The canopy support cylinders provide built-in pilot check valves as a safety measure. In the event of excessive roof loading or a ruptured hose the canopy will not abruptly collapse. The canopy is certified to pass the requirements set forth in the MESA informational report 1002, "A Testing Procedure for the Certification of Underground Protective Cabs and Canopies."

The three support columns are telescoping square tube sections designed to withstand canopy/roof impact while tramming. The top section is the weakest member and is inexpensive to replace in the event of excessive impact which may produce bending. The support columns are located to provide minimum interference with visibility during tramming and bolt installation.

4.2 Bolter Component Assembly - Figure 13, drawing number 3401600, depicts the bolter component assembly which is essentially a bolt insertion system made up of the drill, elevation, carriage and frame assemblies. These items are discussed individually in Sections 4.2.1 through 4.2.8.

4.2.1 Frame Assembly - Manufacturing cost, ease of assembly, and structural integrity considerations have led to this frame concept. The frame is not an integral weldment but is made up of individual structural members precisely

located with dowels and bolts. These smaller elements are more conveniently machined and when bolted to form a structure, distortion is not a problem as may be the case with welded fabrications. Also, it is less expensive to machine small parts than a large weldment. The fit and clearance tolerances are easier to hold on small items and if the frame is damaged or additional machining is required, the element in question can be removed and repaired or replaced without impacting the entire frame. This is also in keeping with the modular component philosophy.

The base section is welded using with pads on the top. After the base is fabricated and stress relieved, the pads are faced (machined to be level) and dowel holes are precisely located. This is the largest member and locates the other frame elements as shown.

4.2.2 Carriage Assembly - Figure 14 illustrates the component carriage which is comprised of the roof bolt inserter, thrust/torque assembly, thrust/torque deployment assembly, and plate feed system. The components are modular for ease of maintenance. This permits unit change out at the working place and component repair in a more appropriate shop environment.

4.2.3 Roof Bolt Inserter - The roof bolt inserter (RBI) is similar in operation to the USBM/Benfix developed anchor bolter but has been redesigned to interface with the thrust/torque assembly and plate feed receiver. The overall size has been reduced to enable the system to work in a 37" seam. The following tabulation outlines the changes incorporated into the ARM RBI:

- Drive wheel diameter decreased
- Drive wheel motor size increased
- Drive wheel motor relocated
- Splined drive gear (was keyed)
- Splined drive wheel (was keyed)
- Splined worm shaft (was keyed)
- Relocated rear reaction roller
- Decreased straightening roller diameter
- Decreased straightening roller spacing
- Modified straightening roller adjustment
- Provided cam clearance cavity
- Minor cam geometry modification
- Modified clamp arm for plate receiver
- Modified clamp arm latch
- Modified shuttle pin and ramp
- Added hydraulic bolt feed switch
- Torque reaction block incorporated

The entire housing is smaller and of modular design.

4.2.4 Thrust/Torque Assembly - This assembly thrusts the bolt into the hole and spins the bolt to the preselected torque level. The thruster is a two stage double acting cylinder which thrusts the bolt and torquer assembly 16 inches upward with a force of 500 lbs. The design process was arduous due to the limited space available and the high torque requirement. The length was limited

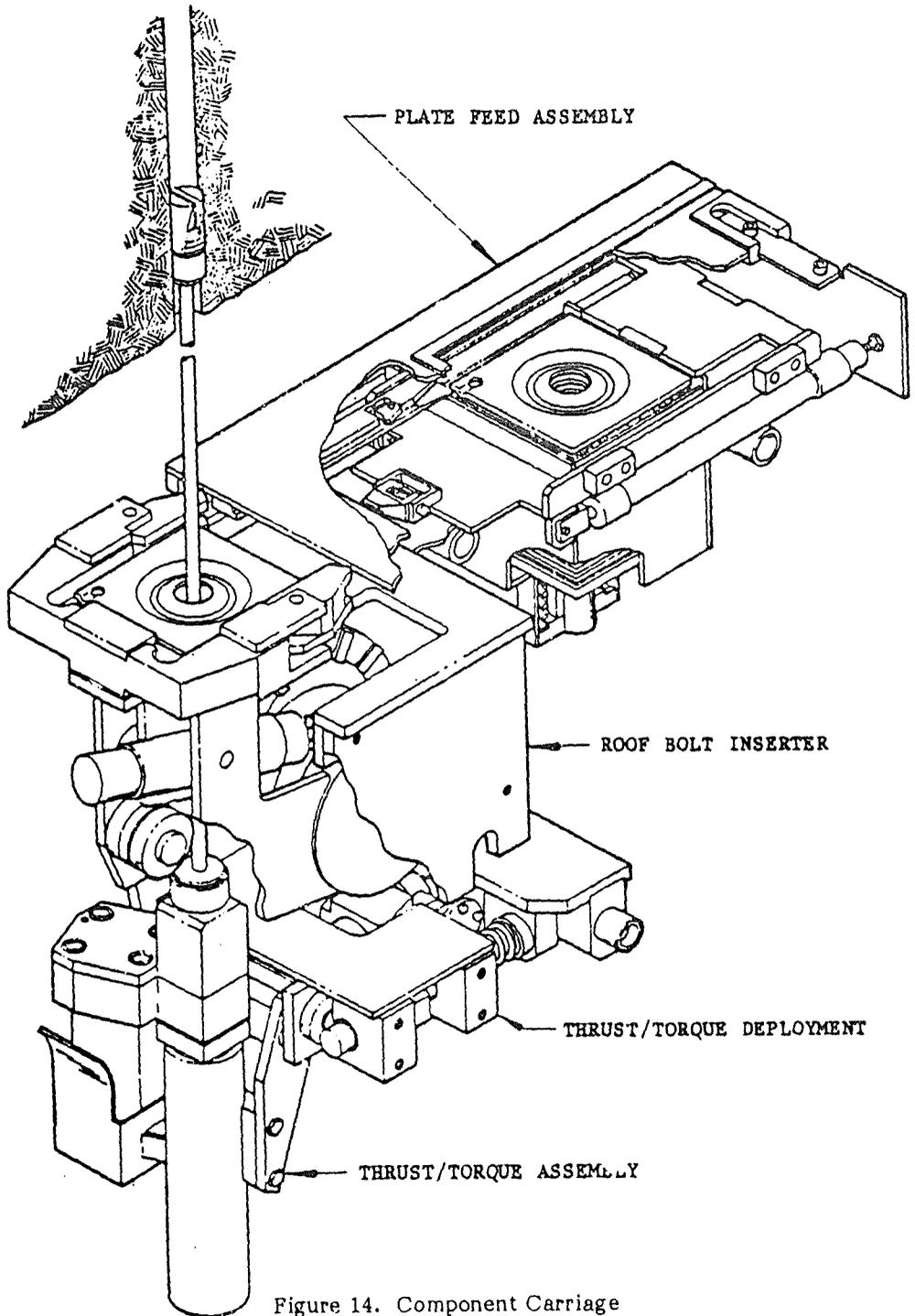


Figure 14. Component Carriage

by the drill string clearance requirements. The top housing must clear the plate receiver and the outline is dictated by the RBI and the 2 1/8" opening between the drive wheel and clamp arm rollers. Because of the space and torque requirements, 29½ degree pressure angle gears were used. The space limitations also precluded using needle bearings in some areas; phosphor bronze alloy plain bearings were used instead.

4.2.5 Thrust/Torque Deployment Assembly - The deployment assembly, serves two functions: shifting the thrust/torque assembly between the stow and operating positions and anchoring the thrust/torque assembly in a fixed position under the bolt while the carriage retracts to provide room to thrust the bolt. As the double rod deploy cylinder extends, the thrust/torque assembly is rotated from the horizontal stow position to a vertical operation position under the bolt. Two locking pins extend into the frame. Shims and screw adjustments are used to initially align the unit. This allows for greater manufacturing tolerances.

The frame, which is attached to the RBI carriage, slides on the guide rods when the carriage deploy indexing cylinders retract. The two rod springs reset the device when the deploy cylinder is reversed.

4.2.6 Plate Magazine, Feed, and Receiver - The plate feed system consists of three components: the plate magazine, plate feed, and plate receiver. The 7.75 lb/in magazine spring forces the plates up against the feed chamber at which point the top plate is pushed forward to the intermediate feed location. The previous plate (which was in the intermediate position) is shuttled into the receiver arm. As the plate enters the receiver, two locking jaws capture the plate on the back end. The front end of the plate is under a hold down lip. The jaws are "over center" detent spring cams. The plate stays in the receiver arm as it swings down to receive a bolt which is inserted into the plate hole.

Mounting the plate receiver on the clamp arm was beneficial in that the plate does not have to be lifted to clear the anchor as it is wrapped under the plate. This results in a less complex device. A further advantage is that the operator can see the plate as he inserts the anchor into the hole, thus providing a simple and reliable visual feedback indicator.

After the bolt has been initially bent its expansion shell is located under the drilled hole. As the bolt is driven further it enters the hole in the roof and moves until the bolt head reaches the drive wheel/head interface. The thrust/torque chuck captures the bolt head and the clamp arm is opened. The plate, retained in place by the bolt, snaps the receiver jaws open permitting the plate to disengage from the receiver arm assembly. The thruster then pushes the bolt head and plate to the hole.

4.2.7 Elevation Assembly - The elevation assembly in addition to locating the module against the roof, preloads the drill, indexes the module up/down during bolting cycle, interfaces the module with the frame, and serves as a temporary roof support while bolting. The floor cylinders are used only to position the inner telescoping section to the floor while bolting and for lifting this section 6" during tramping. While tramping the entire module and

elevation assembly weight is carried through the floor cylinders. No drilling or roof loads are ever seen by the floor cylinders however. The second telescoping section is attached to the vehicle frame. The third section floats and provides rigidity. The fourth, or outside mast section, is attached to the module. The locating pad indexing cylinders are also affixed to this section. The telescoping main mast cylinder attaches between the first (inner) and fourth (outer) mast sections.

The bolting seam height range is between 37" and 60". The tool module may be raised or lowered depending on seam height. To accommodate a 60" seam the module is raised 20 inches, and the inner mast is lowered 6" to the floor. To bolt a 37" seam the module is lowered 3", the inner mast is lowered 6" to the floor, leaving a 3" ground clearance. After the hole is drilled and the drill is swung to the side, the locating pad indexing cylinders will lower the module 2", leaving 1" ground clearance. It is obvious that 37" seam bolting requires a fairly clean floor to obtain the clearance for indexing. However, the full two inch drop may not be necessary because .1/2" is the minimum drill swing clearance requirement that would provide 2 1/2" ground clearance if necessary.

4.2.8 Drill Assembly - The drill is essentially the same 1 3/8" flexible drill which was developed under a USBM/Bendix contract. A test drill has drilled (12,800) 8 ft. holes in the Roadside Mine near Grand Junction, CO and drilled 20,000 eight foot simulated holes in the laboratory. The drill used with this system incorporated improvements which have evolved from the above mentioned test program. A minor modification involved the way in which the drill depth indicator cable exits the drill. Clearance requirements necessitated this change.

The drill support frame, like the main frame, is made of dowelled and bolted elements for cost effective manufacturing. The drill and frame is rotated 62° to either side of vertical during bolt insertion to provide clearance for the RBI carriage and during tramming to present a lower profile. A rack and pinion type rotary actuator is utilized in conjunction with two locating/locking pins to position the drill assembly and resist the reaction loads. These hydraulically actuated pins insure that the drill is held in the appropriate location for drilling, tramming, or bolting carriage clearance. They engage into the drill support frame as it rotates over center or at either end of the swing arc to provide positioning. The frame also rests on a saddle pad which is part of the journal housing frame.

The drill string guide arcs from the drill and extends slightly below the module. This is necessary to maintain adequate clearance for the thrust/torque assembly and exhibit a 27" module profile to work in a 37" seam. The drill string is within the module profile, however, when the indexing cylinders lower the module.

5. TEST RESULTS

5.1 Laboratory Testing - The Bolter Components Assembly (BCA) and the hydraulic controls were tested by mounting the BCA in a test fixture which

allowed four foot long test samples of concrete in three inch diameter cardboard tubes to be mounted above the Flexible Drill. Approximately forty bolts were installed during this phase as the control system refinements and mechanical adjustments were made. The BCA was then attached to the chassis and the hydraulics installed in the right hand bay of the chassis.

The test fixture was again mounted over the BCA and the integrated ARM Bolter tested utilizing the In-Pro chassis hydraulic supply and dust collection system. Approximately seventy-seven bolts were installed during this phase of testing.

5.2 Underground Testing - The ARM Bolter was shipped to the Cari-Eagle #1 mine near Drennen, West Virginia. On 3/17/83 the machine was inspected by MSHA and West Virginia authorities and was trammed into the mine. Testing continued until 4/22/83. A total of 188 bolts were installed. Major failures were as follows:

1. On cycle 47 the plate receiver was broken when the operator jammed it against roof.
2. On cycle 83 several drive links in the Flex Drill were broken due to failure of dust collection system.
3. On cycle 133 the drill string stowage hose wore through at the bend just below the drill head.
4. On cycle 188 the flex drill stopped feeding due to a broken alignment key in the lower shaft.

Underground testing was curtailed due to funding limitations.