DESIGN OF A RETROFITTABLE TEMPORARY FACE SUPPORT SYSTEM

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

by

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16. Abstract

The objective was to develop and design a remotely operated temporary roof support system that provides a safe working environment between a freshly cut coal face and the last line of permanently supported roof in which to perform roof bolting activities. This system was to take the form of a retrofit package which could be adapted to a majority of the bolters currently in service.

The result is an integrated piece of hardware which will retrofit onto virtually all single boom bolters by removing the drill boom and relocating and modifying the hydraulic controls. The system is composed of three basic components: a pair of cantilevered roof supports which reach forward to the desired line of support, a mast type drill unit for drilling holes and torquing bolts, and a transverse slide assembly to carry the drill from hole to hole across the entry without relocating either the bolter or the roof support.

A converted bolter not only provides a much safer operation but is projected to increase the production speed as well as reduce the manpower required to operate a section. This improvement in productivity is shown to make the job of retrofitting a bolter cost effective in less than two months and provide a potential profit thereafter.

Based on the findings presented in this report it is recommended that a prototype be built and tested in an underground coal mine to demonstrate its effectiveness.

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FOREWORD

This report was prepared by Foster-Miller Associates of Waltham, Massachusetts under USBM Contract Number H0262016. The contract was initiated under the Coal Mine Health and Safety Program. It was administered under the technical direction of SMRC, with Mr. John Owens acting as the Technical Project Officer. Mr. David Vila 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 June 28 to December 28, 1976. This report was submitted by the authors on December 13, 1976.

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1. INTRODUCTION

This report summarizes the results of the survey, conceptual design and detail design as required by the U.S.B.M. Contract No. H0262016, a research and development contract for a Temporary Face Support System.

1.1 Objectives

The overall objectives of this program are to conceive, design, construct and test a remotely operated temporary support system that will provide a safe working environment between a freshly cut face and the last line of permanently supported roof in which to perform roof bolting activities. The specific objectives of Phase I have been the development of the proposed concept, a drilling and support system which can be retrofitted onto existing bolters or supplied as part of a new machine. This work has included the determination of the concept's applicability to roof bolters currently in service as well as a detailed design. A sample design of how a particular roof bolter machine can be outfitted with this retrofit package was also completed.

1.2 Background

The work performed at a freshly cut face is perhaps the most hazardous in the entire mining process. Roof falls in this region are responsible for more injuries and deaths than any other single cause. This is true despite the refinement of current temporary supports and the extensive operational precautions specified by MESA. The reason is two-fold:

a) Procedures are clumsy and time consuming to the point that they are frequently circumvented.

b) Even when followed precisely, the jack setting operation still exposes the miner to unsupported roof many times a day.

Therefore, it is necessary to have a support system which not only can be remotely installed but which also is so easy to use that it is readily adopted without resistance by the mining personnel. If the support system adds work or slows the cycle, it is likely to be rejected. For example, while a number of manufacturers have tried to add single hydraulic posts to the drill head for roof support, the posts are unpopular because they slow the bolting cycle.

In the following we present a bolter support design which will fulfill these requirements, i.e., that it is both safer and easier to use than current techniques. It has the further attractive feature that it is much easier for the operator to use it as designed than not to use it at all.

1.3 Summary

Figure 1 shows the FMA-TRS design. A single arm boom-type bolter is modified by removal of the boom and shortening of the front end of the frame. To this has been welded a TRS conversion kit consisting of:

a) Two roof support cylinders and support pads,
b) A crosslide (transslide) to carry a
c) Mast drill with dual operating controls

The features of this unit are as follows:

a) Controls for tramming the machine and actuating the supports are located at the back of the machine, so the operator can be under supported roof or a TRS during <u>all</u> operations.

b) The TRS is actuated and then not moved again until bolting of the row is complete. This should reduce chances of damaging the roof.

c) An entire row of bolts can be installed from a single bolter position in the center of the entry.

d) In its collapsed tramming position the entire unit is almost as compact as the conventional bolter before conversion.

e) With only minor changes the unit can be retrofitted to most single arm bolters in existence (determined by a survey of existing bolters).

f) The unit could be provided on new bolters as well.

g) It is simpler and requires less effort for the operator to actuate and set the TRS than to use conventional posts or jacks.

h) Furthermore, it is easier for the operator to use the system than not to, since it is very difficult to work beneath an undeployed system.

i) The mast drill unit has a centralizer which provides effective "hands-off" drilling.

The unit can put in a new row of bolts faster than a conventional single head bolter since

a) Only the slide and mast drill have to move between holes.
b) It is faster to actuate the TRS than to set conventional posts.
c) The mast drill provides more thrust than arm bolters (time saving in hard top).

This time saving is estimated to be 3.4 minutes per place in any top and more where the higher thrust is of benefit. A detailed economic analysis has shown that the retrofitting cost could be paid off in less than two months in mines where roof bolting limits the mining cycle. This single head machine should have almost as much production as a more expensive dual boom machine.

Thus, we recommend that the program proceed to fabrication and testing since a successful unit could improve both safety and production. Furthermore, since it could boost productivity and since it could be retrofitted it could be quickly put into use in the industry if proven successful in underground testing.

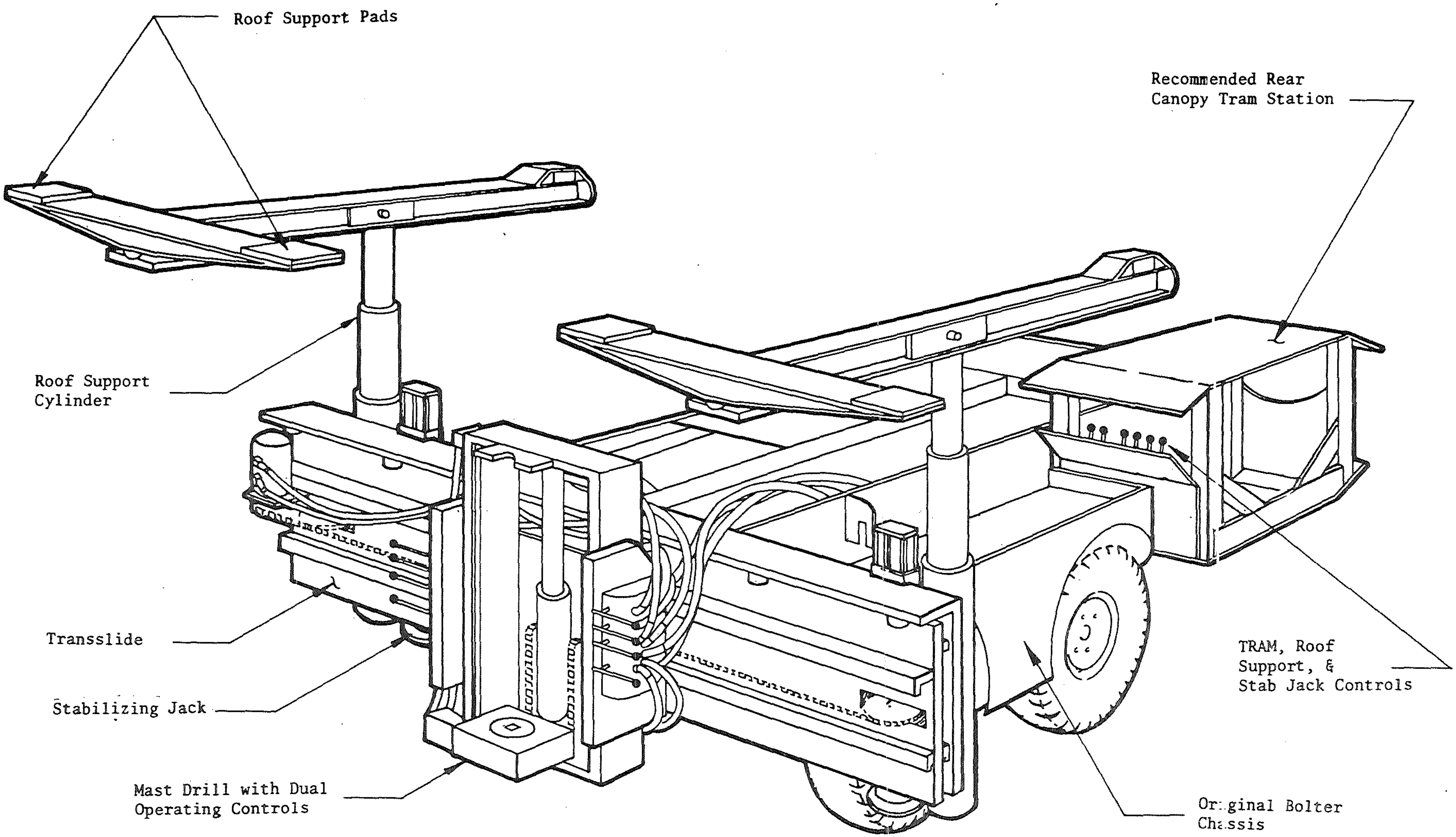


Figure 1 - Features of the FMA-TRS Bolter

2. DEFINITION AND DEVELOPMENT OF CONCEPT

This chapter defines the goals of the program and the needs of the industry. It briefly describes the FMA-TRS design and presents its features, feasibility, and benefits.

2.1 Objectives

The major objective of this program is to provide a device which performs these fundamental functions:

- Remotely sets temporary support from a safe position under supported roof.
- Maintains adequate temporary support during the entire roof bolting procedure.

In addition to these basic objectives, a viable, alternative product which is acceptable to mining operators and personnel should have the following features:

- Advances easily and sets up in minimum time.
- Does not restrict the movement of personnel and equipment.
- Is capable of moving from place to place and negotiating turns between typical entries and crosscuts.
- Is operable over a range of roof heights such as 5 to 7 feet and is modifiable for other ranges as well.
- Can perform in entries and crosscuts and is able to install the first row of bolts in a crosscut without requiring advancement of personnel beyond supported roof.
- Can operate in seams inclined up to 10 percent without requirement for special features.
- Can be used in conventional as well as continuous mining sections.
- Is designed to meet all the relevant MESA requirements.

2.2 Requirements of the Industry

The first task embarked upon for this contract was a survey to determine the adaptability of the proposed design to a majority of the bolters in current service. The detailed results of this survey are summarized in Tables 1 and 2. The conclusions were two-fold: that the design should be tailored for the single head bolter and, secondly, that virtually all of the single head bolters could be retrofitted with the FMA-TRS design.

The former conclusion was made after considering the number of units affected as well as the cost implications of making a retrofit. Table 1 shows that there are more than five times as many single head machines as dual. This ratio is further increased by the fact that a number of the dual head machines are already outfitted with some type of temporary roof support. J.H.Fletcher and Co., for example, has been selling several forms of temporary support for years, including both "single-bolt" TRS (support put in place for the installation of only one bolt) and "multiple-bolt" TRS (support in place during bolting of an entire row or more). (See Figures 2 and 3.) Furthermore, even the dual arm bolters which do not have temporary roof supports integral to their design have a greater proportion of their cost associated with the boom mechanism with its ability to pivot horizontally and to sump fore and aft. The proposed design would reduce discarding a major portion of that mechanism -- more than half the value of the machine.

The latter conclusion, that virtually all the single arm machines are adaptable to the FMA-TRS design, was based on a detailed analysis of the structure and function of each of the currently manufactured bolters. They all have a main structural member along each side just inside of the wheels which can be cut off as required and used for solidly welding the retrofit equipment in place. All the hydraulic circuits are similar and operate at about the same pressure.

There are undoubtedly some exceptions to the above conclusion such as some radical departure from conventional design, some greatly modified machine, or design extremes such as the miniature Wilcox bolter. The machine barely weighs more than the FMA-TRS package and is only half as wide. But these exceptions constitute a small portion of the total of over 6000 bolters in current use.

TABLE 1

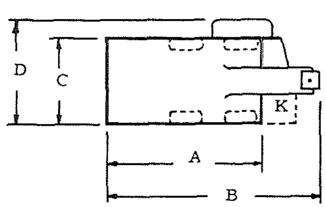
ROOF BOLTERS CURRENTLY IN SERVICE

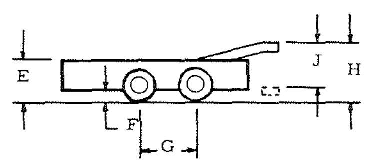
Manufacturer	Double Boom Bolters	Single Boom Bolters
ACME W. Va.		1500
EIMCO Ut.	0	1
FMC W. Va.	300	3000
FAIRCHILD W. Va.	0	337
FLETCHER W. Va.	900	700 mast 400 arm
JOY Pa.	0	155
LEE NORSE Pa.		250
LONG-AIRDOX W. Va.	54	213
MYERS-WHALEY Tenn.	0	0
NORTH AM. GALIS W. Va.	0	0
TOTAL BOLTERS ESTIMATED TO BE IN SERVICE	1254	6556

TABLE 2

DIMENSIONAL SUMMARY OF ROOF BOLTERS

BOLTER MODEL		A (in.)	B (in.)	C (in.)	D (in.)	E (in.)	F (in.)	G (in.)	H (in.)	J (in.)	Weight (lbs.)	Hydraulic Oil Pres. (psi.)	Hydraulic Oil Cap. (gal.)	To Be Removed "K"	Comments
Galis	300	132	180	61	93	24-27	5-7	36		53	8,700	1,450			Tram Platform At Forward Side
	310	125	196	48		26.	5.5	36		53	8,300	1,450		Controller	
	320	148	220	72		36	8	47.5		84	11,500	1,450		Oper. Platform	
	320A	150	236	80		36-40	8-12	47.5		91	15,700	1,450		Dust Collector	
	350	158	224	79		36-42	8-12	47.5		84	15,700	1,450		Oper. Platform	Swinging Boom
	380	130	180	76	97	27-29	5-7	36		53	9,950	1,450			
Fletcher	DO	130	210	66		30-33	8-11	40		72-84	12,500	2,000 max.	80	Dust Tank, Cyclone Tank	
	LTDO	105	135	70		24	6	39		46-60	8,200	2,000 max.		Cyclone Tank	
Acme	D1	109	115	53	58	27	6	42	47	38	4,140			Drill Controls	Tram Platform At Rear
	D2	112	173	66	78	32-35	6.5-9.5	42	62.5	53	6,600	1,500		Pre Dust Collector, Canopy	
	D3	127	180	68	78	27-30	6-9	42	57.5	48	7,200	1,500		Vacuum Pump, Canopy	
	D4	114	174	66	78	32-35	6.5-9.5	42	81.5	72	8,700	1,500		Pre Dust Collector, Canopy	
Lee Norse	TDI-24	115	162	69		24	5	44	46		9,500		98	Dust Collector	
	TDI-36	132	213	76		36	8	48	72		13,000		120	Dust Collector	
	TDI-43	140	213	76		43	10	48	92.5		13,000		147	Dust Collector (Cyclone Tank)	
Long Airdox	LRB-15A	124	177.5	72	72	26-32.5	5.5-12	42	70		7,500		55		Tram Platform At Rear
Wilcox	J-6	76	100	48.5		26	6	30	46	38	4,500		24	Fire Ext., Starter	





NOTES:

1. Above data from current manufacturer's literature.
2. All bolters also require removal of Boom Assembly, Hydraulic Controls, and some forward Frame Components.
3. All bolters have differential steering ("tractor" or "squirm").
4. Underlined items are maximum or minimum dimensions.

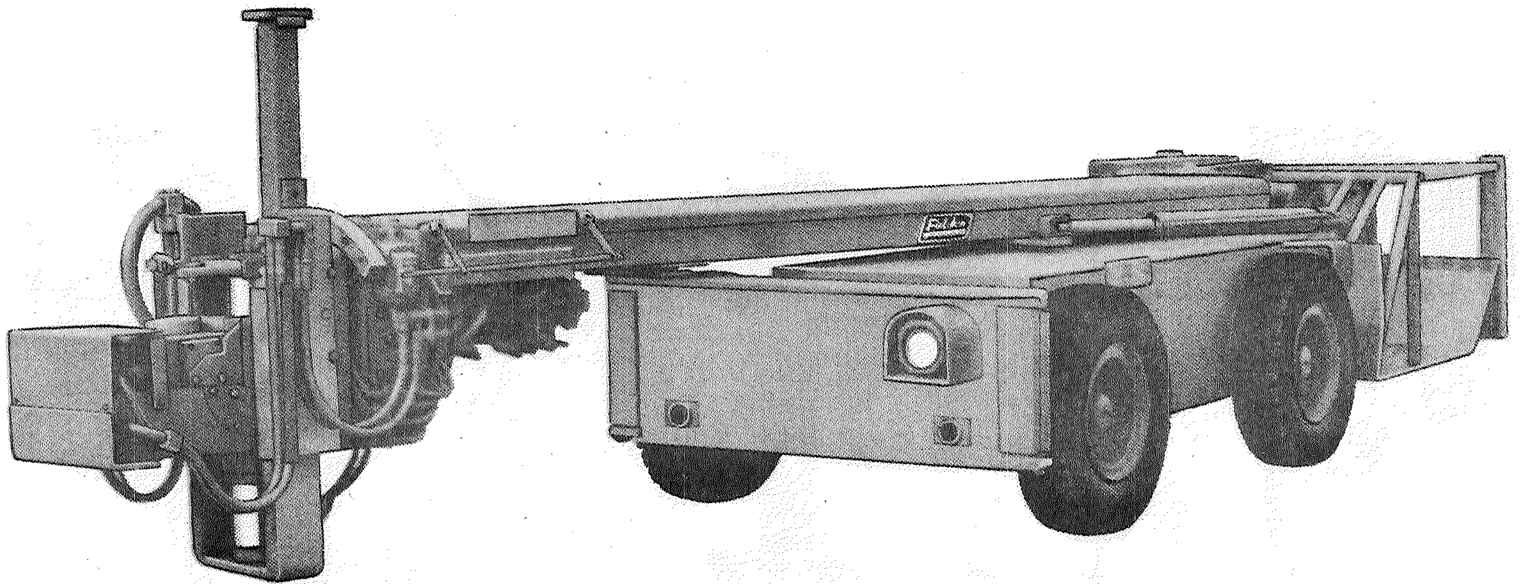


Figure 2 - "Single Bolt" TRS

Single boom bolter with safety post
(Courtesy of J.H.Fletcher)

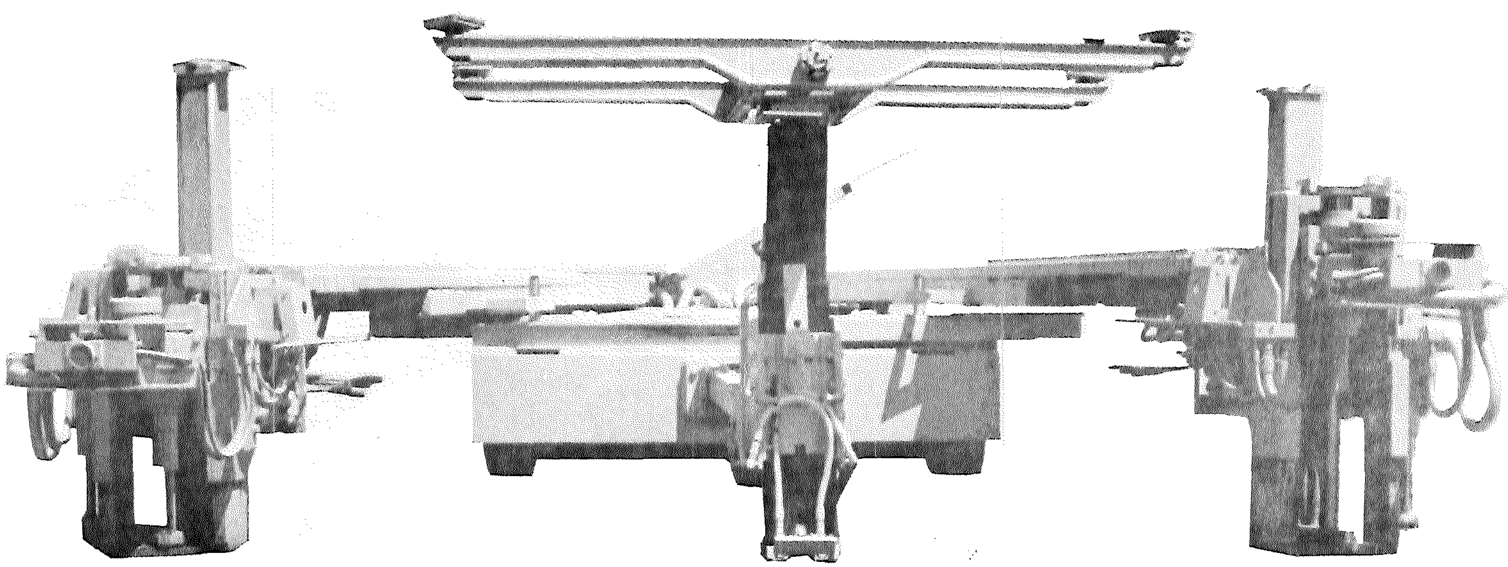


Figure 3 - "Multiple-Bolt" TRS

Dual boom bolter with TRS
(Courtesy of J.H.Fletcher)

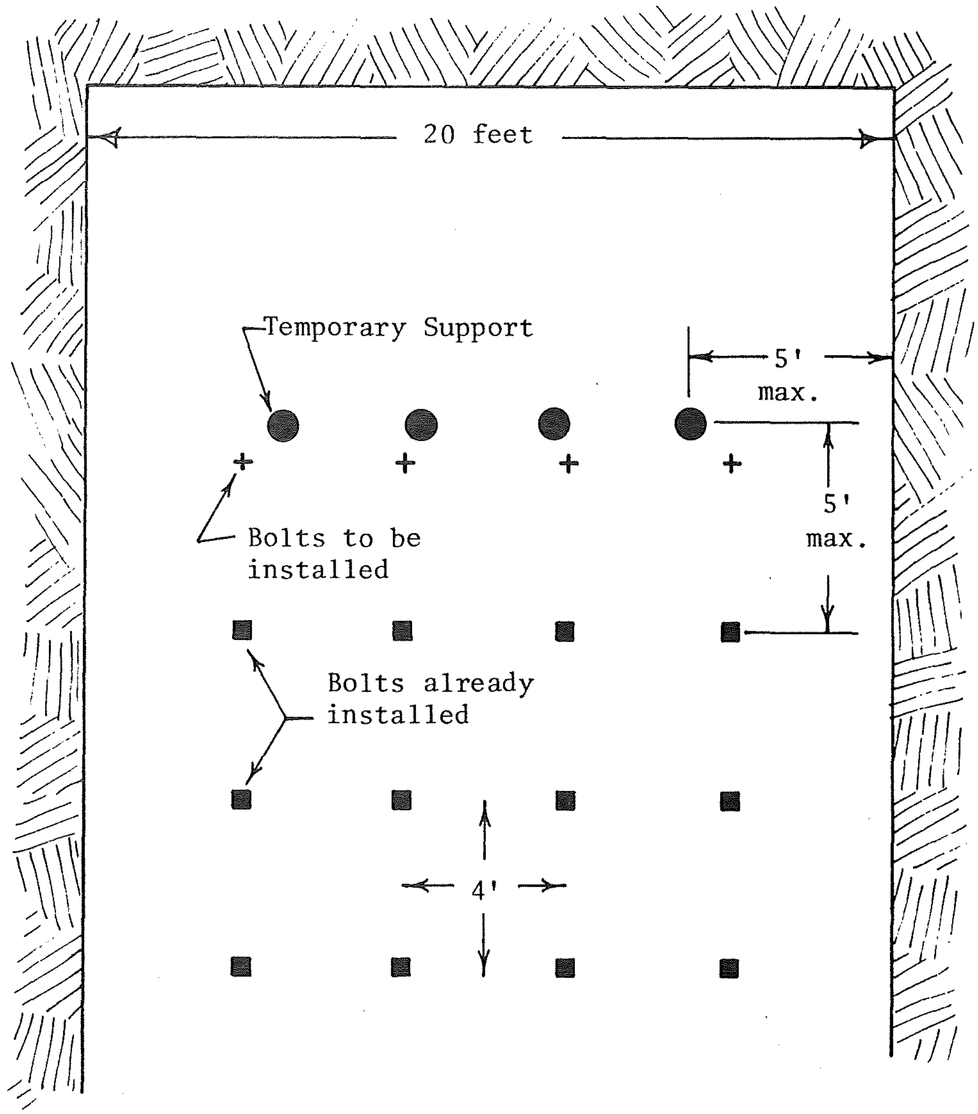


Figure 4 - Typical Face/Entry Roof Bolting Pattern Showing Minimum Temporary Support Requirements

Mining operators have also been interviewed for their bolting requirements. By far the most common bolting pattern currently in use has four bolts across, spaced 4 feet on centers. All mines employ deviations from this pattern when conditions warrant. Some of the wider entries of 19 or 20 feet have a 5 bolt pattern, in which the outer bolts are placed only 2 feet from the rib. One operator felt that low tram height and adaptability to a large range of roof heights was the most important requirement, while maintaining as much stroke as possible. Others felt that dual head machines would be the trend in the future. However, when the retrofit nature of this design was pointed out, they endorsed its application, particularly at sites where a number of single boom machines in good working order were still in service.

2.3 Current Procedure for Installing Temporary Supports and Bolting Roofs

The major operations of a typical mining cycle are cutting and bolting. These operations are advanced from place to place sequentially covering two or more different faces. The cutting function is limited and must cease when the machine operator is on the verge of advancing beyond supported roof.

When the continuous miner completes its cut and vacates the working place, a jack setting crew arrives to install temporary roof supports. Common supports are wooden posts with wedges, screw jacks, ratchet jacks, or hydraulic jacks. All of these are set at relatively low roof loads compared with their ultimate capacity. Hydraulic jacks are usually designed to yield dimensionally while maintaining a predetermined load if and when the roof converges or fails. The other supports can yield only in the form of punching the roof, bending or breaking -- none of which maintain much continued resistance to the roof load.

During installation, the jack setter is momentarily exposed to the unsupported roof and to the occasional hazard of dislodging pieces of roof rock with the top end of the jack or post, whether the entire place is set or only a single row at a time varies from mine to mine. A typical pattern is shown in Figure 4.

Subsequent to jack setting, the bolting crew arrives to install bolts one row at a time close to, but outby the line of temporary supports. Refer again to Figure 4. After each row, or sometimes after each bolt, the temporary support is removed and advanced -- again exposing the jack setter to unsupported roof momentarily.

The removal of jacks is hazardous. Hydraulic jacks usually have a remote release feature but usage of this entails extra work which is frequency short-circuited by the miners, thereby exposing themselves to a section of the roof during the moment of support pressure release. Timbers are sometimes removed by swinging the boom of the bolter at their base to knock them down. At first glance, this would appear to have safety advantages. However, the operator is usually quite close to the tip of the boom and the practice can damage the drill head, its hydraulic connections, etc., possibly causing an unsafe condition of the machine.

Bolt locations are usually laid out and marked by hand with spray paint prior to positioning the machine. Single head bolters require tramming to maneuver to each successive bolt position. This is accomplished by "inching" the machine to the respective position under each mark, judging by eye when the drill head is in place.

The drilling and bolting operation is nearly universal. Minimizing the number of drill changes or extensions added speeds up the operation. For increased safety there is a trend toward "hands-off" drilling using drill guides or centralizers. The bolt is usually inserted most of the way by hand, using the drill head for the final push and torquing only. Most bolters have a hydraulic "switch" to select a reduced torque during the bolting cycle.

2.4 Proposed Procedure for Supporting and Bolting a Cut

The machine proposed and designed to provide TRS is illustrated in Figures 1 and 5. These show the slide, support cylinders and roof beams mounted on a modified Galis 320 bolter. At the front of the machine a Fletcher mast drill is attached to the slide. The tram station is at the rear under the canopy.

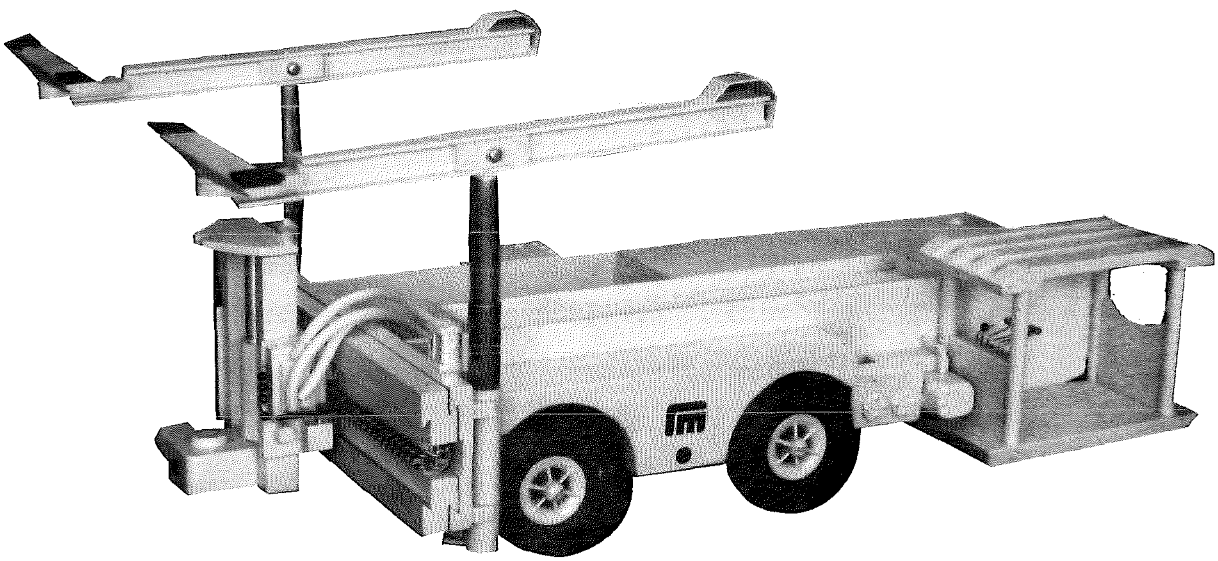


Figure 5 - Photograph of the FMA-TRS Scale Model

In order for the TRS to be set into position and left in place for the bolting of an entire row of bolts, the bolting head must move relative to the TRS. In the FMA design, the TRS is fixed to the machine and the drill head is traversed across the front of the machine from bolt to bolt. (See Figure 6.)

An example of the procedure for bolting a new cut with this modified bolter begins with the operator tramming the bolter along the centerline of the entry toward the place to be bolted. As he reaches the last line of bolts, he stops the machine with the drill centerline at the specified distance beyond the last line of bolts. This measurement can be made by lining up marks or some other indicator with the previous bolt line. The operator then engages the valves which erect the TRS up against the roof at low pressure. At this point, the TRS is fully in place, making contact in four areas, approximately four feet apart, one foot ahead of the new bolt line, and yet no one has had to approach even the last line of bolts. The operator then walks to the front of the machine along the left side, reaches for the slide control located on the left side of the mast drill and, in effect, pulls the drill towards him. Index marks on the slide aid in the final locating of the drill to conform to the bolting pattern.

The drilling and bolting procedure with the FMA-TRS bolter is identical to that of currently used mast drills -- the mast unit is lowered to the floor, drill steel inserted in the chuck, torque and thrust applied, extensions inserted as required and, finally, the bolt installed and torqued.

After each bolt is installed, the mast unit is hydraulically lifted and translated to the next position on the pattern. After the last bolt is installed the mast unit is traversed back to its central position and the operator returns to the tram station to lower the supports and tram the bolter forward.

2.5 Feasibility

For this design to be useful, it must be acceptable to both the regulatory agencies and the mining industry. The following paragraphs demonstrate its efficacy and feasibility.

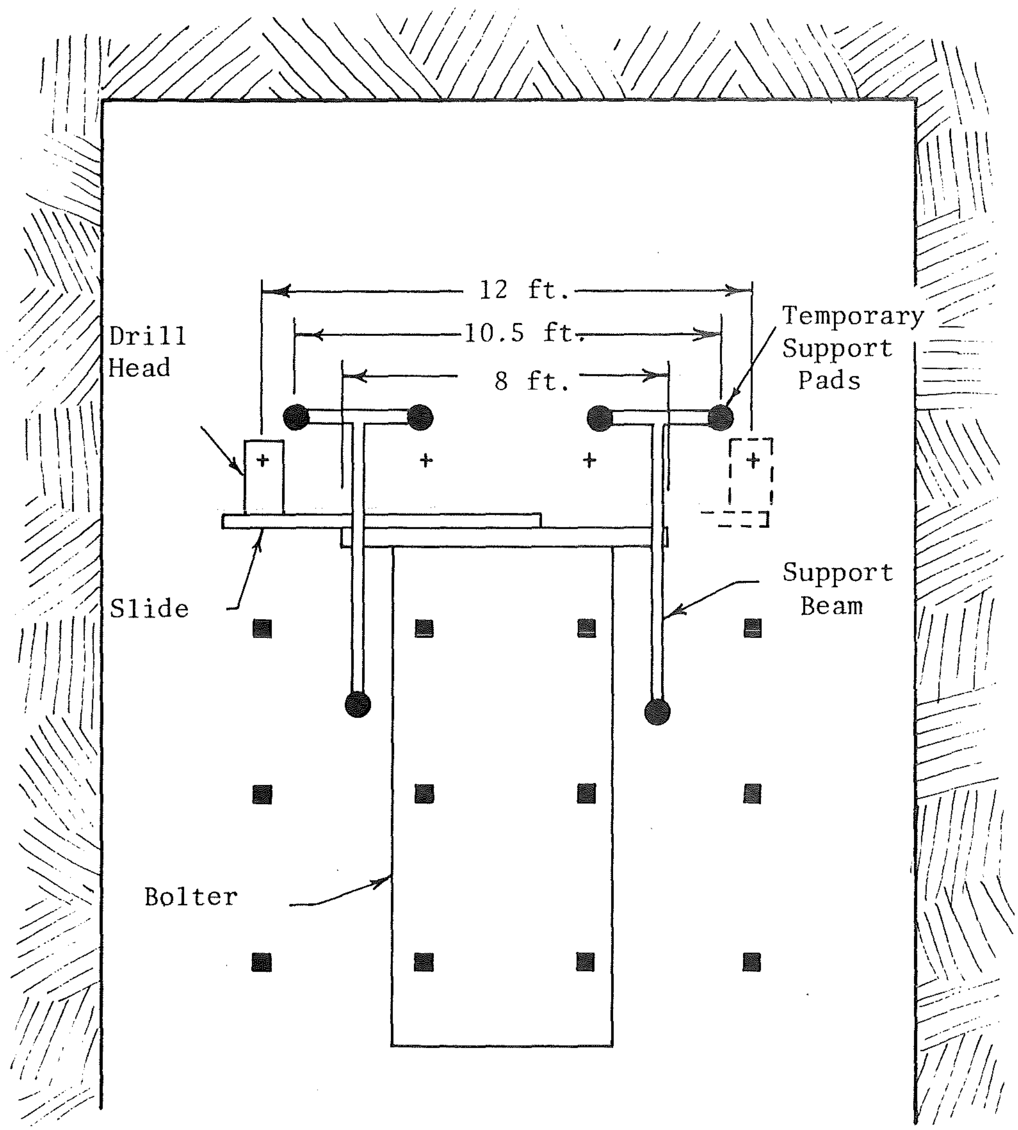


Figure 6 - Superimposed Relationship Between Typical Bolting Plan and FMA-TRS Bolter

2.5.1 Technical Feasibility

In the design of this retrofit device every effort has been made to specify components or materials which have a proven record in mining environments. Most of the hydraulic components such as control valves, reliefs, check valves, regulators, and the roof support cylinders themselves, will be supplied by Commercial Shearing. The slide will move on McGill Camrol® bearings which have been used for many years in mining applications. The mast drill will be a conventional Fletcher Titan drill that has been proven by many years of underground use.

The design has been kept as simple as possible in order to increase reliability and expedite manufacture and service. The slide, for example, is composed of plates and bars bolted or welded together to form the roller tracks, supports, end stops, etc. There are no special castings or complicated machined parts. Design stresses are conservative under the worst loading configuration, resulting in large safety factors under normal loading conditions.

2.5.2 Health and Safety

The primary purpose of this contract is to increase the safety of the roof bolting process. This is accomplished by providing a remotely deployable support system which is erected from the tram station 10 to 12 feet away from the line of support. This support stays in place during the entire process of bolting one full row.

The controls at the drill head can only command drilling and drill placement operations. The operator must return to the tram station either to release the supports or to move the machine. The tram platform with canopy should be installed near the rear of the machine. Rear canopy tramming stations are now routinely constructed for older machines by repair and maintenance shops, and some new machines come equipped with this feature standard. Therefore, the design for such a tram station is not included as part of this report.

The mast drill and its dual controls have been arranged so that it is possible for the operator to stand either behind the drill or beside it. Operation from behind is required only when the drill is close to the rib at the extremes of its stroke. In either of these positions the operator can control the entire drilling and bolting process from behind the slide. (See Figure 7.)

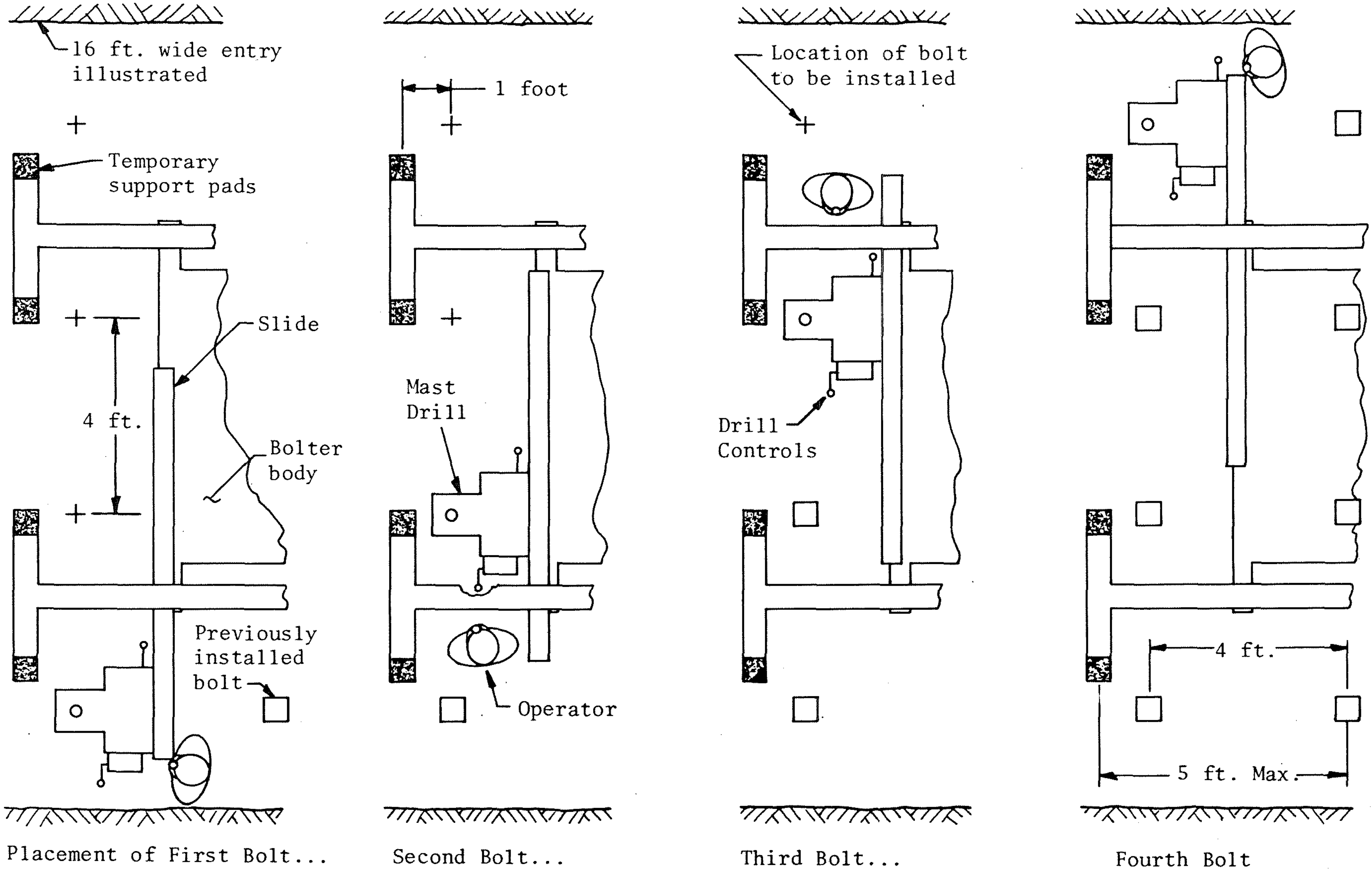
Section 75.1710-1 of the Federal Regulations describes the canopy requirements for self propelled face equipment. As above, the tram position has a canopy. However, in the simplest form of this design, the drilling and bolting position does not have a canopy. The TRS has broad coverage and in several positions, the operator will virtually work under one of the support beams. Hence, our TRS will probably satisfy the "in lieu of" conditions of paragraph 75.1710-1(f). Any additional fixed canopy coverage will interfere with the flexibility of the bolting pattern; however, the mast drill can be provided with an extensible safety post with a small canopy to protect the immediate operating zone.

Lighting requirements for underground equipment are proscribed by Section 75-1719 of the Federal Regulations. Lighting units to meet these requirements may be mounted at the rear of the slide and project over the slide into the work area.

2.5.3 Industry Needs and Acceptance

After discussions with several operators, it is concluded that the mining industry has two basic requirements: speed and safety. Another, but ancillary ,requirement is that of low cost.

The present bolting operation is frequently the bottleneck in a mining cycle. The usual method of speeding it up is to introduce a dual boom bolter which increases the rate of the drilling and bolting portion of the process. Though this has additional benefits such as labor efficiency, the high capital cost of dual arm bolters is frequently prohibitive. Also, these dual boom machines are sometimes so large and awkward that their maneuvering speed during tramming and starting a cross cut partially offset the gain in bolting speed.



<u>Figure 7 - Typical Sequence for Bolting</u>

(Illustration shows 4 across, 4 foot spacing pattern)

Furthermore, the current bolting operation is a hazardous one, being responsible for about 20 percent of the accidents which occur in continuous mining operations. (See Table 3.) This represents a significant safety problem stemming from a single operation. It is desirable, therefore, to create a protected area in which the miner can work during all phases of the bolting cycle.

The FMA-TRS design addresses both of these requirements. The safety aspect has been discussed in Section 2.5.2 and the matter of increased speed will be discussed below.

2.5.4 Productivity Improvement

Section 4.2 explores the economic and productivity benefits of this product in detail. In summary, the production rate of the bolting operation is increased by the FMA-TRS bolter in two ways -- faster support installation and faster sequencing from bolt hole to bolt hole. The comparison is made between the FMA-TRS bolter and a conventional bolter using procedures which conform to current MESA requirements. (In actual practice the legal requirements are sometimes circumvented in order to minimize production time.)

The savings in bolting time is estimated at about 5 minutes per cut. For an average cycle, this represents an increase in productivity of roughly 20 percent. For an operation in which the bolter always stays ahead of the continuous miner this savings is of little consequence. But, in most operations where the bolter sometimes or always sets the pace, this savings can be of great importance, particularly since it is gained without resorting to a very expensive dual boom bolter.

2.5.5 Economic Feasibility

Two sources of economy are evident from the use of this bolter. One, described above, is the reflection that the decreased time to perform a job has on the total coal output per day, and the other is the savings in manpower by eliminating a particular function such as moving and installing individual temporary supports. These are itemized in Section 4.2. In some applications, the upgrading of a conventional bolter to an FMA-TRS bolter will pay for itself in only a few weeks. Even with a much longer payback period, this bolter pays for itself well within commonly acceptable time limits.

TABLE 3

COAL MINE FATALITIES

January - August,1976

Personnel Job Title	Number of Deaths	Potentially Avoidable Deaths with Adequate TRS
Roof Bolter/timberman	10	10
Supervisor	8	
Laborer/trainee	8	
Motorman	7	
Shuttle car operator	6	
Utilityman	6	
Roof bolter's helper	5	5
Loader/miner operator	4	
Repairman	4	
Truck driver	4	
Driller	4	4
Mine owner	4	
Bratticeman	3	
Beltman	3	
Shot firer	3	
Jack setter	3	3
Miner operator's helper	3	
Tractor/scoop operator	2	
Bulldozer operator	2	
Car dropper	2	
Welder	2	
Oiler	2	
Tipple operator	1	
Electrician	1	
Watchman	1	
	98	22

Moreover, depending on accounting procedures, there are often benefits to making expenditures in the form of repairs or modifications as opposed to making capital investments in new equipment.

2.6 Benefits of the FMA-TRS Bolter

The development of an acceptable and feasible design which meets the objectives set forth earlier, provides a range of benefits to the coal producers.

Mining personnel benefit in the form of safer operation. Presently, about 90 minutes* a day in each section is spent standing under freshly cut, completely unsupported roof. As Table 3 shows, the elimination of such exposure can significantly reduce the accident and death rate experienced in American mines today.

The mining operators can obviously benefit from the reduction of the exposure hazards mentioned above. Additionally, this design will also improve productivity on two fronts. For one, the faster erection of the supports and the slightly faster sequence of bolting without the need of roof layout and tramming between bolts will reduce or eliminate production delays caused by the bolting operation. And, secondly, manpower in such related activities as jack setting, supplying and maintaining individual props and moving them from place to place can be reduced and totally eliminated in some operations.

A significant consideration is that a retrofit system such as this is probably the most expedient way of providing automated support in the least time. Even if funds and designs were available, it would take many years at today's production rates to replace the 7000 or so non-TRS bolters with new bolters outfitted with TRS. The FMA-TRS package is much simpler and faster to manufacture than a complete bolter and can be largely constructed by new suppliers otherwise untutored in the roof bolter business.

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*Estimated as follows: 100 ft. advance per shift = approximately 200 supports per day. 20 sec. installation exposure + 7 sec. removal exposure = 27 sec. total exposure for each support. 200 x 27 ÷ 60 = 90 minutes.

3. DETAILED DESIGN OF THE FMA-TRS PACKAGE

The purpose of this section is to delineate the governing design parameters, to describe the development of the FMA-TRS concept, and to illustrate the capabilities of a retrofitted machine operating within the typical constraints of the mining environment.

The system design is composed of three separate functions:

1. Remotely deployed roof support and machine stabilization
2. Roof bolting by use of a mast drill
3. Cross-slide positioning of the drill for an entire row of 3, 4 or 5 bolts without moving the vehicle.

Each function can be considered without regard to any particular machine. The following paragraphs discuss the detail design of the associated units and their union to the current industrial bolters.

3.1 Roof Support

Temporary roof support must comply with the 1969 Coal Mine Health and Safety Act, specifically Section 75.200-13 "Criteria--temporary support." Briefly, paragraph 3 states that a minimum of four temporary supports should be applied to the roof on areas inby of permanent support at not more than 5' centers, and not more than 5' from either the rib or other permanent support. Figure 4 depicts the minimum locations for support in a 20 foot entry which conforms to these requirements.

The load requirements for temporary roof support were confirmed with MESA representative, Steve Gaydos,and are summarized as follows:

- o Temporary supports are assumed to support a rectangular region of roof extending 2 1/2 feet all around the support.
- o The thickness of this supported region is assumed to be 3 feet.
- o The density of this supported block is assumed to be 150 pounds per cubic foot.

For the geometry of the FMA-TRS support, these requirements work out to be a total capacity of 36,000 pounds.

Foster-Miller's approach is to apply this support remotely by an operator well under a permanently supported roof. From the normal position of the machine during drilling, an extensible mechanism must reach forward from the bolter to the support location. Four concepts were considered and are shown in Figure 8, 9, 10 and 11. These figures also describe the advantages and disadvantages of each of these concepts and serve to illustrate the function and simplicity of the final form of roof support chosen.

The final design for the support uses a fixed telescopic cylinder attached to the main bolter chassis, with an overhung intermediate beam carrying the roof support one foot beyond the drill head. (See Figure 12.) The fixed cylinders have the desirable features of simplicity, low cost, and interchangeability for various seam heights, and are better suited for a retrofit package than a more complex, articulated deployment scheme.

The supporting structure has been designed to provide a three-point support and is composed of three major units: spreader beam, main beam, and support cylinder. The cylinders are to be manufactured with two mounting feet which will attach to the slide frame and can be interchanged or removed for repair. The two stage cylinder is single acting and has an extension of 3 feet 8 inches. The setting pressure provides a 500 pound setting load to the roof by each forward pad. The hydraulic circuit has been designed to resist roof fall forces up to 5 tons on each pad before yielding. This corresponds to 40,000 pounds total which exceeds the 36,000 pound minimum requirement defined above. Both support cylinders attach to the main beams by a pin-eye joint which is located to permit a $\pm 10^{\circ}$ angle of tilt between the main beam and the vertical axis of the telescopic cylinder.

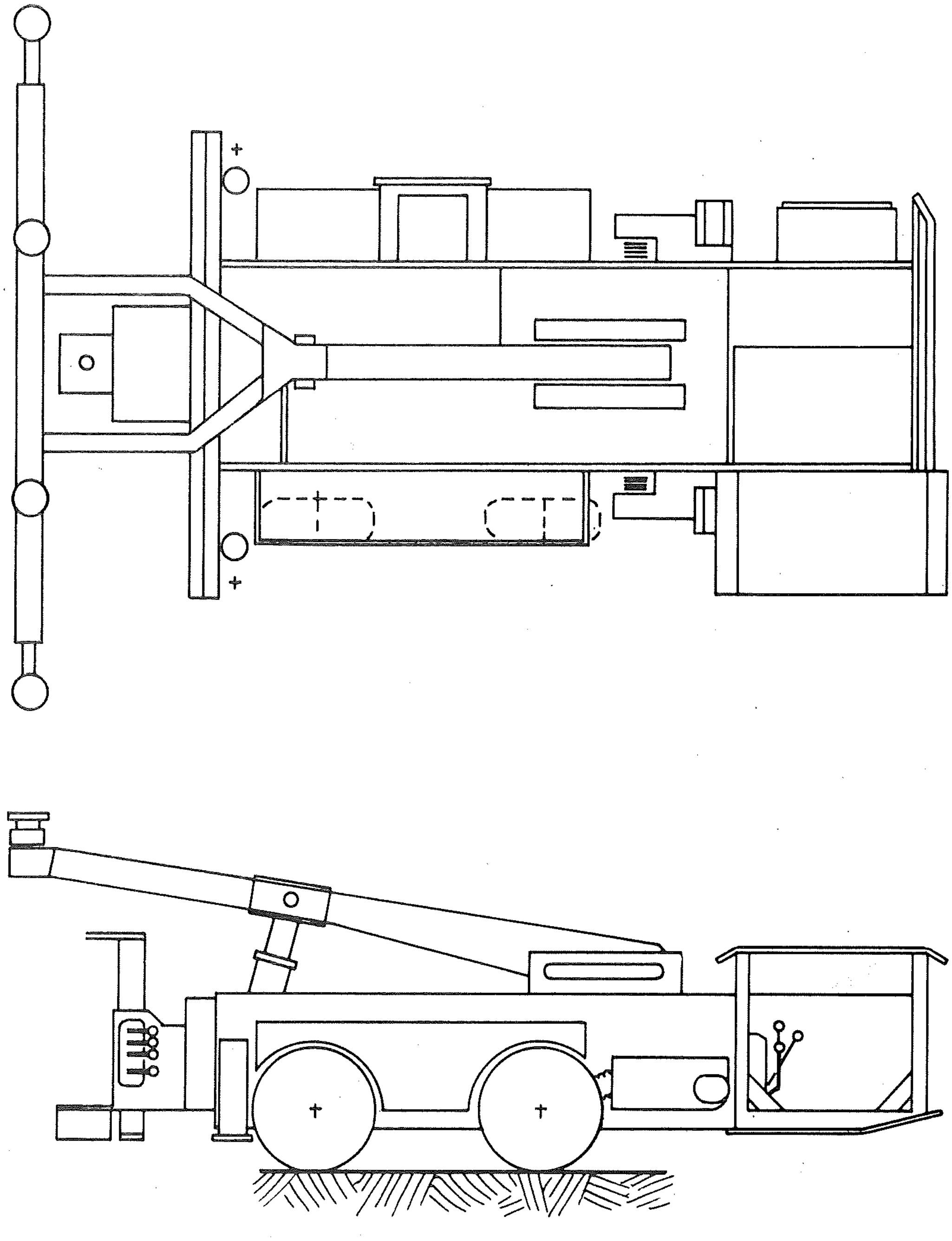
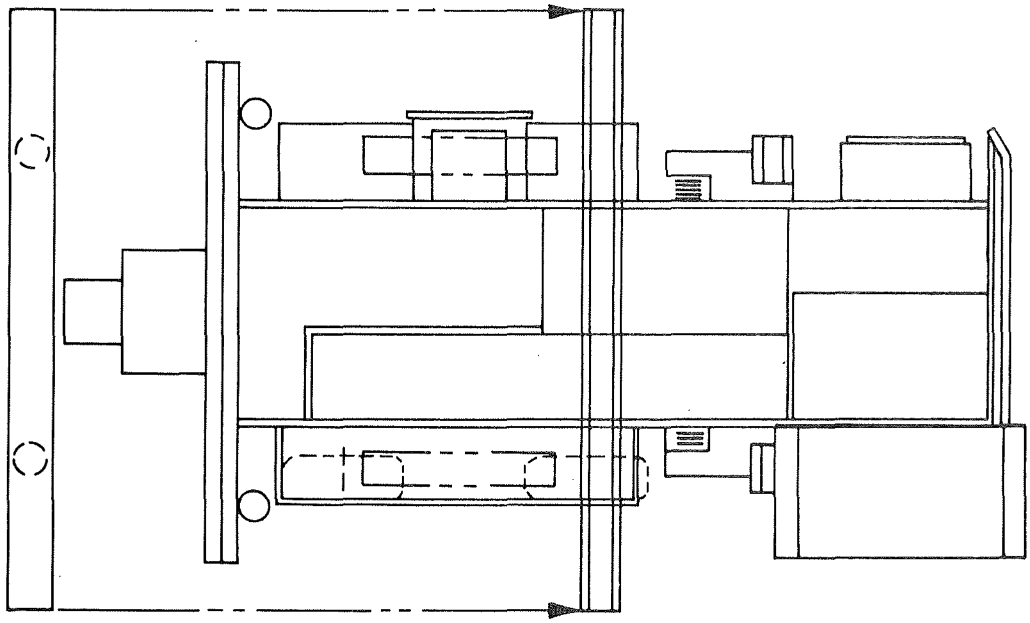


Figure 8 - Cantilever Boom Deployment

This method of remote support deployment has the advantage of a multiplied lift stroke but is limited as follows: (1) the TRS load capacity, by geometry, is no more than the weight of the machine; (2) the inclined nature of the boom severely restricts the operating space of the mast drill; and (3) the single beam contacts an irregular roof at only 2 points and therefore does not meet minimum MESA requirements.



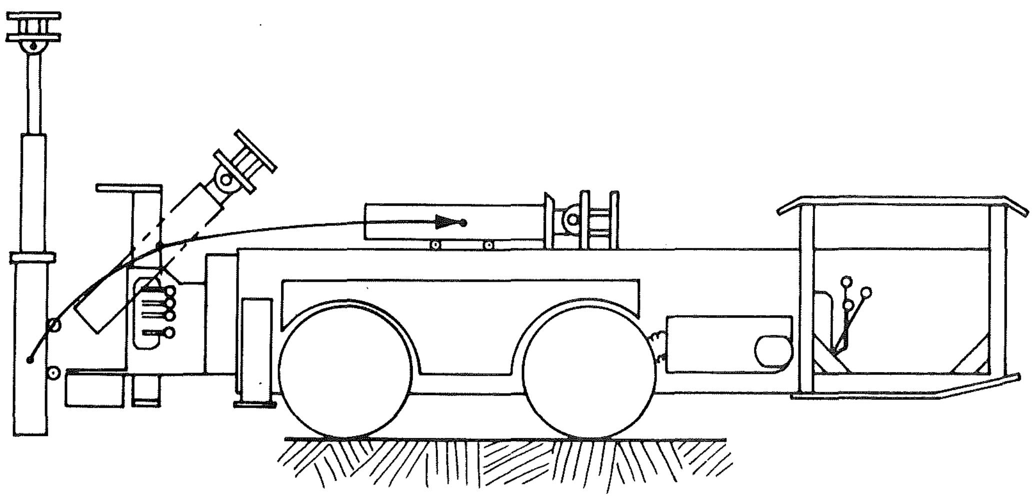


Figure 9 - Linkage Deployment Concept

Direct support offered by minimal size cylinders under the beam at line of TRS. Linkage lifts and carries both beam and cylinders up onto the machine carriage for tramming. The L-shaped space envelope available for deployment of this lightweight support structure is very restrictive in a 5 ft. seam and would require a more sophisticated mechanism than a simple 4-bar linkage. At this point, in light of the lightweight compact package, it was concluded that the additional design effort would not enhance the safety of the system and would only add to the cost of the package. Therefore, it was not pursued for the prototype design and testing but would be saved for consideration on future development.

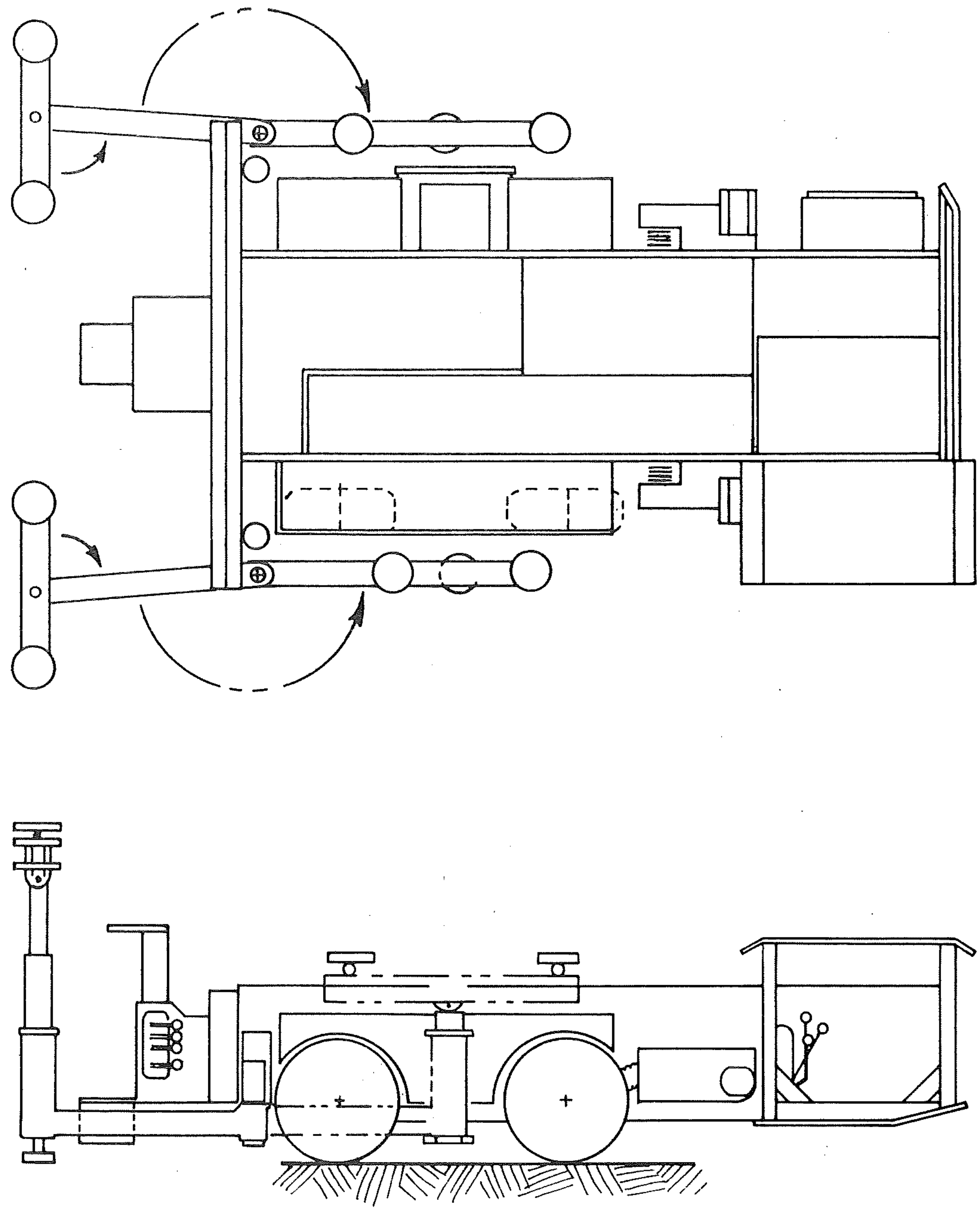


Figure 10 - 180^{o} Swing Deployment Concept

This concept offers many of the same advantages of the linkage concept with a straightforward hinge. However, in narrow entries or in cases when the support must be deployed while adjacent to the rib, this system will not operate.

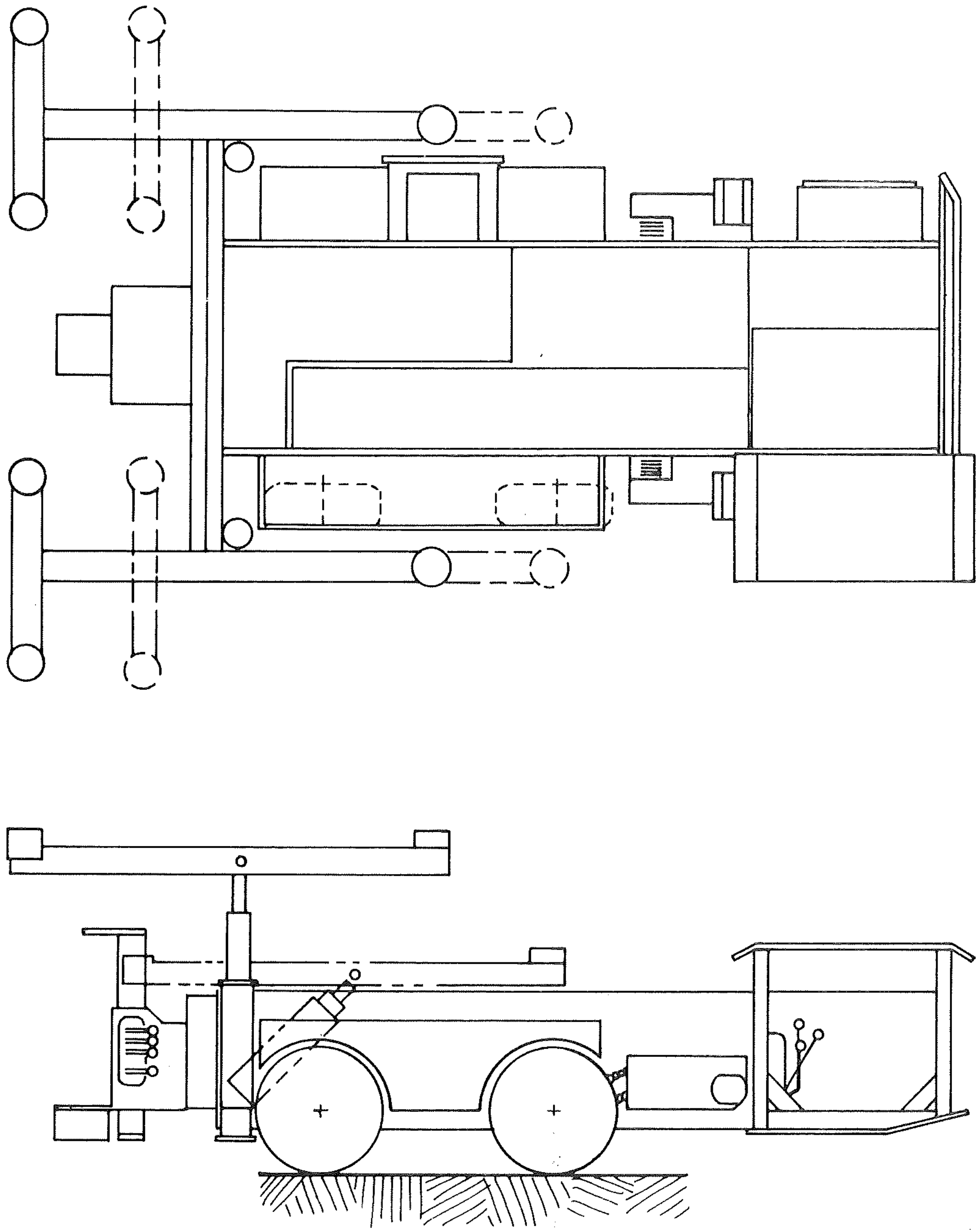


Figure 11 - Lay-back Deployment

The Lay-back concept, shown above, was proposed to eliminate the need to move the beam and/or the cylinders through complicated arcs and large distances relative to their working position. The support cylinder carries twice the load of the forward pads because of the three-point support and therefore must be larger than those shown in the previous two cases; however, it could be affixed to the main body of the machine by a foot hinge and when tilted back would move the center of gravity of the entire supporting structure rearward about 1 1/2 ft., and simultaneously lower the roof support to a minimum height, compact, tramming position. The major drawback of this design is the additional hydraulics and mechanism required to position the system.

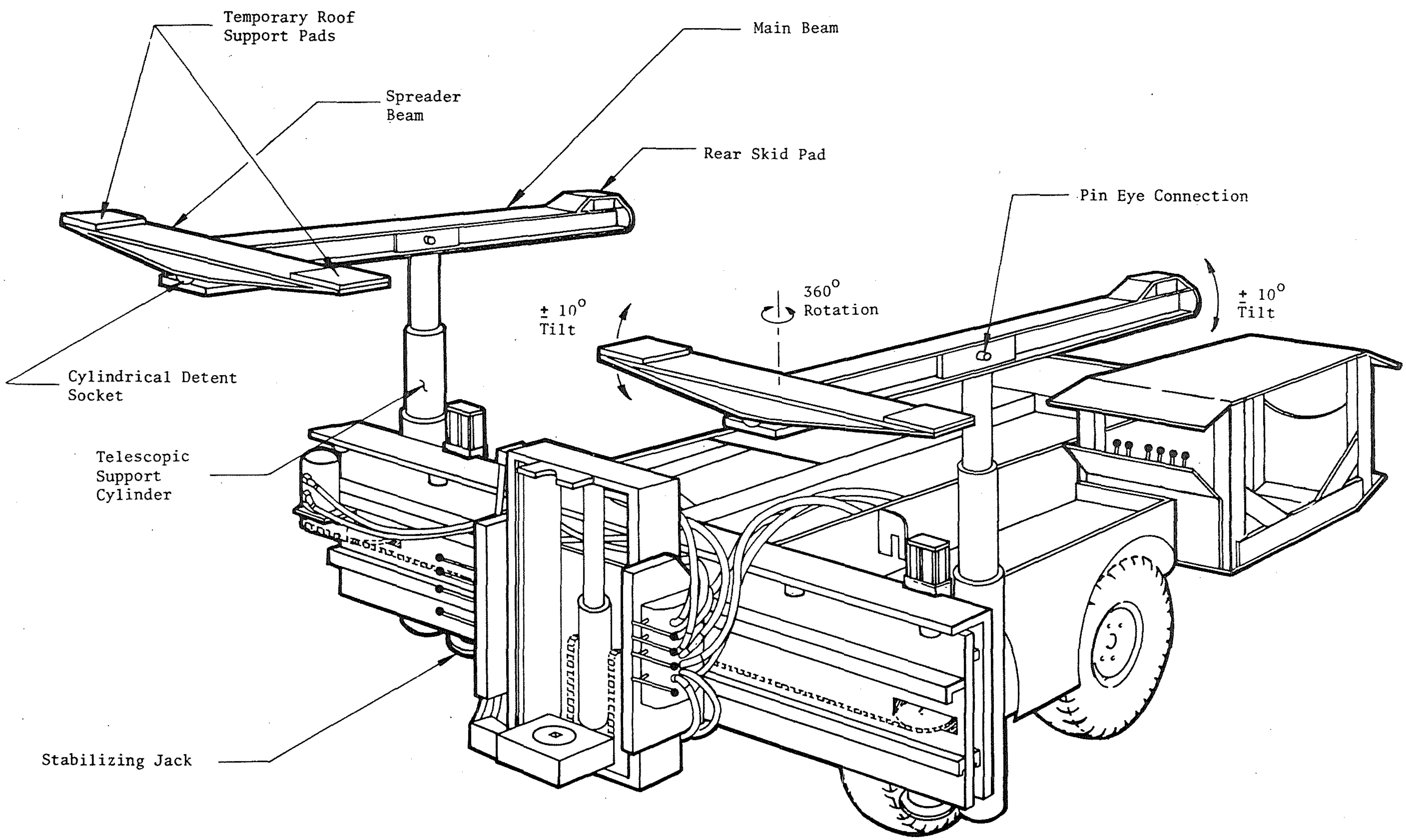


Figure 12 - Components of TRS Assembly

The main beam transmits half the load carrying capacity of the cylinder to the roof out in front of the bolting line for TRS and the other half to the rear skid pad. This beam is a modified 6" wide flange beam. The central portion has been slotted to accept the pin-eye and has been substantially reinforced by welded plates which also contain the pivot bushings. The use of the 60,000 yield stress material in compliance with ASTM A572 Grade 60 allows the main beam to carry the 40,000 pounds with a safety factor of 1.5. The forward end of the beam is joined to the spreader beam with a cylindrical socket joint to accommodate local irregularities of the roof. This joint also swivels horizontally to permit orientation of the spreader beam in line with the main beam. This flexibility facilitates tramming operations, particularly those of turning into cross cuts. (See Section 3.6.1.) The spreader beam is a fabricated weldment of T_1 steel (100,000 yield). The beam is tapered to maximize strength at the center and minimize space consumption at the extremities.

The support assembly is front heavy and assumes an inclined position of 10^o when lowered from contact with the roof. When the support reaches its lowest position, the bolter body readjusts the beam to the horizontal plane where it rests in a stabilized position on the slide and bolter body for tramming.

3.2 Mast Drill

The choice of drill was dependent on the physical constraints posed by the conceptual design. This required a drill unit which would easily index across the entry to a desired location and then drill vertically. The simplest available form of drill meeting these criteria has been commonly used on roof bolters for the past twenty-five years and is referred to as a mast drill. It is frequently found on Fletcher machines. The drill head is lifted vertically by a three-stage cylinder and chain arrangement which offers an extension of 140 percent of the collapsed height. The Fletcher mast drills have been successfully operating underground for the past two decades and can be purchased as off-the-shelf items.

A common drilling problem associated with any type of roof drill is the tendency of the machine to be loaded via the structural members connecting it to the chuck during drilling thrust. This can change the machine's attitude relative to the drill steel which is constrained by the hole being drilled. Consequently, the drill occasionally must be repositioned to finish the hole and torque the bolt.

Another problem, if the TRS is mounted on the machine, is caused by the drill thrust being transmitted back to the machine. This force results in a deflection which may lower a roof support slightly from contacting the roof. If the hydraulic system is pressurized correctly, the roof cylinder will fill again until loading of the roof reaches the predetermined pressure. This condition is fine until the drill thrust force terminates and the corresponding over-balanced machine weight is now applied to the roof through the support. As a result, the roof is loaded above the desired load and upon repetition it becomes stress cycled.

The FMA design has modified the mast drill retracting foot operation in such a manner as to eliminate the aforementioned problem. The retracting foot has been hydraulically valved to allow the mast drill to lower to the floor by virtue of its own weight and then apply drill thrust solely against the floor. The retracting cylinder is valved open and therefore cannot transmit drill thrust back to the mounting plate when the control is detented in this position. Now the drill forces are vitually isolated from the rest of the bolting machine, being transmitted directly to the floor. After the drill and torque cycle is completed, the retracting foot cylinder is pressurized and lifts the drill and carriage up off the floor enough for tram clearance (4" to 8"). This feature is time saving, prevents stress cycling the local roof, and is not currently possible with boom drills.

3.2.1 Mast Drill Controls and Functions

The mast drill valve bank will control the following functions:

a) Slide motor control

b) Drill retracting foot cylinder

c) Drill feed cylinder - thrust force

d) Drill - rate of feed

e) Drill rotation

f) Drill rotate speed

g) Bolt torque setting

h) Panic bar

Items a, b, c and e will be mounted as one valve bank on the upper portion of the mast drill side-mounting plate; the remaining items d, f, and g will be mounted separately, but directly below on the same plate. Briefly, the purpose of each control is as follows:

a) Slide Motor Control

This is a four-way, three position manual control valve with spring return to the neutral position. Included in the circuit are flow restrictors and a cross-over relief to prevent excessive pressure build up on either side of the slide motor. The flow restrictors will be sized to provide adequate flow for moving the slide but prevent excessive speed from injuring an operator or damaging a machine component left in the pathway. This valve is sequenced in the bank such that it can only be activated when the drill retracting foot is in one of its lifted positions and thereby holding the mast drill off the floor.

b) Drill Retracting Foot Cylinder

This control valve is a special spool arrangement. It is a four-way, three position valve, manual operation which has a detent hold in the float position. The ports have been so designed to prevent any hydraulic flow from entering the slide motor which prevents accidental moving of the slide while operating the drill rotation or feed. The valve has a spring return on its alternate position for raising and holding the drill carriage off the floor for translating the drill to the next position.

c/d) Drill Feed Control

This valve is a four-way, three position, spring return valve used to raise and lower the drill head motor. It is connected in series to item d, which can be adjusted to set the feed speed and thrust force. A special feed control package (shown on the hydraulic sequence as the "Flow Control and Relief Valve Package", items 33 et. al.) is standard equipment with the Fletcher mast drill. Its circuitry provides for fast feed when little resistance is felt by the drill steel and a much slower controlled high pressure feed when drilling hard rock.

e) Drill Rotation

This control valve is detent set and will cause the drill head to rotate in either direction or stop when operated manually.

f) Speed of Rotation

The actual speed of rotation can be set by the operator to accommodate different roof conditions by a pressure compensated flow control valve. This operation is usually infrequent and therefore not a spool action valve but rather a screw set valve.

g) Bolt Torque Setting Valve

This valve permits the man to operate the drill motor under a lower fluid pressure for torquing the bolt to the required setting.

h) Panic Bar

The drill is outfitted with a panic bar per Federal requirements.

3.2.2 Control Locations

Referring to Figure 13, the hydraulic controls for bolting will be situated on the left side of the mast drill mounting plate. Dual control handles will be on the right side. The working valves are banked on the upper portion of the plate and the setting or adjustment valves are located on the lower portion of the side plate.

3.3 Transslide

The transslide concept for the reference design was proposed as a method to reduce tramming time between each bolt in a row and to allow the machine mounted TRS to be set once and remain undisturbed while bolting an

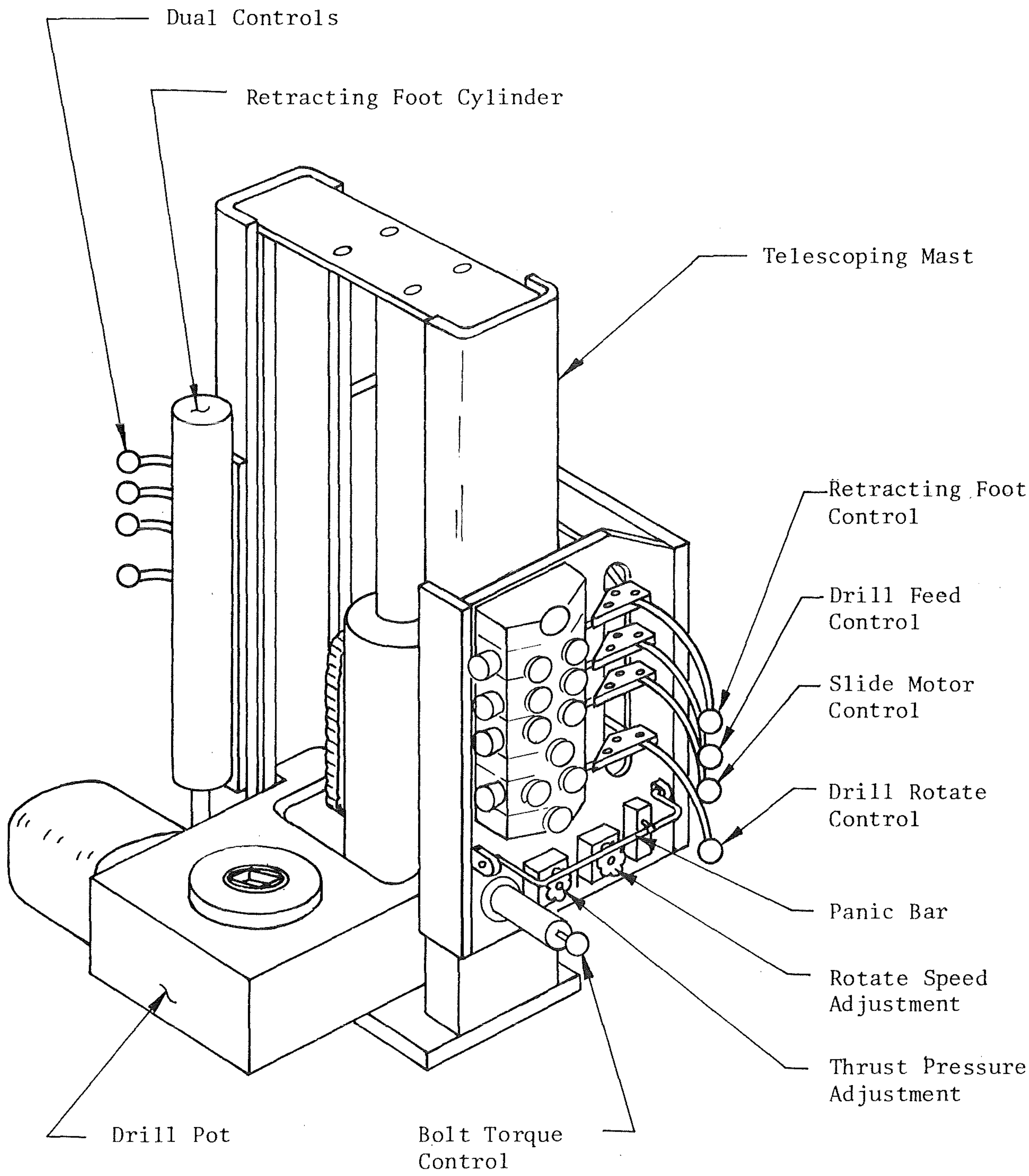


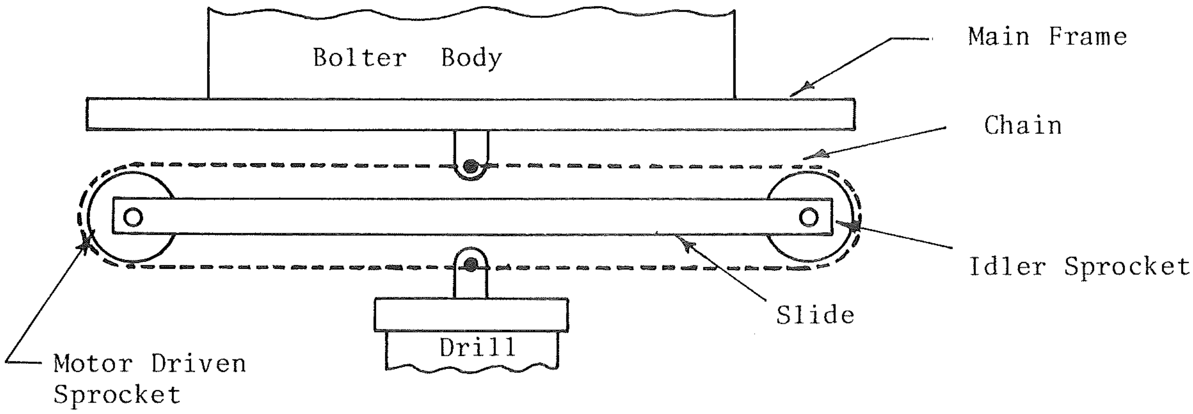
Figure 13 - Mast Drill

entire row. When used with a mast drill, it offers the added advantage of indexing the bolt locations and eliminates the need for the operators to "mark" the roof with paint for each bolt hole. The detail design of the slide was conceived after the mine studies to determine typical and widely used bolting patterns.

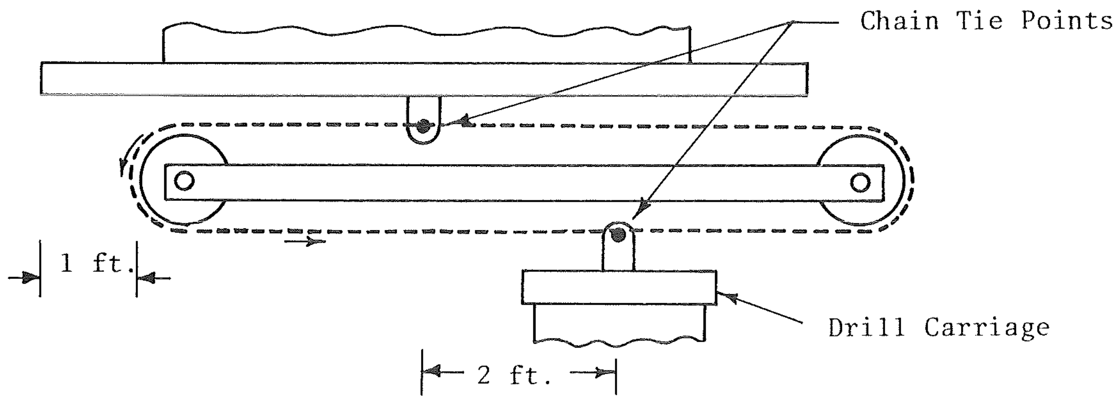
The slide structure is composed of simple structural and machined members with uniform cross-section and is of arbitrary length, determined by the geometric constraints of the entry. The design is based on the most common entry support which is a 4 bolt pattern with the bolts spaced on 4 foot centers. As shown in Figure 6, a double 8' slide would accommodate this as well as other patterns having a maximum distance between end bolts in a given row of 12 feet. If a mine has conditions which warrant bolting closer to the rib on a regular basis, the basic FMA design can be custom fit by providing longer slides with more traversing capability. If only occasional needs require bolting closer to the rib than central positioning of the machine allows, the bolting procedure is modified and the machine has to be positioned twice for that row.

3.3.1 Function

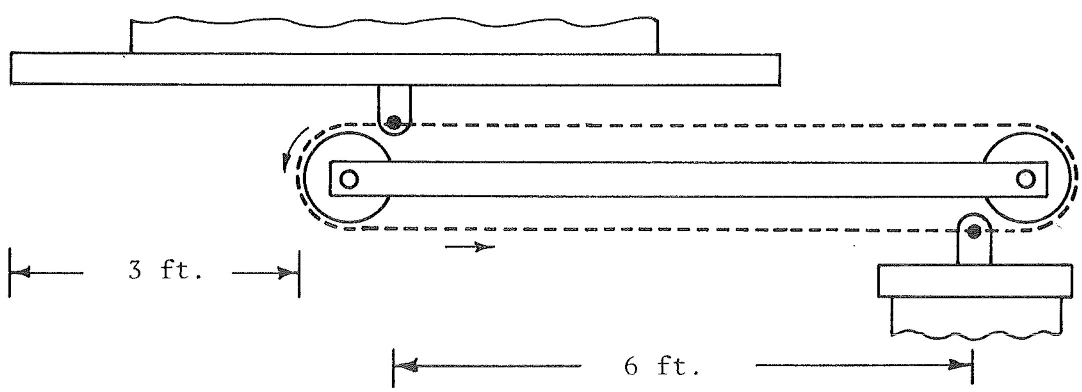
Two sliding members and one stationary frame form the transslide. Diagrammatically shown in Figure 14, the fixed frame also attaches the retrofit kit to the bolting machine chassis; the second 8' slide, or intermediate member, carries the track out beyond the width of the machine for reaching the rib bolt locations. The third section, which is affixed to the mast drill, carries the mast drill across the 12 foot bolt row. Two options were readily available for powering the slide: (1) chain drive with hydraulic motor, or (2) a pair of hydraulic cylinders with chains, similar to a forklift, independently driving the two slides. To minimize space, weight, cost and complexity, the first option was chosen. One small hydraulic motor, two sprockets and a 16 ft. chain provide all the necessary drive components.



a. CENTERED POSITION (for tramming)



b. PARTIAL TRAVERSE (for hole 2 ft. from center)



c. FULL TRAVERSE (for outer bolt 6 ft. from center)

Figure 14 - Diagram of Slide Operation

3.3.2 Strength and Serviceability

The strength of the slide members is designed to satisfy the following conditions:

- Carry the 1,100 pound mast drill unit a cantilevered distance of three feet beyond the end of the fixed slide.
- Transmit a 40,000 pound roof load from each support cylinder to the two stab jacks.
- Resist the torquing moment produced by attempting to drill rock without the feed cylinder planted on the ground surface.

3.3.3 Hardware Selection

There are three levels of loads which the slide components may experience over their lifetimes: normal sliding forces, drill thrust if the extending foot is not on the floor during drilling, and unpredictable, catastrophic, destructive forces caused by misuse or roof collapse. The first two are predictable, and the third is partially accounted for by applying good design practices and conservative strength criteria.

The McGill Camrols® were chosen for the slide bearings because of their wide use and acceptability by mine operators. At each sliding interface there are three rows of rollers; one takes the vertical weight while the other two counter the moment caused by the weight of the drill extended forward. With the particular geometry involved, the forces on each of these sets of bearings is nearly identical. And, although there are several bearings in contact at all times, the analysis assumes that only one bearing at a time experiences peak loads. The rear set of bearings takes the greater load which, under normal conditions, is approximately 1,600 pounds dynamic. In the remote event that the full drill thrust is applied through these bearings the load becomes the above weight plus the drill thrust, or 11,600 pounds static. The Camrol chosen has ratings of 11,720 pounds of dynamic and 16,450 pounds static, which gives an adequate safety factor.

The life of these bearings on the slow speed duty cycle that this application requires is high. Using bearing factors suggested by McGill, the minimum life of these bearings should be in excess of 1 million revolutions. This represents approximately 220,000 bolts which, in a typical mining section excavating 1,000 tons per day, implies a life of over five years.

The chain and hydraulic motor are chosen for adequate capacity to translate the slide even if the tracks are congested with coal, sand or mud. On clean tracks, the coefficient of friction of roller bearings is about 0.01 which requires only 19 pounds of chain tension to translate both the slide and drill carriage. The Char-Lynn "Orbitrol" hydraulic motor chosen has a maximum torque of 1,250 inch-pounds which, when driving the chain through a 9 tooth sprocket, applies 855 pounds of tension to the chain. This accounts for a dsitributed coefficient of friction of .45 (or, taking one slide component at a time, a coefficient of friction of .77). This is adequate capacity for all conditions except for a mechanical jam, which is best corrected by reversing the direction and clearing the obstruction. The rated capacity of the chain is 14,500 pounds, which is well above the stall torque of the motor.

3.4 Hydraulics

As part of the survey, hydraulic circuit drawings were obtained from each of the three leading roof bolter manufacturers for both single and dual head machines (Fletcher, FMC-Galis, and Acme). These were compared and found to be similar. Most machines operate from a 3 or 4 section pump at a line pressure between 1,000 and 1,450 psi. Commercial shearing directional control valves, pumps, motors and cylinders are common to these machines. Some special flow control devices are required in the drill loop and are commonly supplied by Fluid Control, Inc.

The complete hydraulic circuit schematic for the FMA-TRS is shown in Figure 15 (also Drawing D 00HYD). This schematic shows two separate valve banks; one for functions performed from the tram station, and the other for functions performed at the drilling head. The first valve bank contains the typical tram and diverted-flow controls and is supplied by the first two sections of the pump. In addition, since the working spools can be combined, both

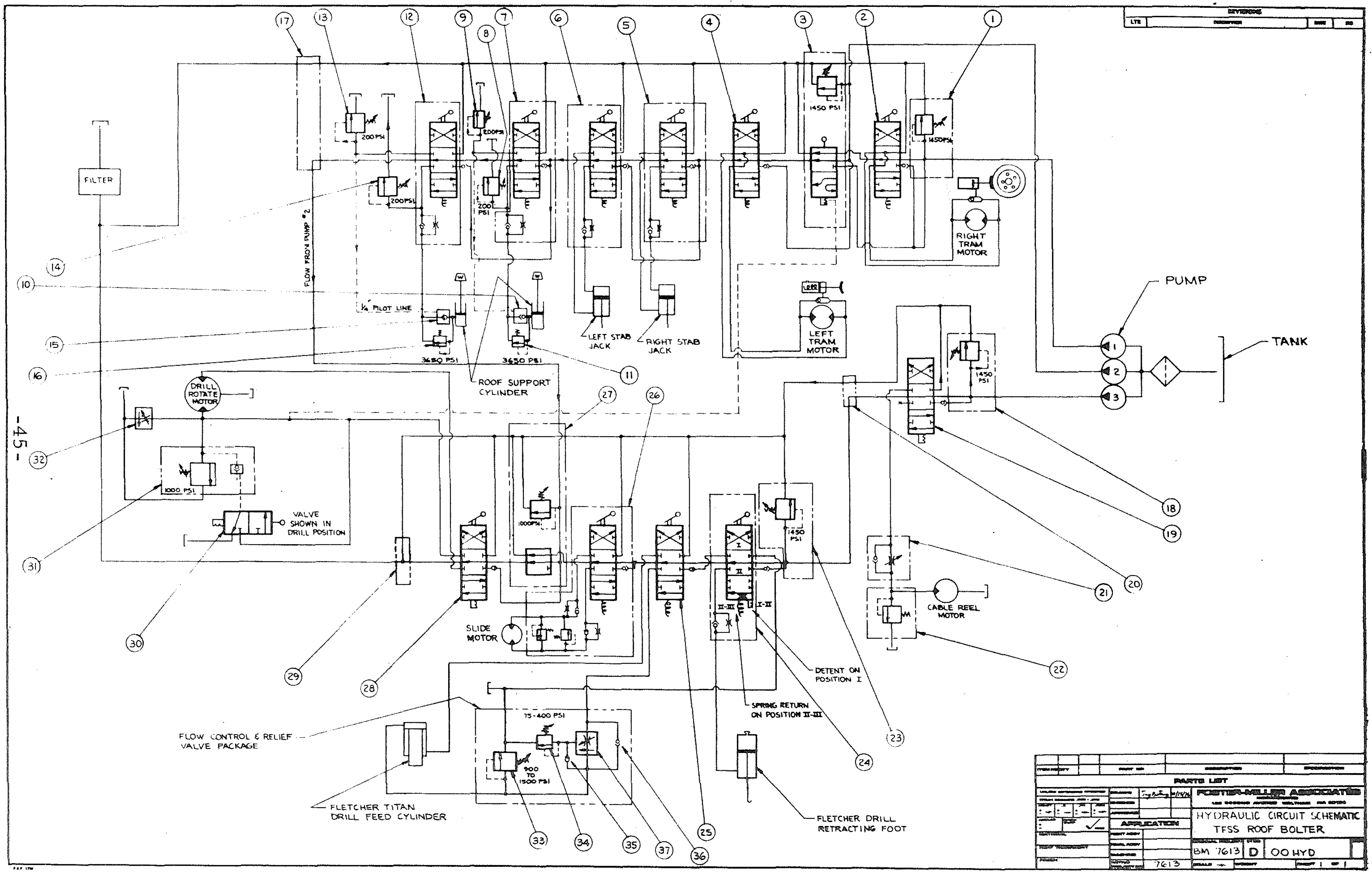


Figure 15 - Hydraulic Circuit Schematic

stab jack valves and roof support valves have been added in tandem to the "flow beyond" section of the tram valves. This is possible because these functions are not operated during tramming and, hence, the entire flow of the first two pump sections feed the support and stabilizer valves. A mechanical interlock may be provided to prevent the operator from using the support controls during tramming or using the tram controls while support is pressurized.

With the exception of the smaller bolters, the increased fluid volume required by the telescopic support cylinders and stab jacks is within the capacity of the existing systems. For the bolters which require additional hydraulic oil capacity a small reserve oil tank may be added. The stab jacks are supplied at line pressure and are capable of maintaining support loads up to 30 tons each. The roof support supply network involves a low pressure relief. This feature permits the roof support to be set against the roof at a maximum of 500 pounds per support pad. The cylinder port is special, containing both a pilot-operated check valve for draining the support and a high pressure relief which senses actual pressure developed in the cylinder during loading. The relief was designed to bleed at the equivalent of a 5 ton load per support pad. Mounting this relief on the cylinder port insures the correct operation despite accidental breakage of any hose or lines leading to or from the cylinder.

The drilling associated functions: slide indexing, retracting foot placement, hole drilling, and bolt torquing, are mounted as a valve bank assembly on the side of the mast drill superstructure. This assembly is fed by two supply lines: one from the third pump section via the neutral position of the cable reel valve and the other from the pressure line of the tram/support valve bank (supplied by the first two pump sections).

These functions are hydraulically sequenced to protect the operator from injury and prevent damage to the machinery. This is accomplished by separating the supply lines for the drill operation, i.e., pump sections 1 and 2 are combined and feed only the drill rotation control valve, while pump section 3 feeds the drill thrust control if and only if the retracting foot cylinder has been lowered to a floor float position. Simply, the drill may be rotated but cannot exert a thrust force until the assembly has been properly lowered to the ground by the retracting foot control valve. This is a special valve which simultaneously controls the direction of the main pressure feed line. In its alternate work position (lifting the drill assembly preparatory to moving the slide) it shuts off flow to the drill thrust and also to the slide motor. When the valve is finally returned to the neutral position it insures that the drill has been lifted. Only when both the drill thrust valve and the retracting foot control are in the neutral position can the pressure feed line activate the slide motor control valve. The slide motor control valve is a standard directional control valve with a cross-over relief and flow restrictors on each work port to prevent excessive slide speeds during indexing.

The remaining drill controls (torque valve, flow controls, thrust rate, fast feed, etc.) are standard equipment and currently available through J.H. Fletcher Co.

3.5 Attachment to Machines

3.5.1 Existing Frame Construction, Boom Removal, Control Removal

All roof bolting machines surveyed have a common frame structure. It generally consists of two substantial steel side plates extending the full length of the bolter. The two plates are spaced by a bottom plate and intermediate internal bracing. The front section is additionally reinforced to contain the cantilevered boom feed assembly. Most of the machine's equipment is attached to the side plates, e.g., dust box, controller, tram motors, wheels, rear canopy, cyclone tank, and control valves. Mounted within the back half of the frame body are the three-section hydraulic pump, hydraulic oil tank, cable reel, blower, and AC or DC motor. All of the latter components remain undisturbed during the retrofit. The entire drill assembly and boom have to be removed from the old machine along with existing drill control valves. The ideal point of attachment of the FMA-TRS package is 25" in front of the front wheel axis. This provides ample clearance for tire changes, replacement of support cylinders, or stabilizer jacks, and routine maintenance. At this point, the side plates of the frame are cut vertically and all structure protruding further forward is removed. On many older machines this includes the removal of not only the drill controls but the tramming valves as well. Some of these valves, if not all, can be utilized by the retrofit package, depending on their mechanical condition. Tram controls, new or old, are relocated to a rear tram station along with stabilizer and roof support valves. The drill control lines are reconnected to the mast drill on its side mounted valve bank by suitable lengths of hydraulic hose which permit full translation of the slide. With the front of the old machine stripped as mentioned and the structure cut back to the point of attachment along a vertical plane, the FMA-TRS package can be mounted.

3.5.2 Preparation and Mounting

The FMA-TRS package was designed so that the entire retrofit kit is carried by the rear frame of the 8 foot transslide. Thus, the package is simply attached to the old roof bolter by weldment between the flat back side of the slide and the cut vertical edges of the two side plates. A set of flanged plates tailored in size to the specific dimensional requirements of a given machine are used to reinforce this union. In addition, two side gusset plates, shown in Drawing D7613-06000, are cut to fit and welded in place to complete the rigid attachment of the structural FMA-TRS package to the old or new machine. Once the rear slide fixture is securely affixed to the machine the cylinders are bolted in place and the remaining assembly of the roof support, transslide and mast drill is completed.

3.5.3 Hydraulic Circuits

For each machine being rebuilt an inspection of the existing hydraulics is necessary to determine usefulness in the FMA-TRS system. Assuming, for purposes of discussion, the worst case, a complete hydraulic overhaul is necessary. New hoses, seals, flow controls, and valves are sized and selected per the FMA-TRS Hydraulic Schematic (Figure 15). These are plumbed from the existing 3 or 4 section hydraulic pump to all operating functions. (See Section 3.4.) In the case of a new or recently rebuilt machine, many of the existing lines and valves would be re-used by relocating on the machine and re-routing into the new circuity.

3.5.4 Effect on Conventional Controls

Because of the importance of operator acceptance on the feasibility and success of a new prototype machine, the design effort concentrated on using mine-proven components and procedures. The control valves suggested are Commercial Shearing products. The drilling functions are performed with exactly the same hydraulic logic as most current mast and boom drills. The major difference results on the older machines where the tram controls have to be relocated to a rear tram station. The controls, however, are the same and operate in the same manner. The four additional control levers for the stabilizer jacks and roof supports pose no problem because their hydraulic circuitry has been designed to eliminate any judgment requirement on behalf of the operator. Only one control is new to the operator: the slide motor control which is mounted with the drill bank. Special attention was devoted to sequencing this valve to prevent unintentional indexing of the mast drill. The resulting design allows this valve to be operated only after the mast drill has been retracted and raised from the floor. This is the logical time to move the drill so it is easily integrated into the bolting cycle.

3.5.5 Relocation of Lights

Relocation of lights was not a task of the contract. However, FMA has addressed the possibility of light relocation and/or general updating of a given lighting system by contacting Ocean Energy, Inc. OEI is in the process of designing a complete MESA approved illumination system for the FMA-TRS bolter, compatible with the specifications herein.

3.5.6 Operator's Platform and Canopy

A tram station must be added near the rear of the bolter being modified unless one is already in place. It is recommended that this station be equipped with one of the currently available designs for a canopy protected tram platform.

3.5.7 Effect on Center of Gravity

The center of gravity is affected by both the removal of old components (boom, controls, etc.) and the addition of new equipment (slide, mast drill, supports, tram station, etc.). The new equipment is usually heavier than the old, but it is partially offset by its compact design with its CG closer to the center of the machine. The shift in CG has been predicted for two sample designs: one, a relatively lightweight unit, the other a Galis 320.

(The Galis 320 is the proposed bolter to be used for the first prototype.) Where exact figures were not available, estimates were used. These calculations are summarized in the diagrams shown in Figure 16 and 17.

The lightweight Acme D-2 (only the miniature Acme D-1 and Wilcox bolters are lighter) suffers a weight increase of 32 percent to 8700 pounds, yet the CG only shifts 7.4 inches forward. This is only 18 percent of its wheelbase and should have little effect on its handling.

Similarly, the Galis 320 experiences a shift in CG of 8.8 inches which is 19 percent of its wheelbase. The Galis' CG is originally at a point about 1/3 forward of the rear wheels. This shift, therefore, puts the CG almost exactly midway between the wheels. Though not ideal, this is certainly not an adverse position. Furthermore, if it must be fully corrected, this can be accomplished by the addition of approximately 1200 pounds of weight at the rear.

3.6 Operation of a Converted Bolter

This section describes some of the normal operational features of this design as well as some of the abnormal problems which may be encountered from time to time. It also discusses modes of operation under both ordinary and non-ideal conditions.

3.6.1 Maneuverability in Entry and Cross Cuts

Since this design fits onto a variety of bolter chassis with different sizes and characteristics, no single discussion could cover all cases. Figure 18 shows a composite of different bolters currently in production. From this, it is apparent that there is quite a range in turning ability from the largest to the smallest machine. (It is unreasonable to expect to outfit the very compact Wilcox bolter with an FMA-TRS package, so it will be omitted from any detailed discussions.)

The maneuverability under normal conditions is not greatly affected by conversion to an FMA-TRS bolter. Because of its compact design the overall length is less than with a boom, and its center of gravity is, for most machines, virtually unchanged. The overall width of the machine is

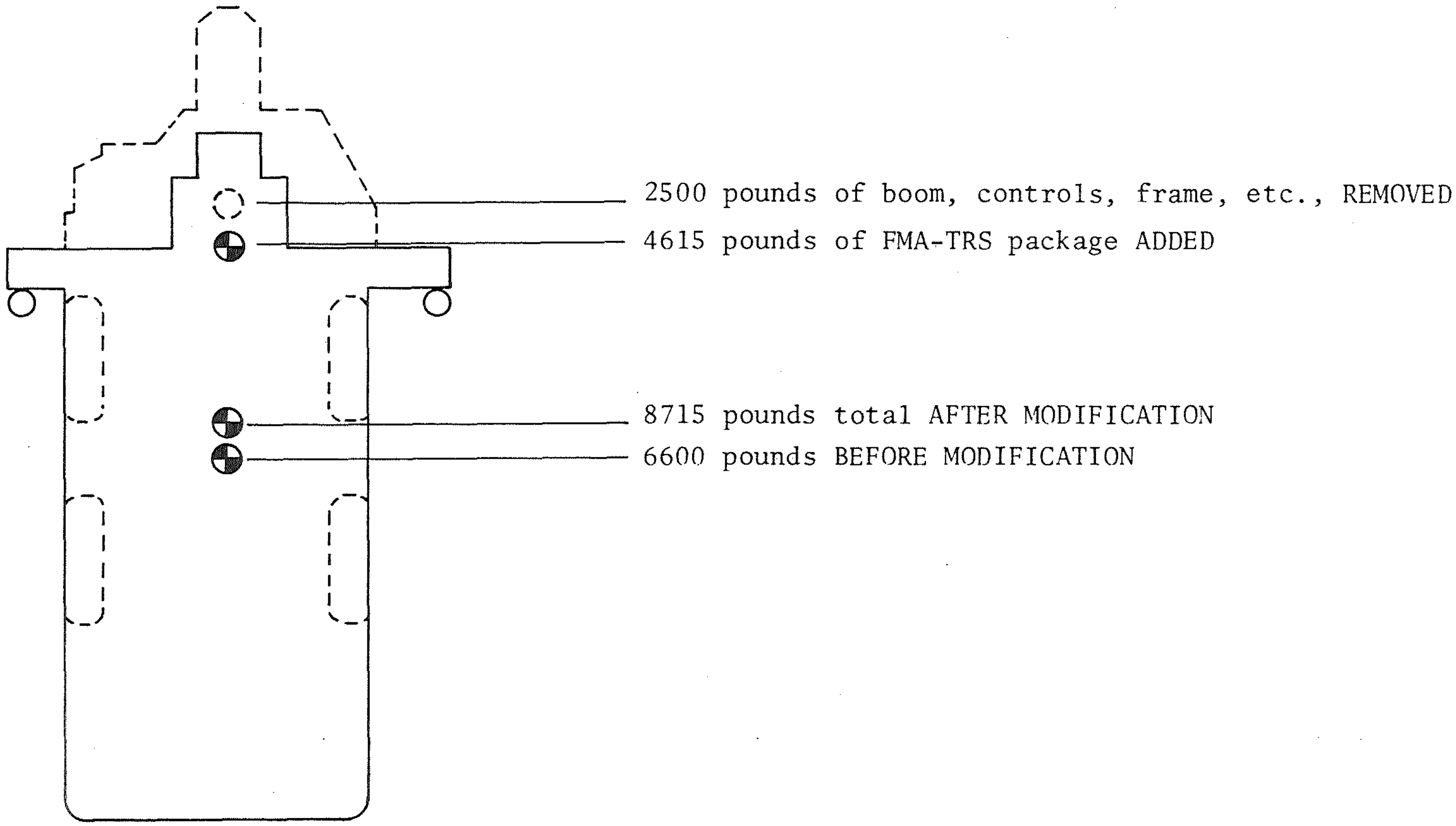


Figure 16 - Shift in Center of Gravity of an Acme D2 Roof Bolter When Outfitted with an FMA-TRS Package

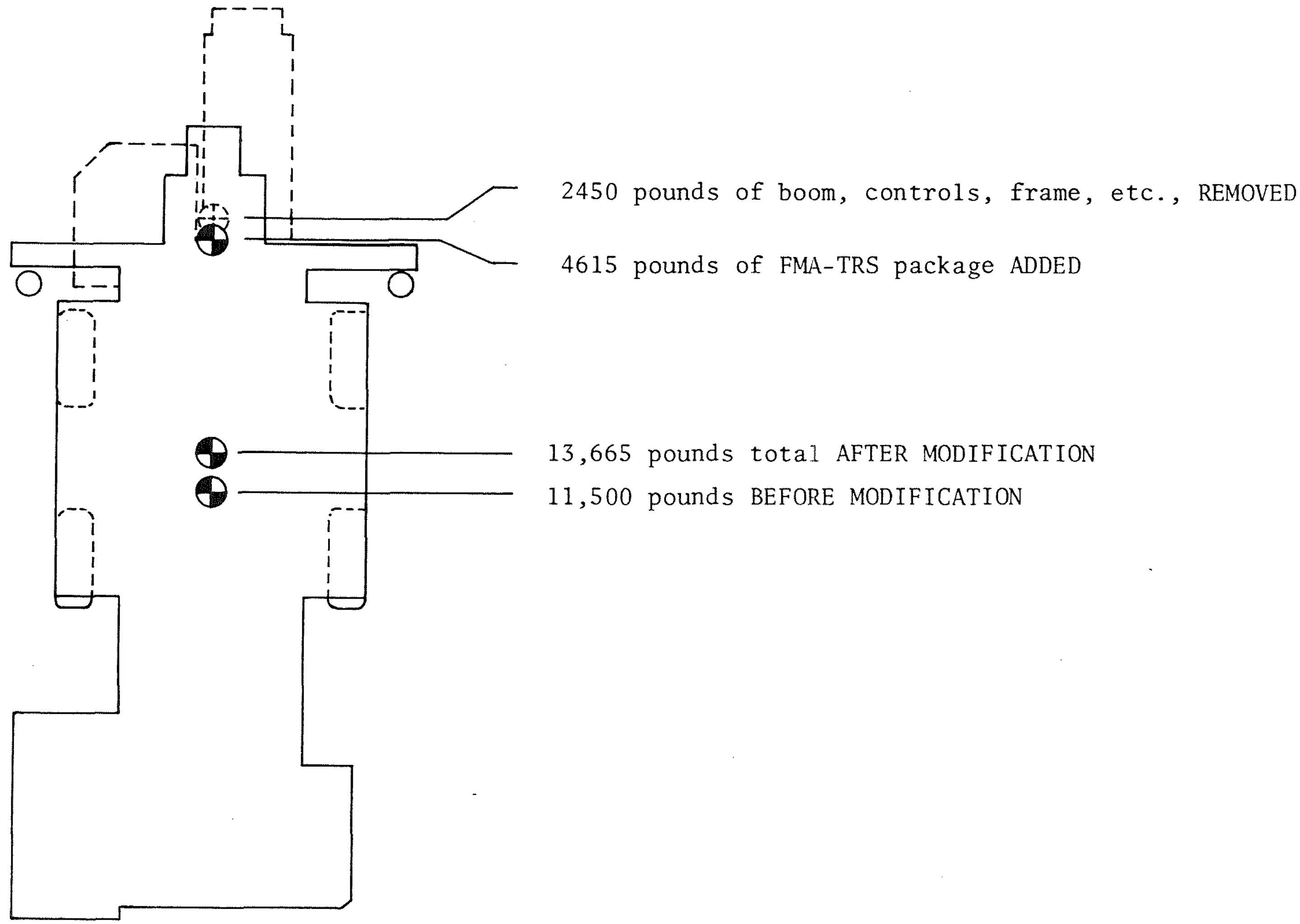


Figure 17 - Shift in Center of Gravity of a Galis 320 Roof Bolter When Outfitted with an FMA-TRS Package

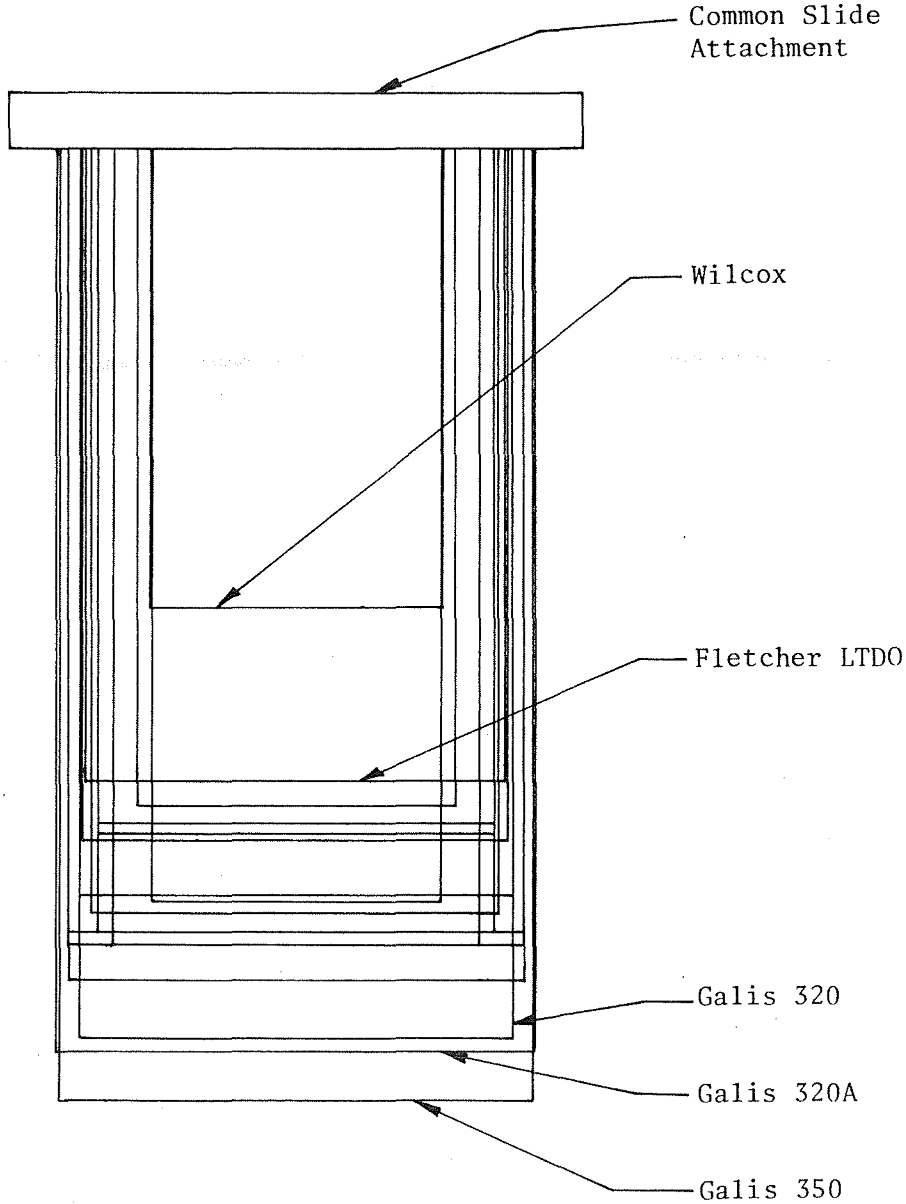


Figure 18 - Composite of Currently Manufactured Bolter Outlines Commonly Attached to FMA-TRS Package

increased to 8 feet by conversion which restricts its ability to pass other vehicles or objects and to negotiate turns, but in most entries little increased difficulty will be encountered. The 8 foot width is measured not only at the slide but all along the zone of the support beams. With the spreader beam at the front turned to its longitudinal position, this region is 9 feet long -- half of which is ahead of the slide. It is this forward portion which presents the greater problem during turning; however, since both the spreader beam and the main beam can swivel, they can be canted for clearance during a turn, if necessary.

All currently manufactured bolters have differential steering which makes it possible for them to turn about their center under ideal conditions. If this procedure is used, a bolter can readily turn from an entry into position to install the first row of bolts in a cross cut. (See Figure 19.)

This type of turning in its purest form is not usually practical in a real mining environment with floor irregularities and obstructing piles of loose coal. Therefore, a more conventional form of turning is recommended. Figure 20 and 21 show two paths that will negotiate the turn. The first uses a short turning radius which delivers the bolter directly to the site of bolting the first row of bolts in the cross cut. The second shows a longer turning radius combined with backing up to the first row. Note that the operator does not have to venture beyond bolted roof. In reality, neither of these paths would be followed exactly but the illustration shows the clearances available to permit typical deviations.

3.6.2 Sequence of Operations

Tramming will be performed in the ordinary manner except that the tram station is located aft -- unlike most of the currently used bolters. As the FMA-TRS bolter approaches the new bolting location it must approach along the centerline of the bolting pattern which, in most cases, is coincident with the entry centerline. The best procedure for tramming on center will be selected after the prototype is in service for its trial run.

There are several options available. One is to use alignment guides (to be described later) which would point to the bolts already installed.

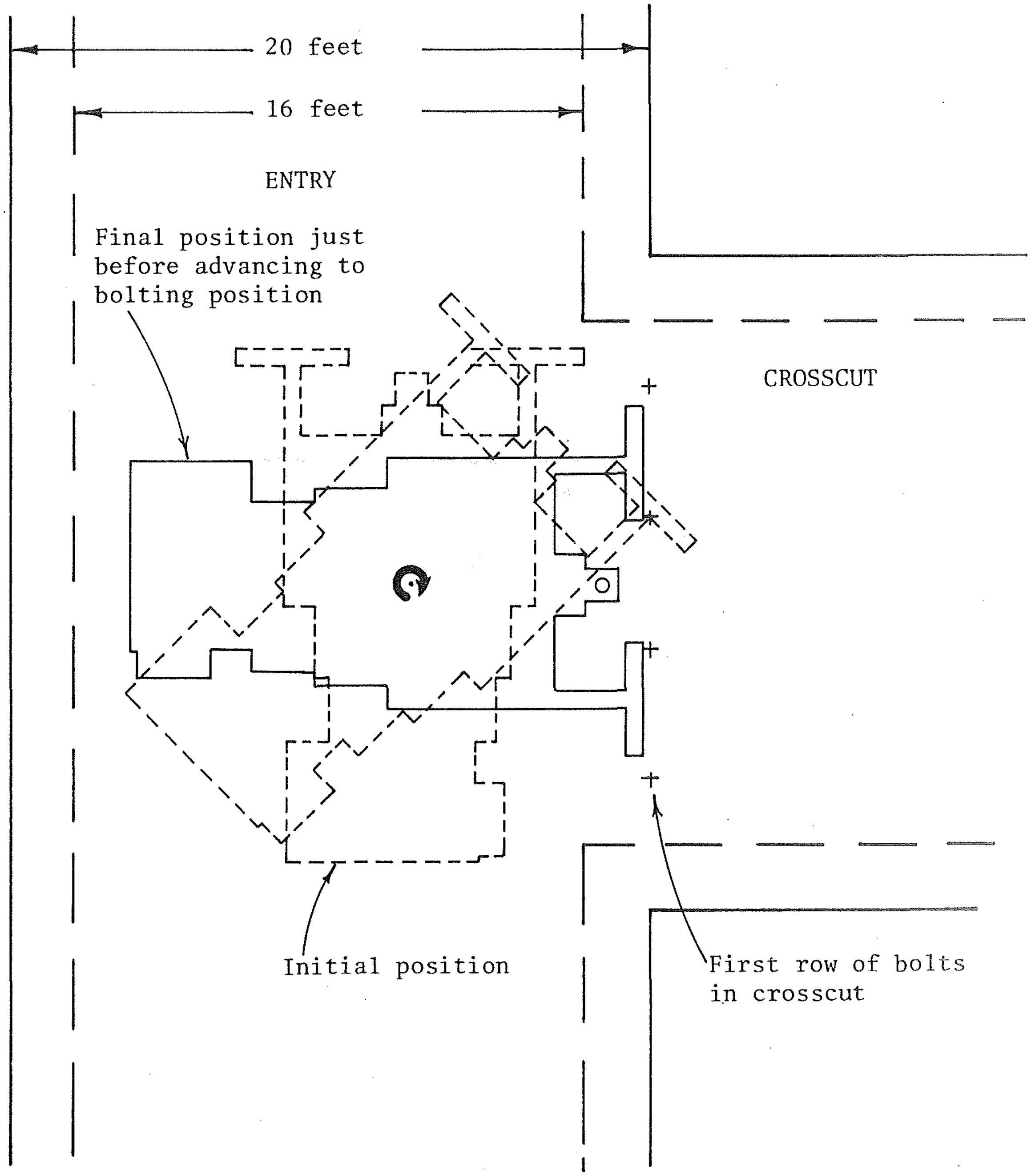


Figure 19 - FMA-TRS Bolter Turning Into A Crosscut By Squirm Steering About Its Center

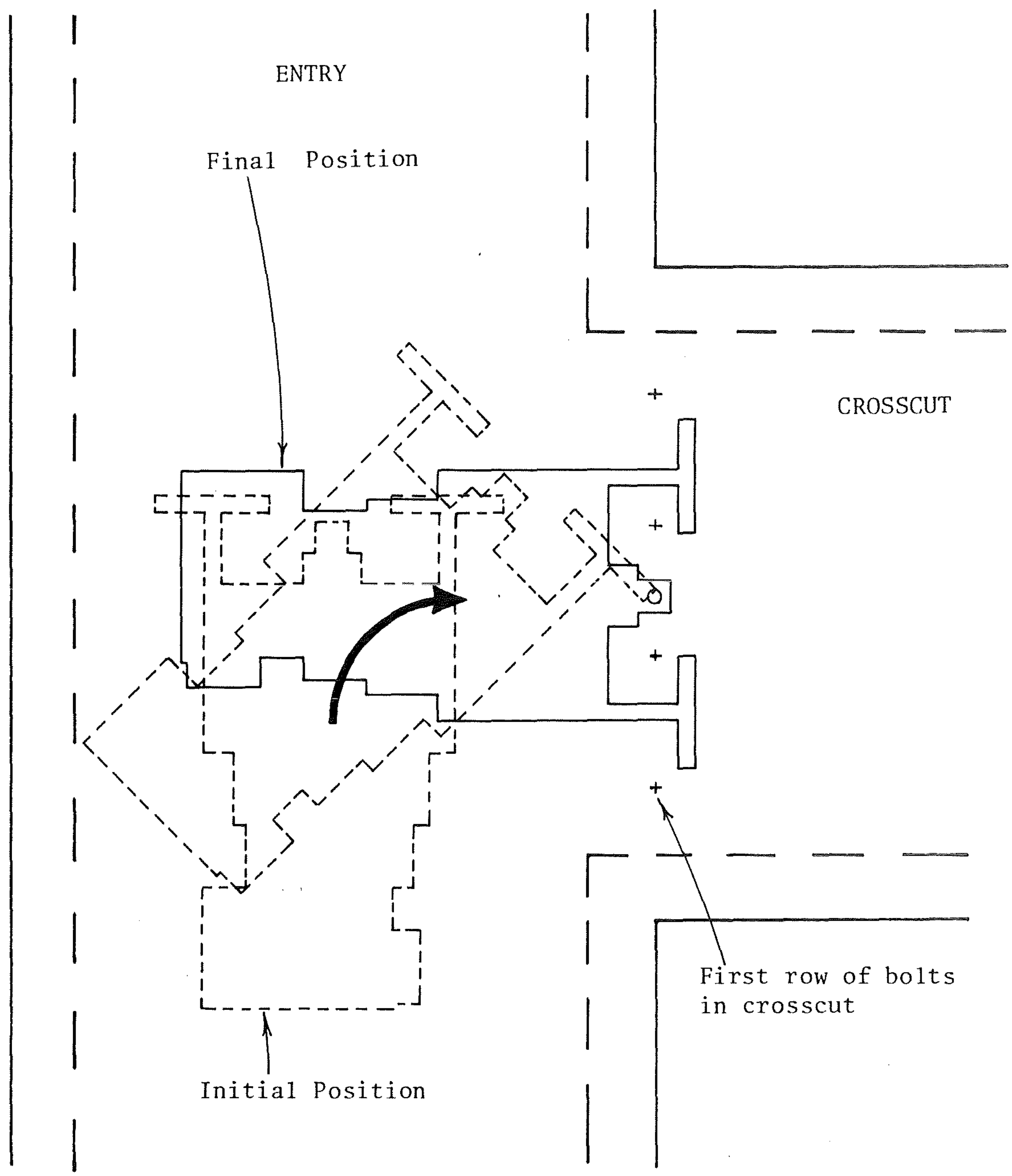


Figure 20 - Bolter Turning Into Crosscut Through a Short Turning Radius Which Delivers Bolter to Proper Position for Bolting First Row

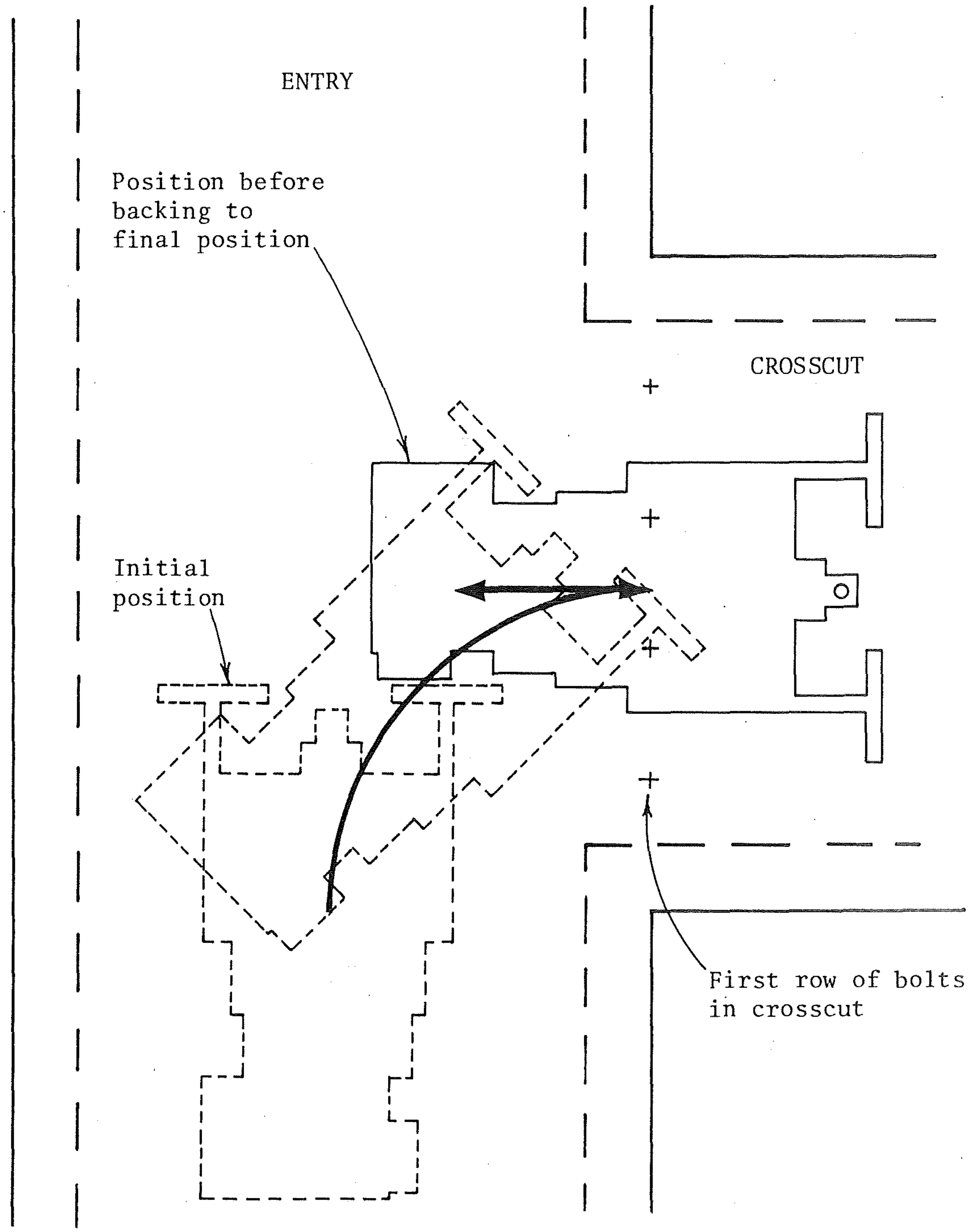


Figure 21 - Bolter Turning Into a Crosscut Through A Long Radius Then Backing Up to Proper Position for Bolting the First Row

This method may suffer from "drift" of the bolt pattern toward one rib or the other. Similarly, the alignment guides could point to a pre-marked centerline along the supported region of the entry. This has the disadvantage of requiring the measuring and marking of the roof. In a 16 foot entry it may be adequate to estimate the 4 foot clearance between the end of the slide structure and the rib, but this procedure would be highly dependent on the ability and conscientiousness of the operator and would be even less accurate in wider entries. This same procedure can be refined to objectivity by the installation of a "rangefinder" illustrated in Figure 22. The lights could be miner's lamps focused for the sharpest image and outfitted with one red and one green filter. The lights would be aimed at the wall so that their images would be coincident if the wall were the correct distance away. If the bolter came too close to the rib, the red image would move above the green, signalling the operator to steer away. If the green image moved above, it would signal the operator to steer closer. All of these methods are ideas which must be tested during the prototype demonstration.

Assuming the operator has trammed the bolter along the centerline, he approaches the last line of bolts and stops the machine under the supported roof. At this point, the helper adjusts the spreader beams to be in their transverse position. Detents hold them in this position for the last few feet of tramming into final position. The operator then trams slowly until the drill centerline is 4 feet* ahead of the last line of bolts. For most FMA-TRS bolters, this puts the last line of bolts almost directly over the front wheels. Some type of alignment guides can be used for this process. The simplest guide would be a mark painted on the bolter body or on the support beams which the helper, standing near the last row of bolts, visually lines up with the bolt row. If painted on the support beam, this method could be quite accurate since it is relatively close to the roof to begin with and, if necessary, the bolter position could be given a final adjustment as the beam approaches the roof.

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*Or whatever dimension is required by the roof bolting plan of the particular mine being bolted.

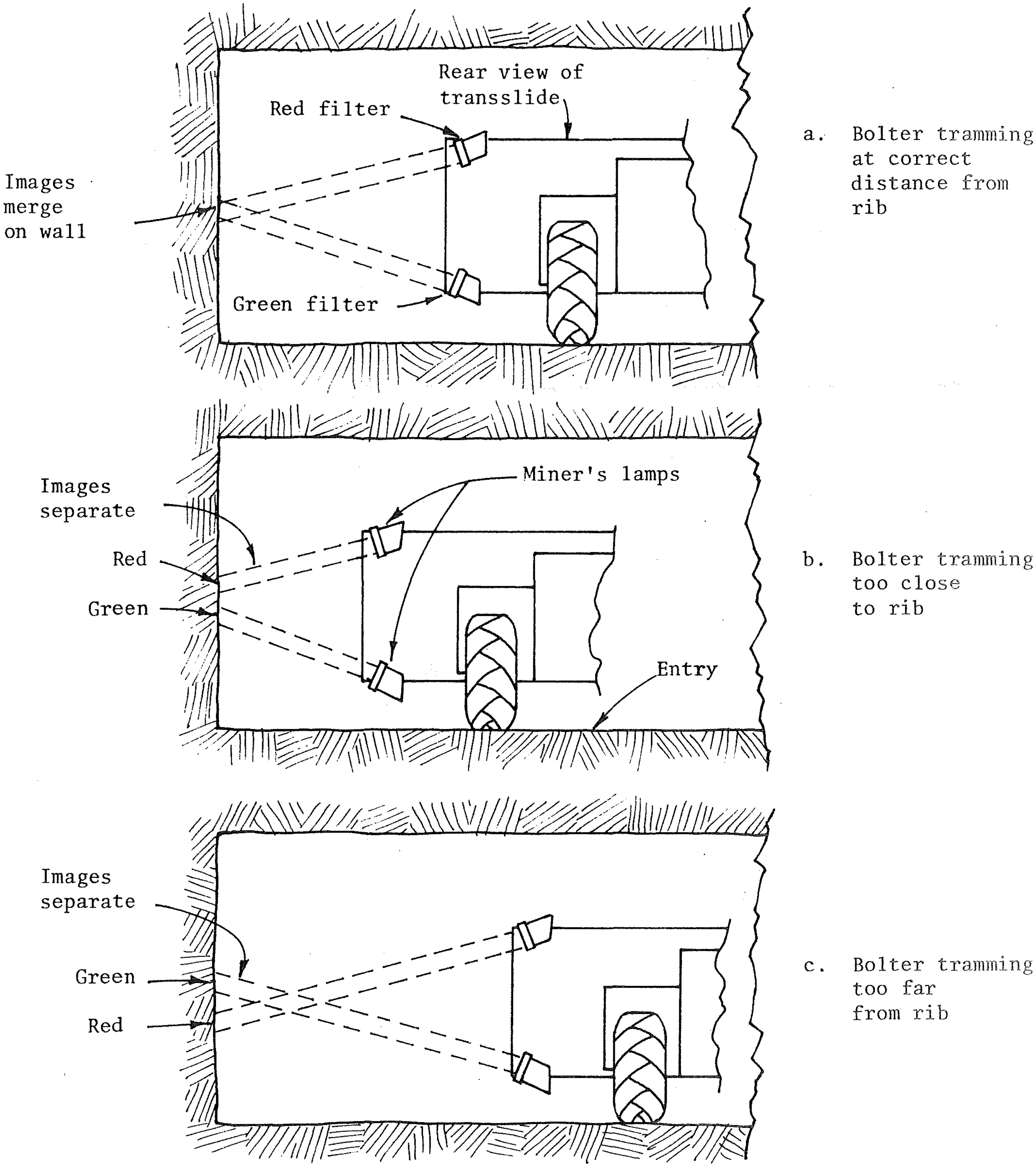

Figure 22 - Rangefinder to Aid in Tramming FMA-TRS Bolter Along Center Line of Entry

To obviate the need for the helper's spotting the alignment, two other methods are available. One is simply to install two telescoping auto antennas under previously installed bolt positions. These are adjusted to be close to, but not touching the roof and are visually aligned with the bolt heads. A much better method is to aim a pair of lights, such as miner's lamps, straight up from the same positions that the antennas would have been mounted. Then, the operator adjusts the bolter until the lamp is illuminating the bolt head. This method is almost maintenance free once adjusted and is completely free of parallax error.

Once in position, centered and squared in the entry and aligned with the bolt row to be installed, the operator erects the temporary support. This is controlled from the tram station. Two controls operate the stabilizer jacks, one near each end of the slide, and two controls actuate the support cylinders. Both parts of these controls are located adjacent to one another, permitting the control knobs to be engaged simultaneously with one hand like the usual tram controls.

The support beams are normally free to rotate about the hydraulic jack axis, so it may be necessary for the helper to square these up just before they settle against the roof. This can be done from the safety of a supported roof by adjusting their rear tips. As part of the test program, a crossed pair of nylon lines will be used to hold the support beams square at all times. Attachment points for these have been provided on the support beam.

Once the temporary support is in place the operator can leave the tram station and walk forward to the drill head -- normally along the left side, but symmetry renders this unimportant. One of the controls is used to "pull" the mast drill unit to the extreme side position which may or may not be at the end of the 6 foot stroke, depending on the details of the bolting pattern. Before drilling, it is necessary to lower the mast drill base down onto the floor. The mast drill will be supplied with a centralizer to hold the drill, thereby affording "hands off" drilling. The drill steel is placed into the chuck and supported by the centralizer. Drilling commences using two controls, rotation and thrust, in the conventional manner. Adding drill extensions, installing the bolt and torquing the bolt will all be done in a normal manner.

Whenever a hole is being drilled only 2 feet from the rib (e.g., a 12 foot bolt pattern centered in a 16 foot entry), the side of the mast drill body will be close to the rib. In this case, the operator can stand to the rear and reach around or over the mast drill frame to the drilling area. Except for the installation of long bolts requiring bending, this should present little problem since the reach is only about 2 feet forward and the top of the collapsed drill frame is only 3 feet 7 inches high (about waist height). The solution to the bendable bolt installation will be worked out during the first demonstration test and may require shifting the drill sideways and returning to the same index mark for torquing. In any case, the position of the operator is no worse than with a dual arm bolter. In fact, with the FMA-TRS system the operator has the advantage of a clear escapeway from the inside control position, unlike dual arm bolters.

After the first bolt is secure, the operator lifts the mast drill and traverses it across the slide to the next bolt position. The need for marking the roof is eliminated by the use of index marks across the front of the slide which show the position of the drill measured in feet from the centerline. Once the new position is reached, the drill is set back down and the process is repeated as before.

Once the drill reaches the centerline, the operator's working position will be 2 1/2 to 3 feet to one side of the centerline, taking a closer position while handling the drill and stepping back a little while operating the hydraulic valves. This places him 12 to 18 inches inside the corner of the slide mechanism. Therefore, in the event that quick escape becomes necessary, the operator must step sideways 1 or 2 feet before he is in a position to run away from the bolting area. Although this is not considered to be a serious safety problem, any further advancement across the front of the machine would place the operator in a difficult escape position. For this reason, the drill unit is supplied with dual controls so that all drilling operations can be done from either side. At this point, therefore, the operator must go to the other side of the drill or turn over continued drilling to his helper.

After the row of bolts is completed, the operator returns to his tram station to lower the TRS and tram the bolter forward to the next row of bolts. The only difference between this short tram and long distance tramming is that the TRS does not need to be fully lowered for such a short advancement forward. The support beam is weighted so that the front end dips down about 10 degrees before the rear end begins to drop. This, in combination with the "skid" shaped rear pad permits the operator to lower the hydraulic cylinder only about 6 inches, lowering the front support pads about 12 inches and dragging the rear of the beam along the roof the 4 feet required to reach the next row to be bolted.

Upon completion of the place, the support is fully retracted to not only effect the lowest tram height but also to set the support beam down on top of the bolter frame so that it is level and stable during the long distance tram.

3.6.3 Operation in Non-ideal Conditions

3.6.3.1 Irregular Floor

The most common difficulty encountered is irregular floor or the presence of piles of loose coal. For this reason, the slide is mounted fairly high on the bolter -- nominally 12 inches above the floor. This was done to obviate the possibility of the slide acting as a snow plow. The slide can be mounted lower if conditions, such as a low roof, warrant the tradeoff.

The stab jacks and roof support cylinders are mounted with their lower ends 6 inches above the floor. They may, under some conditions, have to plow through loose coal. The mast drill has a maximum height above the floor of 8 inches which is typical of mining equipment currently outfitted with mast drills.

3.6.3.2 Irregular Roof

The support beams can tilt on the tops of the support cylinders by 10 degrees. This is equivalent to a height difference between the forward pad and the rear pad of 15 inches. Similarly, the spreader beam at the front can also tilt by 10 degrees, giving a tip to tip height difference of 7.25 inches.

The support pads stand 2.5 inches above the top of the support beam. This will permit bridging of a 2 inch header while still contacting the roof only at the support pads. Alternatively, it will accommodate roof irregularities of 2.5 inches without bearing against the "high spot" instead of the support pads. Although this is not generous, it is adequate under most conditions, and exceeds the 0 to 2.0 inches available on working equipment observed during the survey.

Both the support beam and the spreader beam can rotate in azimuth so that extreme local irregularities such as kettle bottoms, out-of-pattern roof bolts, etc. can be avoided by turning the beam to seek more accommodating contours.

As noted in the hydraulic description, the two roof support jacks can be operated independently so that if one support cannot be deployed at all due to extreme conditions on one side of the cut, the other support can still be used in the normal manner.

3.6.3.3 Inclined Seam

This FMA-TRS bolter can accommodate any seam incline which the original unretrofitted bolter could accommodate. Naturally, the drilled holes will be perpendicular to the plane of the seam, not vertical.

3.6.3.4 Mast Drill Clearance

The mast drill as shown in Figure 23, stands above the roof supports in their lowest tram position, but this figure illustrates a particular design, viz., a design sized for a 5 to 7 foot seam. Since the mast drill is less prone to bouncing and lunging than the support beams because it is located close to the front wheels, the roof clearance above the mast is adequate for this height seam. Furthermore, the mast drill can be lowered toward the floor if necessary to pass local protrusions.

For applications which require a tram height less than the 51 inches indicated for this design, a different mast drill can be selected.

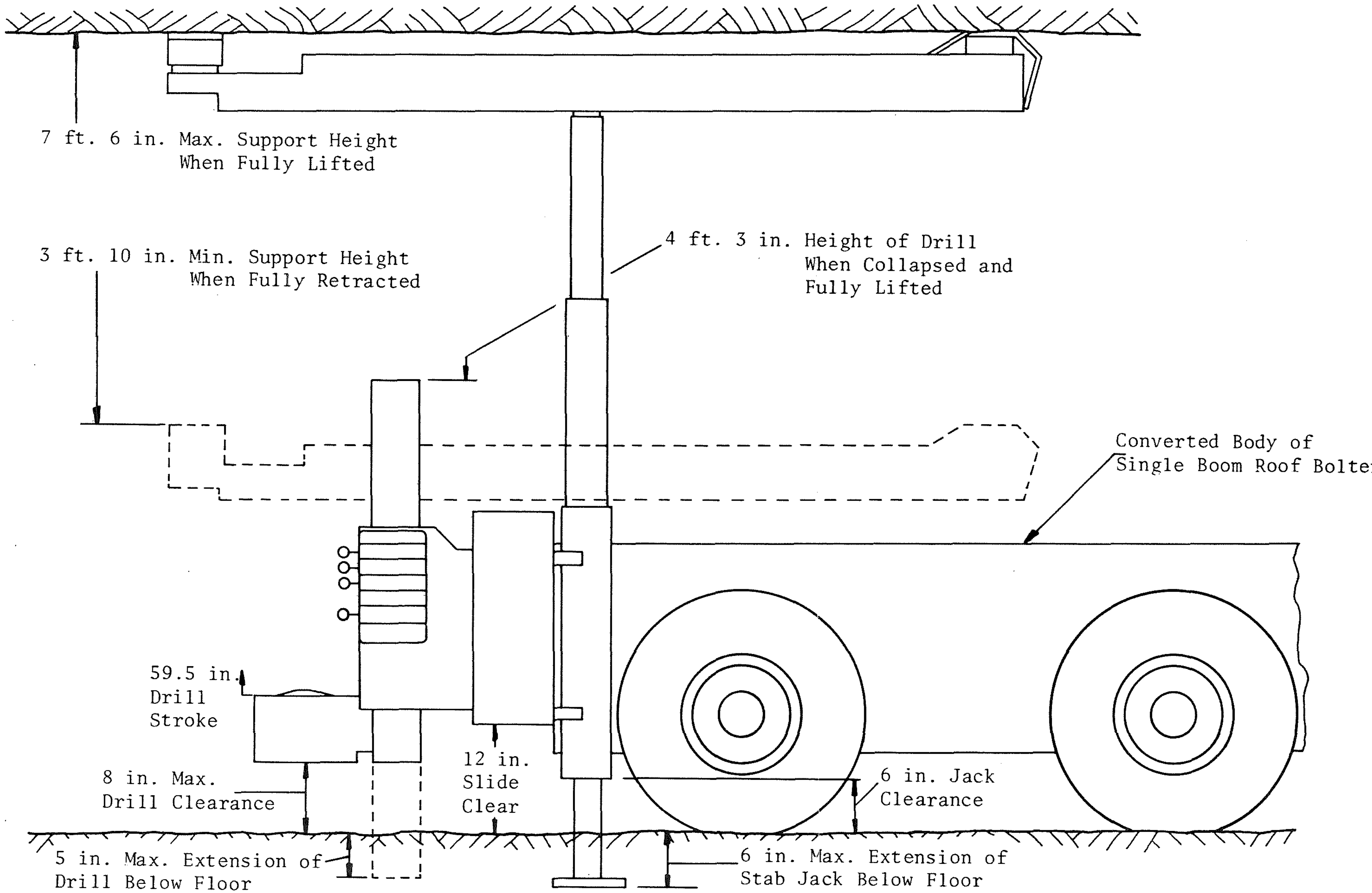

Figure 23 - FMA-TRS Bolter Sized for a 5 to 7 Foot Seam

Either a drill with less height and therefore less stroke, or a drill outfitted with a pivot to permit tramming with the drill in a horizontal attitude may be selected. The latter choice permits drilling inclined holes if desired.

If the roof support is set to support any roof under 60 inches, the mast drill cannot be fully traversed without striking the bottom edge of the support beams. Under such conditions, the operator must first lower the mast drill closer to the floor than the nominal 8 inches so that the drill can pass under the beam.

4. ECONOMIC ANALYSIS

4.1 Introduction

The features of the FMA-TRS bolter will enhance not only safety but also production. The time saved by employing the remotely positioned FMA-TRS and the automatic bolt locating of the indexing transslide is a significant amount of the non-drilling segment of today's bolting cycle. The current cost of providing labor to install, remove and transport posts, and to mark the bolting pattern on the roof is eliminated by the FMA-TRS bolter design. The improved capabilities of the FMA-TRS bolter simultaneously reduce roof support deployment time and eliminate excessive positioning time between bolt holes.

It is apparent that many mines experiencing routine delays from TRS setting, accidents, and excessive machine positioning would readily benefit from the new concept. The following section shows that the FMA-TRS concept can improve single boom bolter speeds in any mine. This could increase production by at least 11 per cent even in mines with good roof conditions, resulting in additional profits of \$13,000/month to the mine operator. This analysis does not apply to operations in which roof bolting does not limit production.

4.2 Cost of the Retrofit Package

The initial cost incurred by a mine for the FMA-TRS package mounted on one of their used single boom bolters would be \$20,000. This figure is as purchased from a shop which specializes in roof bolter rebuilding. The package is broken down by major components as follows:

Fletcher Titan Mast Drill Assembly	\$7,684
Commercial Shearing Support and Stabilizing Cylinders	1,465
Commercial Shearing Valves and Flow Controls	658
Fabricated Steel Components for Slide and Support Beams	4,500
Hardware (Motor, Rollers, Chain, etc.)	700
Labor - Retrofit builders 80 hours @ \$15/hr. x 2	2,500
	\$17,507
Contingencies (15%)	2,626
	\$20,133

Note that this price does not include rebuilding such items as tramming motors, hydraulic pumps, filters, tires, chains, etc., which may be necessary if the machine was taken out of the mine for general maintenance.

* TABLE 4

SAVINGS USING THE FMA-TRS BOLTER

Operations Where Time is Saved	Time Required By FMA-TRS Bolter (Min)	Time Required By Conventional Techniques (Min)	Machine Time Saved Using FMA-TRS (Min)	Temporary Support Time Saved (Min)	Labor Time Saved (Min)
Mark 16 Bolt Locations	0	4			4
Position Drill Head for 16 Bolts	1.6	4	2.4		
Set 16 Post or Equivalent TRS	2	16		14	14
Withdraw 16 Post or Equivalent TRS	1	2 2/3		1 2/3	1 2/3

Summary:

1) Actual machine manuevering time saved per 16 Bolts ...... 2.4 min.
2) Labor functions eliminated: A) setting and removing TRS
   B) marking bolt hole locations
3) Labor Time saved per 16 Bolts is 19.3 min.
4) By directing the helper's saved time of 19 2/3 minutes toward reducing typical bolt preparation, repairs and delay time, estimated reduction of cycle time ...... 1.0 min.

Savings: Minimum Time Saved per 16 Bolts ...... 3.4 min.

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* See Appendix E

4.3 Key Features Providing Increased Performance

Table 4 shows the major operations where the FMA-TRS bolter will provide improvement to the procedure of installing four rows of 4 bolts per row in a new cut while conforming to MESA safety standards, and points out that the FMA-TRS package should conservatively save 3.4 minutes. This is a result of two features which are not currently available on conventional roof bolting machines.

(1) The entire row of TRS (4 points across a typical 16' entry) is remotely deployed and automatically transported by the vehicle. Not only does this decrease the total length of the bolting cycle, but it actually reduces the extra manpower required to install conventional supports.

(2) The slide mounted mast drill permits drilling and bolting a complete row of bolts from a single position of the machine in the clear central portion of the entry. It also directly measures (indexes) the bolt hole locations, eliminating the manpower and most of the time associated with marking the roof and squirming the bolting machine for each individual bolt in a row.

Note that it has been conservatively assumed that saving almost 20 minutes of helper time will save only one minute on the total cycle. Despite the fact that the mast drill can provide higher thrust forces, no increase in drilling rate has been assumed.

4.4 Return on Investment

Table 5 illustrates how the FMA-TRS retrofitted bolter could pay for itself after 34 days of average operation.

TABLE 5

PAYBACK SUMMARY

Assumption: Mine is producing 300 tons/shift

Current Production	600 tons/day
Feet of Advancement (600 tons, 16 ft. wide entry, 6 ft. seam)	156 ft./day
Bolts Required (4 bolts across, 4 ft. on centers)	156 bolts
Bolting Cycles (16 bolts per cycle)	9.76 cycles
Bolting Time Saved (9.76 cycles, 3.4 min/cycle, from Table 4)	33.2 min/day
Increased Tonage Mined (assuming only ¼ of the bolting time saved will materialize as continuous miner cutting time, and average cutting rate of miner is 4 tons/min.)	33.2 tons/day
Rate of Return (33.2 tons increase/day, $18/ton)	$597/day
Payback ($20,000/machine)	33½ days

5. CONCLUSIONS

The major conclusions reached as a result of this research and development program are summarized as follows:

a. A well integrated retrofit package has been designed and can be built which will provide existing bolters with a temporary roof support capability.

b. Most of the single boom bolters in use today can be outfitted with the FMA-TRS package.

c. An FMA-TRS bolter has the capability of installing temporary roof support from a remote location.

d. An FMA-TRS bolter provides a well supported region of roof under which miners can work installing roof bolts.

e. The FMA-TRS package is designed using mine proven components, techniques and procedures.

f. An FMA-TRS bolter can improve productivity through increases in work rate and decreases in labor intensive functions.

g. The FMA-TRS package is cost effective.

h. Federal safety standards are met by the FMA-TRS design.

i. The FMA-TRS design meets all the requirements set forth in section 2.1.

It is recommended that since the design has successfully addressed and exceeded all the objectives, that the program should proceed along the original lines outlined in the proposal to build and test a prototype.

APPENDIX A

LIST OF DRAWINGS

D 7613 - 04000	Dual Control Linkage Assembly
B 7613 - 04001	Left Side Control Handle
B 7613 - 04002	Right Side Control Handle
B 7613 - 04003	Left Side Pivot Bar
B 7613 - 04004	Right Side Pivot Bar
A 7613 - 04005	Drag Link
A 7613 - 04006	Connecting Link
A 7613 - 04007	Linkage Pin
D 7613 - 00HYD	Hydraulic Schematic
D 7613 - 05000	Boom Removal From Galis 320
D 7613 - 06000	Attachment of FMA - TRS to Stripped Galis 320

APPENDIX B

<u>PARTS LISTS</u>

FOSTER MILLER ASSOC.
WALTHAM, MASS.

ASSEMBLY PARTS LIST

SHEET 1 OF 1

MODEL: BM-7613

ASSEMBLY: TEMPORARY FACE SUPPORT SYSTEM (TFS)

ASSY DWG. NO.: 7613-D-00000

PREPARED BY: R.H. ESTEY

APPROVED BY:

DATE: 12-8-76

ITEM	PART NO.	DESCRIPTION	UNIT QTY.	ASSY. QTY.	VENDOR OR MANUFACTURER	DATE ORD.	QTY. ORDERED	P.O. NUMBER	DUE DATE	DATE REC'D	REMARKS	PRICE
1	J01000	SLIDE ASSY	1	1								
2	D02000	SUPPORT SYS. ASSY	2	2								
3	D03000	MAST DRILL ASSY	1	1								
4	C02006	ROOF SUP. CYLINDER	2	2								
5	C02007	STAB JACK CYLINDER	2	2								
6		3/4-16 UNF-2B x 2¼ LG. HEX HD. CAP SCREW (GRADE 5)	6	6								
7		1"-8 UNC-2B x 2¼ LG. HEX HD. CAP SCREW (GRADE 5)	16	16								
8		3/4" SPLIT LOCKWASHER	6	6								
9		1" SPLIT LOCKWASHER	16	16								
10		1" x 2" FLAT STOCK AISI 1020	AR	AR								
11	C02001	PROP PIN	2	2								
12	5160-175	RETAING RING (1¾ SHAFT)	4	4	WALDES TRUARC							
13	1610-BL	FITTING, LUBRICATION	2	2	ALEMITE							
REF.	D00HYD	HYDRAULIC SCHEMATIC (TFS)	1	1								
REF	D05000	BOOM REM'V'L, GALIS 320										
REF	D06000	ATTACHMENT TO GALIS 320										

FOSTER MILLER ASSOC.
WALTHAM, MASS.

ASSEMBLY PARTS LIST

SHEET 1 OF 2

MODEL: 7613

ASSEMBLY: SLIDE ASSY-TEMPORARY FACE SUPPORT SYS.

ASSY DWG. NO.: J7613-01000

PREPARED BY: R. H. ESTEY

APPROVED BY:

DATE: 10-21-76

ITEM	PART NO.	DESCRIPTION	UNIT QTY.	ASSY. QTY.	VENDOR OR MANUFACTURER	DATE ORD.	QTY. ORDERED	P.O. NUMBER	DUE DATE	DATE REC'D	REMARKS	PRICE
1	J01000	SLIDE ASSY	1	1								
2	J01001	MAIN FRAME WELDMENT	1	1								
3	J01002	SLIDE PLATE	1	1								
4	D01003	DRILL CARRIAGE WELDMENT	1	1								
5	D01004	SLIDE COVER	1	1								
6	D01020	ROLLER GUIDE	1	1								
7	C01019	SPROCKET BRKT-ADJ	1	1								
8	C01018	MOTOR MOUNT BRKT	1	1								
9	B01017	SPROCKET BRKT.-FIXED	1	1								
10	B01016	SPROCKET ASSY-FIXED	1	1	BOSTON GEAR #80B8							
11	B01014	SPROCKET ASSY-ADJ	1	1	BOSTON GEAR #80A21							
12	B01015	CHAIN CLAMP	2	2								
13	B01013	INNER RAIL	2	2								
14	B01012	INNER RAIL GUIDE	1	1								
15	B01011	OUTER RAIL	1	1								
16	B01010	SPACER-ROLLER GUIDE	1	1								
17	A01009	CHAIN CLAMP SPACER	1	1								
18	A01008	STOP BLOCK-END	1	1								
19	A01007	STOP BLOCK-CENTER	1	1								
20	A01006	RETAINER PLATE	2	2								
21	A01005	BUMPER	2	2								
22	A01021	DRIVE SPROCKET-RWK	1	1	BOSTON GEAR #80B9-1¼							
23	107-1006-004	ORBIT MOTOR	1	1	CHAR-LYNN							
24	CCFL-2½-SB	CAM FOLLOWER	24	24	McGILL							
25		HEX NUT, 1-12 UNF-2B	24	24								
26		1" SPLIT LOCKWASHER	18	18								
27	80	SINGLE WIDTH ROLLER CHAIN		20 FEET	BOSTON GEAR							
28		DOWEL PIN, ½ DIA. x 1½ LG.	2	2	UNBRAKO							

FOSTER MILLER ASSOC.
WALTHAM, MASS.

MODEL: 7613

PREPARED BY: R. H. ESTEY

ASSEMBLY PARTS LIST

ASSEMBLY: SLIDE ASSY - TEMPORARY FACE SUPPORT SYS.

APPROVED BY:

ASSY DWG. NO.: J7613-01000

DATE: 10-21-76

ITEM	PART NO.	DESCRIPTION	UNIT QTY.	ASSY. QTY.	VENDOR OR MANUFACTURER	DATE ORD.	QTY. ORDERED	P.O. NUMBER	DUE DATE	DATE REC'D	REMARKS	PRICE
29		3/4-10 UNC x 1 1/2" LG. SOCKET HD. CAP SCREW (ALLOY STEEL)	4	4								
30		3/4-10 UNC x 2" LG. SOCKET HD. CAP SCREW (ALLOY STEEL)	22	22								
31		3/4-10 UNC x 2 1/4" LG. SOCKET HD. CAP SCREW (ALLOY STEEL)	2	2								
32		3/4-10 UNC x 3 1/2" LG. SOCKET HD. CAP SCREW (ALLOY STEEL)	2	2								
33		3/4-10 UNC x 4" LG. SOCKET HD. CAP SCREW (ALLOY STEEL)	10	10								
34		3/4-10 UNC x 5" LG. SOCKET HD. CAP SCREW (ALLOY STEEL)	9	9								
35		3/4" SPLIT LOCKWASHER	49	49								
36		3/4" FLAT WASHER	2	2								
37		1/2-13 UNC x 2 1/4 LG. SOCKET HD. CAP SCREW (ALLOY STEEL)	4	4								
38		1/2-13 UNC x 1 1/4 LG. SOCKET HD. CAP SCREW (ALLOY STEEL)	6	6								
39		1/2" SPLIT LOCKWASHER	10	10								
40		7/16-14 UNC x 2" SOCKET HD. CAP SCREW (ALLOY STEEL)	4	4								
41		7/16" SPLIT LOCKWASHER	4	4								
42		SHOULDER SCREW 5/16 DIA x 1" LG. (1/4-20 THD) ALLOY STEEL	4	4								
43		1/4" SPLIT LOCKWASHER	4	4								
44		3/8-16 UNC x 1 1/4" LG. SOCKET HD. CAP SCREW (ALLOY STEEL)	4	4								
45		3/8" SPLIT LOCKWASHER	4	4								
46	FB-1620-10	FLANGED BUSHING	4	4	BOSTON GEAR							
47	5160-98	RETAINING RING	2	2	TRU-ARC							

FOSTER MILLER ASSOC.
WALTHAM, MASS.

ASSEMBLY PARTS LIST

SHEET 1 OF 1

MODEL: BM-7613

ASSEMBLY: SUPPORT SYSTEM ASSY-TEMPORARY FACE SUPPORT SYSTEM (TFS)

ASSY DWG. NO.: 7613-D-02000

PREPARED BY: R. H. ESTEY

APPROVED BY: ____________

DATE: 12-10-76

ITEM	PART NO.	DESCRIPTION	UNIT QTY.	ASSY. QTY.	VENDOR OR MANUFACTURER	DATE ORD.	QTY. ORDERED	P.O. NUMBER	DUE DATE	DATE REC'D	REMARKS	PRICE
1	D02005	TEE-BEAM WELDMENT	1	2								
2	D02003	MODIFIED I-BEAM	1	2								
3	B02008	RUBBER BUMPER	2	4								
4	GR 769	SOLID SHAPE, 3/4 THK. x 6.0 LG.	2	4	GREEN RUBBER							
5		FLAT WASHER, EXTRA HEAVY DUTY 13/16 I.D. x 2 3/8 O.D. x .165 THK.	1	2								
6		BOLT, HEX 3/4-10 UNC x 3 1/8 LG	1	2								
7	EASTMAN 910	ADHESIVE	AR	AR								

FOSTER MILLER ASSOC.
WALTHAM, MASS.

ASSEMBLY PARTS LIST

SHEET 1 OF 1

MODEL: ____

ASSEMBLY: MAST DRILL—DUAL CONTROL LINKAGE

ASSY DWG. NO.: 7613D04000

PREPARED BY: R. J. LEPKOWSKI

APPROVED BY: ____

DATE: 12-15-76

ITEM	PART NO.	DESCRIPTION	UNIT QTY.	ASSY. QTY.	VENDOR OR MANUFACTURER	DATE ORD.	QTY. ORDERED	P.O. NUMBER	DUE DATE	DATE REC'D	REMARKS	PRICE
1	7613B04001	LEFT SIDE CONTROL HANDLE		4								
2	7613A04005	DRAG LINK		4								
3	7613A04007	LINKAGE PIN		24								
4	7613A04006	CONNECTING LINK		4								
5	7613B04002	RIGHT SIDE CONTROL HANDLE		4								
6	7613B04003	LEFT SIDE PIVOT BAR		1								
7	7613B04004	RIGHT SIDE PIVOT BAR		1								
8		PLASTIC BALL		8	CARR LANE						CAT. NO. CL-672-PB	
9		½"-13 × 1" LG. HEX HD. CAP SCR.		4							CARBON STEEL	
10		½" LOCKWASHER		4							CARBON STEEL	
11		COTTER PIN		24								

FOSTER-MILLER ASSOCIATES INC.
ENGINEERS
135 SECOND AVE.
WALTHAM, MA 02154
617 890-3200

PARTS LIST

Title: HYDRAULIC CIRCUIT SCHEMATIC TFSS ROOF BOLTER

Project No.: BM 7613 Drawing No.: D 00HYD

Prepared by: John L. Curcio Date: 26 Oct 1976

Item	Commercial Shearing Code No.	Description	Related Operation
1	AA 127 (p.20)	End Inlet Section, 1" O.D. Tube Ports, with Cartridge Relief Built In, 1450 PSI	Tram Valve Section
2	LA 57 (p.29)	4 Way, 3 Position, Work Ports Open to Flow When Spool Is In Neutral Position, 3/4" O.D. Tube Ports	Right Side Tram Control Valve
3	EDB 216 (p.44)	Mid Inlet Section Split or Combined Flow with Overload Relief (1450 PSI), 2 Position Manual, Pilot Operated Detent, 1" O.D. Tube Ports	Tram Valve Section
4	LA 57	Same as Item 2	Left Side Tram Control Valve
5	HA 57 (p.26) KB 15-30 (p.15)	4 Way, 3 Position, Manual, Spring Return, Work Ports Block When Spool Is In Neutral Position, 3/4" O.D. Tube Ports, to Include One (1) <u>Flow Restrictor</u> Port Check	Right Stab Jack Control Valve
6	HA 57 KB 15-30	Same as Item 5 " " " "	Left Stab Jack Control Valve
7	HA 57 KB 15-30	Same as Item 5 " " " "	Right Roof Support Cylinder Control Valve
8	BA 6625 K-12	Combination Overload Relief-Pressure Control Valve, 1" NPT Ports, 75-400 PSI, In Line	Right Roof Support Setting Pressure Regulator
9	BA 6625 K-12	Same as Item 8	Pressure Control for Pilot Operated Check Valve to Right Roof Cylinder
10	CL 6625 K-2 (p.60)	Pilot Operated Load Hold Check Valve, In Line, 1" NPT, 180 PSI Pilot Pressure Required to Operate	Check Valve to Feed and Retract on Right Roof Cylinder

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PARTS LIST

(Continued)

HYDRAULIC CIRCUIT SCHEMATIC TFSS ROOF BOLTER (BM 7613) - Dwg. D 00HYD - 26 Oct 1976

Item	Commercial Shearing Code No.	Description	Related Operation
11	BA 6625 K- (p.62)	Combination Overload Relief Pressure Control Valve, 1" NPT, In Line, Relief @ 3650 PSI	Yield Pressure Control for Right Roof Cylinder
12	HA 57 KB 15-30	Same as Item 5 " " " "	Left Roof Support Cylinder Control Valve
13	BA 6625 K-12	Same as Item 8	Pressure Control for Pilot Operated Check Valve to Left Roof Cyl
14	BA 6625 K-12	Same as Item 8	Left Roof Support Setting Pressure Regulator
15	CL 6625 K-2	Same as Item 10	Check Valve to Feed and Retract on Left Roof Cyl
16	BA 6625 K-	Same as Item 11	Yield Pressure Control for Left Roof Cyl.
17	Y 58 (p.39)	Pressure Beyond Outlet Section, 1" O.D. Tube Ports	Tram and Roof Support Valve Bank
18	AA 127	Same as Item 1	Inlet for Cable Reel Valve Bank
19	HB 57 (p.26)	4 Way, 3 Position, 3/4" O.D. Tube Ports, Manual with Detent	Cable Reel Control Valve
20	Y 58	Same as Item 17	Outlet for Cable Reel Valve Bank
21	C1043-3K (p.64)	One Way Flow Control Valve (Adjustable Restriction), 3/4" NPT, 25 GPM Capacity	Cable Reel Speed Adjustment

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PARTS LIST
(Continued)

HYDRAULIC CIRCUIT SCHEMATIC TFSS ROOF BOLTER (BM 7613) - Dwg. D 00HYD - 26 Oct 1976

Item	Commercial Shearing Code No.	Description	Related Operation
22	BA 6625 K-1	Combination Overload Relief-Pressure Control Valve, 1" NPT, Range 800-2000 PSI	Pressure Relief for Cable Reel Motor
23	AA 127	Same as Item 1	Inlet for Drill and Slide Control Valve Bank
24	Not listed KB 15-30	4 Way, 3 Position, Manual, Spring Return From III to II, Detent Hold In I or II, Include Flow Restrictor Check Port (See Schematic)	Retracting Foot Cylinder Control Valve
25	HA 57 (p.26)	4 Way, 3 Position, Work Ports Blocked When Spool Is In Neutral Position, 3/4" O.D. Tube Ports, Manual, Spring Return	Drill Feed Cylinder Control Valve
26	HA 657 (p.28) KB 15-30 KB 15-30	4 Way, 3 Position, Manual Control Spring Return, Include Cross-over Relief, with Flow Restrictor Port Check in Both Work Ports, 3/4" O.D.Tube	Slide Motor Control Valve
27	EAA 110 (p.22)	Mid Inlet Section, Split Flow-Combine Flow to Include A Cartridge Relief, 1000 PSI, 3/4" O.D. Tube Ports	Mid Inlet Section on Drill Control Valve Bank
28	HB 57 (p.26)	4 Way, 3 Position, 3/4" O.D. Tube Ports, Manual with Detent	Drill Rotation Control Valve
29	Z 14 (p.38)	Tank Return Outlet Section, 1" O.D. Tube	Outlet for Drill Control Valve Bank
30	L-1320-3 (p.63)	3 Way, 2 Position,Manual Selective Flow Direction Valve, In Line	Drill Torque Selector Valve
31	Not listed	Pilot Controlled Relief Valve, In Line	Pressure Control for Bolt Torquing
32	Not listed	Flow Control, Adjustable, Pressure Compensated, In Line	Drill Rotation Speed Adjustment
33	Not listed	Adjustable Pressure Relief, 900-1500 PSI, In Line	Drill Feed Pressure Relief
34	BA 6625 K-12	Same as Item 8	Low Pressure Relief for Fast Unloaded Drill Feed
35	Not Listed	Check Valve, In Line	Drill Cylinder Feed Circuit

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(Continued)

HYDRAULIC CIRCUIT SCHEMATIC TFSS ROOF BOLTER (BM 7613) - Dwg. D 00HYD - 26 Oct 1976

Item	Commercial Shearing Code No.	Description	Related Operation
36	Not listed	Same as Item 35	Drill Cylinder Feed Circuit
37	Not listed	Flow Control with Bypass Pressure Compensated, In Line	Drill Cylinder Feed Circuit

APPENDIX C

LIST OF LONG LEAD ITEMS

	Delivery (Weeks)
ROOF SUPPORT CYLINDERS	14-18
STAB JACK CYLINDERS	14-18
ROOF BOLTER (MODEL 320)	17
TITAN MAST DRILL	13-17
HYDRAULIC CONTROLS	13
FABRICATED STRUCTURAL COMPONENTS: SLIDE & ROOF SUPPORT	8-10

APPENDIX D

SUMMARY OF QUOTATIONS

Description	Quotation
FMC Galis Model 320 Roof Drilling Machine with Hydraulic Disc Brakes Torquing Valve Panic Bar Dry Chemical Fire Protection Canopy Filter	$30,670.00 Del'y 4 mos.
Roof Support Cylinder	<u>Commercial Shearing:</u> 4 - $637.46 100 - 444.73 500 - 438.60 Del'y 14-18 weeks <u>Ward Hydraulics:</u> 4 - $830.00 100 - 445.00 500 - 415.00 2000 - 398.00 Del'y 14-16 weeks
Stab Jack Cylinder	<u>Commercial Shearing</u> 4 - $519.59 100 - 287.71 500 - 281.56 Del'y 14 weeks <u>Ward Hydraulics</u> 4 - $496.00 100 - 239.00 500 - 229.00 2000 - 225.00 Del'y 14-16 weeks
Titan Mast Drill (42-inch) without Controls	<u>Fletcher</u> 1-10 $6,737.00 11-50 6,198.00 51+ 5,844.00 Del'y 3-4 mos.

Description	Quotation
Titan Mast Drill (42-inch) Complete with Controls and Panic Bar	**Fletcher** 1-10 $8,667.00 11-50 8,038.00 51+ 7,684.00 Del'y 3-4 mos. **Superior Hydraulics** 1 $9,580 (Similar design)
Safety Jack with Relief and Accumulator without Controls	**Fletcher** 1-10 $2,200.00 11-50 2,045.00 51+ 1,920.00 Del'y 3-4 mos.
Fabricated Components for Slide Assembly and Roof Support Assembly	**Plainville Machine** 1* $5,351.40 2* 5,351.40 50 5,200.00 Del'y 8-10 weeks* **Southbridge** 1 $6,100.00 2 5,600.00 Del'y 8 weeks **Avery & Saul** 1* $6,270.00 2* 6,150.00 50 5,886.00 250 5,675.00 1000 5,580.00 Del'y 8-12 weeks*
Camrols - CCFL - 2½-SB	**McGill** 1-99 $ 13.20 1000 10.21 Del'y - Immediate (few)
Hydraulic Motor - 107-1006-004 MS03006 A02 (M-303)	**Char-Lynn** 1-2 $ 162.00 50 140.40 250 125.28 1000 118.80 Del'y - Immediate (few)

Description	Quotation			
Hydraulic Valves	1-19	20-49	50-99	100---►
Tram, Roof Support, and Stabilization Control Valve Bank	$711.27	$682.81	$640.43	$590.35
(Commercial Shearing)				
Cable Reel Valve Bank	92.33	88.64	83.10	76.63
(Commercial Shearing)				
Drill & Slide Function Control Valve Bank	324.57	311.58	292.11	269.39
(Commercial Shearing)				
Torque Control (Morgantown Machine)	109.51	99.91	78.46	71.61
Feed Rate Control Package	165.30	107.45	107.45	97.52
(Fluid Controls)				
Rotate Speed Control Set	66.57	48.59	43.27	39.27
(Morgantown Machine)				
	$ 1,469.55	$1,338.98	$1,244.82	$1,144.77

APPENDIX E

BENEFITS OF THE FMA-TRS RETROFITTED BOLTER

Features of the FMA-TRS	Conventional Bolter	Additional Labor or Function Which Must Be Used in Conjunction with the Conventional Bolter
1 Operator and 1 Helper	1 Operator 1 Helper	1 Extra Man to Aid Helper Set Post or Jacks or 2 Men from Brattice or Continuous Crew
Drive Machine Easily Down the Center Line of Entry, Stop 4 Times/ Place	Position the Machine 16 Times Per Place	Position Machine 12 Additional Times Per Place
Hydraulically Set 4 Points of TRS Remotely From Under Supported Roof Per Row	Not Provided	* 2 Men Set 4 to 9 Posts Per Row Under Unsupported Roof
Hydraulic Indexing & Positioning of Drill Head by Slide with Machine Stationary Per Row	Not Provided	*2 Men Mark Roof Bolt Pattern on Roof
Hydraulic, Remote Removal of TRS by One Man From Under Supported Roof	Not Provided	* Men Remove Posts and Are Exposed to Unsupported Roof
Transport Entire TRS Compactly and Mechanically By Bolter Between Rows and New Cuts At Optimal Tram Speeds	Not Provided	* Men Carry Supports To or From Bolter or Scoop Before Tramming Is Possible

* Conventional Methods Which Expose Miners to Unsupported Roof