COAL MINE SAFETY AND HEALTH

ROOF-BOLTING-MACHINE COMMITTEE

REPORT OF FINDINGS

July 8, 1994

Please mail comments to:

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Coal Mine Safety and Health
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EXECUTIVE SUMMARY

At the direction of the Administrator for Coal Mine Safety and Health, a roof-bolting-machine committee was convened on April 4, 1994. The objective of the committee was to function as an information gathering group to evaluate roof-bolting machines currently in use and to identify problems with machine design features that may contribute to or cause accidents. The extent of the committee's study was focused on potential hazards to the machine operators during the drilling and roof-bolt installation procedures. In addition to identifying the problems, the committee was asked to determine possible solutions to the problems which are technically feasible for timely application on new and existing machines. The committee also explored options which may be considered for future machine designs.

The committee selected for the assignment was instructed to develop methodology and procedures for obtaining the information, data, and statistics necessary to accomplish the charge of the committee and prepare a report of findings to be submitted to the Administrator.

The committee was comprised of representatives from the State of West Virginia, U. S. Bureau of Mines, Mine Safety and Health Administration, and four major roof-bolter manufacturers as original equipment manufacturer liaisons.

Efforts included:

- Visits to roof-bolter manufacturing facilities and in-depth discussions with manufacturer technical personnel.

- Visits to mining operations where recent roof-bolter accidents had occurred and interviews with bolter operators and others.

- Visits to mining operations to observe various manufacturers' "standard" bolters in different mining heights.

- Visits to mining operations employing additional safety features on roof bolters designed by both the roof-bolter manufacturers and by the mining operators. Interviews with mine personnel and evaluations of the safety features were conducted at these operations.

- Roof-bolter fatal accident analyses for the previous 10-year time period and review of roof-bolter accident studies prepared by West Virginia University and the Bureau of Mines.

- In-mine surveys of roof-bolter feed rates for 197 bolters by State of West Virginia inspectors.

- Round table discussions among committee members to identify the safety problems evident on current roof bolters in operation throughout the country which have contributed to accidents and which may contribute to future accidents.

- A review of all the information collected to aid in formulating viable solution methodologies which address the problems identified.

The solution methodology offered is intended to provide insight into the extent of the problem and the variety of corrective measures available for incorporation on both existing and newly manufactured roof-bolting machines. The following safety feature concepts have been identified:

(1) Two-handed fast-feed control (man-in-position control) -- To prevent actuation of drill head feed controls while machine operators are positioned in pinch-point areas.

(2) Drill head raise shutoff -- A device installed in the drill head raise pinch point that would immediately stop the hydraulic oil flow to the drill head feed cylinder.

(3) Auxiliary controls -- Canopy raise/lower and boom swing controls positioned in a manner to eliminate the pinch point created by the drill boom.

(4) Control guarding -- To prevent inadvertent actuation of controls.

(5) Pinch-point identification -- Provide a means to continuously identify the perimeter of the safe operating area adjacent to the drill boom.

(6) Self-centering controls -- To prevent continued machine movement when the control lever is released.

(7) Hands-off drilling -- To prevent the operator from becoming entangled in moving machine components by providing a means of securing the rotating drill steels or wrench.

(8) Insertion/retrieval devices -- To assist in inserting resin and retrieving drill steel where bolting operations create a reach dilemma.

(9) Standardized control layouts -- To prevent inadvertent actuation of controls due to different roof-bolting-machine control layouts.

(10) Pre-operational inspection -- Inspection of machine controls to detect malfunctions prior to operation.

INTRODUCTION

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The committee selected for the assignment was instructed to develop methodology and procedures for obtaining the information, data, and statistics necessary to accomplish the charge of the committee and prepare a report of findings to be submitted to the Administrator.

The first meeting of the group was held at the District 4 office in Mount Hope, West Virginia, during the week of April 4, 1994. Committee activities during the first part of the week were devoted to organizing the assigned task and developing strategy for gathering the information required. Visits to three major roof-bolting-machine manufacturers were made during the latter part of the week. The manufacturers visited included J. H. Fletcher & Company, Eimco Coal Machinery, Incorporated, and Long-Airdox Company.

In-mine visits to selected coal mines with varying seam heights and different makes and models of roof-bolting machines were started during the week of April 11. The purposes of the visits were to observe roof-bolting operations and to interview the machine operators. The other major manufacturer of roof bolters, Fairchild International, was visited that week by committee members. The in-mine evaluations were completed during the week of June 6, 1994.

The following persons were members of the committee:

Mine Safety and Health Administration

District 3

Nelson T. Blake

District 4

James W. Rutherford
Joseph O. Vallina, Jr.
John G. Cheetham

CMS&H, Safety Division

Richard Stoltz

Technical Support

Joseph F. Judeikis (A&CC)
James L. Angel (A&CC)
William J. Gray (Roof Control Division)

State of West Virginia
Office of Miners' Health, Safety and Training

Doug Conaway
Willis R. Webb

U. S. Bureau of Mines

Richard L. Unger

The following persons were selected as Manufacturer Representative Liaisons:

J. H. Fletcher & Company

Douglas R. Hardman

Long-Airdox Company

James W. Gibson

Eimco Coal Machinery, Incorporated

George T. Daugherty

Fairchild International

Roger Plumley

BACKGROUND AND SCOPE

Sixteen fatal machinery accidents which were related to roof bolting occurred between January 1984 and April 1994. Of the 16 fatalities, 14 involved a drill boom. Of these 14, 9 resulted from the victim being crushed between the boom and the mine roof, 3 resulted from the victim being crushed between the boom and the canopy, 1 resulted from the victim being crushed between the boom and the machine frame, and 1 resulted from the victim being crushed between the boom and the ATRS. The other 2 fatalities resulted from the victim being crushed between the drill mast head and the machine frame. Three of the fatalities occurred within a 6-week period from February 15 to March 25, 1994, which prompted Coal Mine Safety and Health to establish this committee.

In addition to reviewing the fatality reports, the committee reviewed roof-bolter accident studies prepared by West Virginia University (WVU) and the U. S. Bureau of Mines. The first study compiled by WVU was published in the May-June 1994 Holmes Safety Association Bulletin. WVU analyzed the West Virginia Safety Information System (WVSIS) data on West Virginia coal mines for a period of five years between 1983 and 1987. WVU determined from the database that 2,083 accidents relating to roof bolters occurred in this five-year period. This total included all types of accidents, not just machinery accidents related to roof bolting.

The U. S. Bureau of Mines analyzed the MSHA accident files for the years of 1988 through 1991. A total of 613 roof-bolting accidents were identified. The criteria for selecting these accidents were limited to machinery accidents involving roof bolters. These two reviews of accident analysis data indicate that numerous accidents occurred during drilling and roof-bolt installation, which further supports the necessity for additional safety measures.

The scope of the committee's assignment was limited to boom and mast-type roof-bolting machines and did not include continuous-mining machines with integral bolters. The study focused on potential hazards to the roof-bolter operators during the drilling and roof-bolt installation procedures.

IDENTIFICATION OF POTENTIAL PROBLEMS

In order for the committee to identify viable measures to help prevent roof-bolter accidents, it was necessary to first obtain an understanding of the accident-related problems along with how and why they developed. Also, it was important to determine why such problems continue to exist. As part of this effort, the committee posed questions and formulated explanations which would aid in identifying solutions to the problems. These questions, along with probable explanations, are as follow:

Question No. 1. Generally, what were the immediate causes of the roof-bolter fatalities over the past 10 years?

Explanation No. 1. Injuries to bolter operators resulted from unintentional, inadvertent, or accidental actuation of controls resulting in machine movement which, due to operator/machine orientation, caused crushing injuries.

Question No. 2. Why were the bolter operators in the "fatal pinch points" in the first place?

Explanation No. 2. The bolter operators placed themselves in the "fatal pinch points" either knowingly or unknowingly because of:

(a) a confined work space,

(b) reaching a control, materials, or attempting to see some facet of the bolting operation,

(c) reacting to a malfunctioning control, or

(d) performing machine maintenance.

Bolter operators may have also found themselves in a "fatal pinch point" due to imbalance or a sudden loss of balance.

Question No. 3. Why were the controls actuated?

Explanation No. 3. Machine control movements resulting in actuation may have initiated from either:

(a) confusion as to "what lever did what," i.e., moving the wrong lever,

(b) unintentional actuation of a control by something other than the operator's hand while performing bolting/drilling associated functions (e.g., cap-lamp battery, self-rescuer, foreign object),

(c) a machine malfunction which created a surprise control movement (e.g., levers fouling), or

(d) stumbling into or on top of levers.

Question No. 4. Did the machine design allow the uncontrolled movement to happen?

Explanation No. 4. The bolter operator wasn't required to verify control movement before initiating machine movement, i.e., two-handed control or multiple control movement to initiate machine movement for select (potentially harmful) controls, or some other means to verify intentions (the expected machine movement) prior to initiating the resultant machine movement.

Question No. 5. Why couldn't the bolter operator stop the accident from happening?

Explanation No. 5. The bolter operator either:

(a) didn't have room to react,

(b) didn't have time to react, or

(c) didn't know he/she needed to react.

Question No. 6. Why couldn't the bolter operator get out of harm's way once the accident sequence started?

Explanation No. 6. The bolter operator may not have been aware the ingredients for the accident were present or set into motion. He may also have been unaware that he was positioned in a pinch-point area. The operator may have been off balance and/or overextended and, once the accident sequence was set into motion, had no room to get clear and no time to stop it.

Question No. 7. Did the operators need to be exactly where they were when the accident happened?

Explanation No. 7. If the answer to this question is yes, then the "fatal pinch point" needs to be eliminated or at least disarmed when the operator penetrates this area.

If the answer to this question is no, then why was the operator in fact in this area? Possible explanations include:

(a) a lack of space to operate the drill station forced the operator into the fatal pinch-point area,

(b) the control location required the operator to continually place himself/herself in dangerously close proximity to fatal pinch-point areas,

(c) drilling/bolting practices are so repetitive that a casual attitude can develop decreasing respect for the danger created by the fatal pinch-point area, or

(d) due to the extremely fine line of demarcation between a fatal pinch-point area and a harmless area, the bolter operator possibly did not have a feel for, or awareness of, the exact location of this critical boundary. This awareness could be further clouded by focus directed to keeping pace with his co-bolter operator. In a highly production-oriented environment, monotony of repetitive actions and mental and physical fatigue also may dull awareness of mentally defined boundaries.

FACT-FINDING METHODOLOGY

The methodology used to gather the information needed consisted of: (1) review of the 16 roof-bolter fatal accidents which occurred between January 1984 and April 1994; (2) analysis of all roof-bolting-machine accidents in the MSHA accident files for the years 1988 through 1991 and review of the roof-bolter accident study prepared by WVU; (3) review of data collected by State inspectors during a survey of roof-bolting machines in West Virginia and corresponding interviews with the operators conducted in April 1994; (4) visits to the four major roof-bolting-machine manufacturers to observe new and rebuilt machines; (5) visits to 17 mines by committee members to observe the operation of different makes and types of machines and interview the operators on both single and dual-boom drills; and (6) attendance and participation by committee members at the two Accident Prevention Conferences on Fletcher HDDR Roof-Bolting Machines in Golden, Colorado, and Beckley, West Virginia, on April 19 and 21, 1994, respectively.

DISCUSSION

Committee members were divided into groups to conduct visits to selected mines utilizing various makes, models, and types of roof-bolting machines in seam heights ranging from 34 inches to 144 inches. The purpose was to observe drilling and bolting operations including machine functions, valve control arrangements, and also to identify pinch points and hazardous locations. Special emphasis was placed on observing procedures involving the use of the fast-feed function during the bolting operations. The recent accidents involving roof bolters and the goals of the committee were discussed with the machine operators. They were asked about problems encountered using fast feed, experiences with accidental engagement of controls, and about injuries they may have experienced while installing bolts. Input from the bolter operators regarding their work procedures and suggestions to improve safety on roof-bolting machines was also solicited.

In April 1994, West Virginia State inspectors visited a total of 141 underground coal mines in the State and evaluated 197 roof-bolting machines and their operations. Evaluation of the machines included measuring the travel speed of the drill head and time required to install bolts with and without the use of fast-feed controls on machines equipped with such controls. In addition, the inspectors initiated discussion with over 400 roof-bolter operators to obtain their input on the areas of concern. Their findings were comparable to the findings of the committee.

Manufacturer Visits

An important part of the committee's information-gathering effort was carried out through visits to the four major roof-bolting-machine manufacturers: J. H. Fletcher & Company, Eimco Coal Machinery, Incorporated, Long-Airdox Company, and Fairchild International. Bolting machines at the manufacturing plants were examined and detailed discussions with the manufacturers' representatives were conducted. Relevant information provided to the committee included: basic machine and control layout, direction of machine movement corresponding to control movement, and

speed of certain machine movements. New machine designs and protective features were also discussed.

The first manufacturing facility visited was J. H. Fletcher & Company in Huntington, West Virginia. Fletcher currently possesses the largest market share of new bolting machines sold (approximately 70-80 percent of new machine sales). According to Fletcher estimates, there are approximately 800 dual-boom arm-feed-style bolters in operation, with an additional 120 dual-boom mast-feed machines, and 500 various single-boom bolters. Estimates of the roof-bolter population indicate J. H. Fletcher machines account for approximately 50 percent of the total roof bolters in use. Fatal accident data has shown that 7 out of the 16 (44 percent) crushing-type roof-bolting machinery accidents have occurred with machines manufactured by J. H. Fletcher & Company.

Machines observed during the visit included several dual-boom arm-feed units (Models RR-II and DDO), a dual-boom mast-feed machine (Model HDDR), and a single-boom arm-feed machine (Model RR-I).

The RR-II models observed featured a relatively new drill boom arm design fabricated with an offset boom pivot point which enhances several safety aspects of the operator's work station. This offset boom arm (See Appendix A) improves the operator's access to the drilling controls. The offset drill boom also allowed relocation of the controls (compared to a standard boom layout) to a position further outby the drill head. This "streamlining" of the controls allows the roof-bolter operator to be positioned further away from the drill boom arm pinch points. A safer work position is provided while drilling holes and installing bolts and also while swinging the drill boom in order to position the head prior to bolting.

In addition to the safety benefits of the offset drill boom, other protective features were observed and evaluated. Several of the observed machines were equipped with a two-handed fast-feed feature. This design necessitated that a diversion valve be engaged in order to activate the fast-feed functions. Fletcher stated that this two-handed fast-feed design could not be overridden by wiring the diversion valve to the "on" position, and if this was attempted, the drill rotation function would be disabled. In discussions concerning the two-handed fast-feed feature, Fletcher personnel informed the committee that this feature is now standard on all new Fletcher roof-bolting machines. Furthermore, Fletcher indicated that the two-handed fast-feed design was readily retrofittable on all existing Fletcher bolters (retrofit date contingent upon parts availability).

Another safety feature evaluated during this visit was installed on a Model HDDR machine. Stemming from the two recent fatalities with this mast-feed-style bolting machine, Fletcher had designed a "hydraulic" panic bar which extended into the pinch point between the drill mast and controls. Fletcher stated that this device could be retrofitted on existing machines.

The second manufacturing facility visited by the committee was the Long-Airdox Company's roof-bolting plant in Cedar Bluff, Virginia. Long-Airdox recently acquired the Simmons-Rand Company and thus assumed responsibility of existing Simmons-Rand machines and those associated with its

predecessor companies (Ingersoll-Rand, Lee-Norse, and Manson). Estimates place this affiliation of roof-bolting machines as comprising approximately 20 percent of roof bolters currently in operation. This percentage includes numerous models of both single and dual-boom roof bolters (such as Lee-Norse TD2's, Simmons-Rand TD2-A's, Long-Airdox LRB-15's, etc.). No approximations were attempted for each model population.

A review of the 16 roof-bolting-machine fatalities revealed that three crushing-type fatalities (19 percent) occurred on machines under this manufacturer's affiliation.

A dual-boom bolting machine, Model RB2-52A, was observed during this visit. This particular Long-Airdox model was equipped with both a standard feed (approximately 9 in./sec.) and a fast-feed function (approximately 12 in./sec.). Long-Airdox personnel stated that in the past, on Lee-Norse and Simmons-Rand machines, the fast-feed function was only offered on dual-boom roof bolters. Subsequent to the plant visit, the Long-Airdox representative indicated that any machine they manufacture in the future with fast feed will be equipped with controls that require two-handed operation.

Following the visit to Long-Airdox, the committee met with representatives of Eimco Coal Machinery, Incorporated, in their Bluefield, Virginia, office. Eimco is the successor to the FMC and Galis companies' roof-bolting lines. This affiliation of manufacturing companies is estimated to account for an additional 20 percent of currently operating roof-bolting machines. A review of the machinery fatality data revealed four crushing-type fatalities (25 percent) occurred with the Galis/FMC/Eimco machines. Eimco personnel provided information concerning machines manufactured under the Eimco name. The committee was informed that Eimco does not currently offer a separate fast-feed function. The current standard feed rate is estimated to be 10 in./sec. This arrangement has been the Eimco standard on all machines manufactured since mid-1988. Prior to this time, the standard feed rate for Eimco bolting machines was approximately 6 in./sec.; however, dual-boom machines may have been equipped with a separate fast-feed function with a rate of 10 in./sec. Eimco personnel estimated that approximately 42 to 48 dual-boom machines were manufactured with this separate fast-feed function with the aforementioned rate of 10 in./sec. At the time of the committee's visit, no Eimco machines were available for observation. In discussions with Eimco representatives, they did not indicate any plans to incorporate additional safety features to the drilling controls on current designs.

Committee members met with representatives of the fourth major bolting-machine manufacturer, Fairchild International, at their Glen Lyn, Virginia, facility. Estimates put the number of Fairchild machines (and its predecessor company, Wilcox) at less than 5 percent of the roof bolters in operation. A review of the machinery fatality data revealed one crushing-type fatality (6 percent) occurred with a Fairchild machine.

Fairchild International's roof-bolting-machine product line is comprised of single-boom arm-feed-style machines designed for low coal applications. Fairchild personnel informed the committee that their bolting machines have never had a separate fast-feed function. The standard feed rate is designed at

approximately 8 in./sec. Although no machine was available for observation, drawings were presented of a "typical" bolter. As part of the current machine design, a wire mesh guard is provided to block the operator's access to the drill boom pinch point.

Throughout each of the visits, manufacturers were interested in the committee's work and were responsive in providing data on their machines and answering technical questions on machine design and functions. The committee was also shown or informed of any new safety features being considered for new and rebuilt machines, or retrofitted on existing machines in the field.

The manufacturers further indicated they receive only a small share of the rebuild business of their machines. Currently the majority of the rebuild work is being performed by independent rebuild shops and, in some cases, coal company shops. This is a major concern for the manufacturers since machines may not be rebuilt to the original state of repair or to the same design as when the machine was manufactured. They indicated that this may create potential safety problems. Manufacturers were also concerned that machines not rebuilt by the original equipment manufacturer may not incorporate the latest safety feature upgrades.

Mast and Boom Feed Rates

In order to develop an understanding of machine feed rates from an absolute and relative comparison standpoint, committee members evaluated machine feed speeds at bolter manufacturing facilities and mines. Tests were performed on new machines, recently rebuilt machines, and older in-use machines. Test data was collected for all four primary manufacturers of bolters and a variety of machine models which included both boom and mast-type machines. Feed speeds varied for machines of the same model in addition to those of different makes and models. Variations in speeds for machines of the same model can be attributed to manufacturer available options for hydraulic pump sizes (different gallons per minute (GPM) pump options) and also varying degrees of pump and associated hydraulic component wear from machine to machine. Variations can also be attributed to differences in hydraulic hose diameters, oil viscosities, filter condition, and oil temperature at the time tests were conducted, along with individual flow adjustments. Even though there are several factors which contribute to scattering of the feed rate data collected, certain trends in speed differences were clearly apparent. The data collected represented general averages for fast and slow feeds in both the raise and lower directions for the machine models tested. Noteworthy trends include the Fletcher corporate average fast-feed raise rate of 22 inches per second, which is the fastest of all bolter manufacturers, exceeding the 16 inches per second corporate average fast-feed raise rate of Long-Airdox (the only other manufacturer currently providing a fast-feed feature on bolting machines) by over 27 percent. It is also significant to note the Fletcher corporate average slow-feed raise rate of 7 inches per second is the slowest of all make and model bolters tested. Corporate averages for bolter fast-feed raise rate data ranged from 16 to 22 inches per second with individual machine model average ranges from 12 to 24 inches per second. Corporate averages for bolters slow/regular-feed

raise rate data ranged from 7 to 10 inches per second with individual machine model average ranges from 5 to 10 inches per second.

Fairchild and current Eimco bolters are not equipped with a fast-feed feature.

Machine feed rate data which includes both average speeds by machine model and corporate average are included in Appendix B.

Based on a review of current roof-bolting-machine feed rates, the committee has defined "fast-feed" as a feed rate equal to or greater than 12 inches per second. Drill feed rates are to be determined by timing the maximum vertical travel of a point at the center of the drill boom chuck. This measurement is to be made with the drill feed control fully activated and the hydraulic system at normal operating temperature.

FINDINGS

Since January 1984, 16 fatalities have occurred, 15 of which can be attributed to the inadvertent or incorrect actuation of a feed control lever while the machine operator was positioned within the drill head pinch-point area. (See Appendix C.)

The information-gathering and fact-finding efforts of the committee identified the following roof-bolting related problems which may have contributed to or caused accidents. The solutions presented are intended to be performance-oriented and not so narrowly defined as to impede new technology which would provide the same degree of protection. Specific solutions are presented as an example of one way to address the following problems:

PROBLEM NO. 1: Actuation of drill head feed controls while machine operators were positioned in pinch-point areas of the drill head have been contributing causes of numerous fatal and nonfatal accidents. Approximately 50 percent of the fatal accidents can be attributed to inadvertent actuation of the fast-feed lever.

SOLUTION: A machine feature, such as a two-handed fast-feed control which would require a deliberate action by the machine operator to activate the drill feed machine function, could eliminate accidental fast-feed control activation.

Machines that utilize a fast feed should require two-handed operation that positions the operator away from the drill head/pinch points. When any one of the fast-feed controls is released, the fast feed would be disengaged. Care must be taken to position the fast-feed controls so they are far enough apart so that one-handed operation is impossible but they remain accessible from the operator's normal work position. The technology for this retrofit exists and can be performed in-mine.

The two-handed fast-feed feature should be designed so that any intentional wiring down, or otherwise "jumpering out," of the fast-feed diversion valve would render the drill rotation function inoperable for drilling purposes and, therefore, deter any such attempt to circumvent the two-handed fast-feed feature.

An alternative device, such as a man-in-position control, which would provide equivalent protection would be acceptable. If a man-in-position control is employed, it must ensure that the operator is prevented from operating the fast feed while still being able to extend into the pinch-point area. The control should be designed in a manner to deter attempts that would readily circumvent this feature.

BACKGROUND: The solution to the problem of inadvertent actuation of the drill head feed control and repositioning the operator out of the pinch-point area during fast-feed operations was developed through the consideration of the following background information:

In recognition of the aforementioned hazards of fast-feed operation, J. H. Fletcher & Company is incorporating two-handed fast-feed controls on all bolters they are manufacturing at this time. During the mine visits by the committee, some of these machines were observed in operation. Mixed reactions were evident during interviews with the bolter operators. It is relevant to note that these bolters have been in use for a short period of time and normal reluctance to change was evident during interviews with the operators.

Five roof drills using dual fast-feed controls were observed during the evaluation period.

Two dual-boom Fletcher roof bolters which used a joy-stick type control were evaluated. Both machines were in operation for approximately two months. The feed and rotation functions were activated by a single joy-stick control lever which initiated both machine actions. An additional fast-feed control lever (diversion valve) had been installed which had to be engaged to obtain fast feed of the drill boom (two-handed fast-feed control). The roof-bolter operators utilized the fast-feed function only when inserting the resin bolts into the drilled hole. The operators at one mine were observed using one hand to operate both levers simultaneously, thereby defeating the two-handed fast-feed feature. On this machine, the diversion valve was located in a position that made it possible to engage both levers with one hand. The roof-bolter operators at the second mine were observed using the fast-feed function with two hands as intended. The feed lever and diversion valve were spaced sufficiently apart to prevent one-handed operation. All four roof-bolter operators interviewed indicated no operational problems with the additional control.

The third two-handed fast-feed design was viewed on a J. H. Fletcher Model RR-II-13 roof bolter. On this machine, the two fast-feed levers were spaced such that the diversion valve was approximately 9 inches outside the operator's reach when he was in his normal operating position. Although this had the desired effect of positioning the operator away from the pinch point, it required the operator to shift from his normal position in front of the controls in order to reach both levers. Since shifting his position required additional time and effort, the operator consequently relied solely on the slow feed to drill and install bolts. The committee considers that a two-handed fast-feed control can be designed to position the operator away from the pinch point without effectively negating its use.

The fourth two-handed fast-feed design was a two-handed fast-feed retrofit kit purchased from Fletcher and installed by the company on a Model DDO-15. As with the other machines, the installation required two hands to operate the fast feed. Statements made during interviews with the equipment operators indicated they felt the two-handed operation was not viable and unnecessarily complicated the installation of bolts. The coal height on the section ranged from approximately 65 inches to 12 feet. The installation of 7-foot resin bolts that had to be bent for installation caused most of the problems. In effect, the fast feed was not being used because the operators felt they needed one hand free to guide the bent bolt during insertion, catch drill steel, and maintain balance. Some operators at the mine related no problems; however, they were primarily using the slow feed in the installation of bolts. Most operators felt that relocation of existing controls, an offset boom, and possibly a hydraulic panic bar would be adequate to provide a safe operating position in seams over

72 inches. No training or explanation for the installation of the retrofit was given to the operators after the two-handed fast feed was installed on the equipment.

The fifth two-handed design was evaluated during the visit to the J. H. Fletcher & Company. Although the fast feed did require the activation of two levers, the levers were within the range where an operator could activate both levers with one hand. After these observations were made, the valves were repositioned on the machine prior to shipment in a way that required the use of two hands for their operation. This points to the need to require that, if a two-handed fast-feed design is used to position the operator, the levers be spaced sufficiently so that the operator must use two hands to ensure he is positioned away from the pinch point.

A subsequent evaluation of the hydraulic schematics designed by Fletcher for the two-handed fast-feed system revealed that, except for the bolters equipped with a joy-stick control, the systems were not designed to deter the intentional wiring down, or otherwise jumpering out, of the fast-feed diversion valve by rendering the drill rotation function inoperative. The Fletcher representative indicated that this feature could be incorporated into the two-handed fast-feed systems.

"Difficulty in installing resin bolts" was a common concern voiced by bolter operators regarding the need to use two hands to operate the machines' fast-feed function during resin and bolt insertion. This concern was mentioned both in the committee's direct interviews of bolter operators, as well as appearing repeatedly on the surveys conducted by West Virginia State inspectors. Consultation with resin companies and roof-bolt manufacturers has revealed that a feed rate as low as 6 in./sec. during installation of resin bolts should be adequate in most applications.

If specific installation circumstances dictate a longer intermediate time between resin penetration and the initiation of boom feed (such as in extremely low coal where a bolt may be bent and then straightened), the use of slower setting resin may be necessary.

Finally, reports on a man-in-position switch (deadman switch) installed in the floor of the platform on an HDDR angle bolter indicated that the switch was positioned close enough to the drill head that the operator could stand on the switch and still reach into the pinch point.

Drill feed rates for lower working height operations

It is recognized that as the working height available to the operator decreases, additional time is needed for the operator to react and either stop machine movement or move clear of a closing pinch point. When these conditions are prevalent, additional safety measures, such as reduced drill feed rates, should be considered.

PROBLEM NO. 2: The design of the majority of roof-bolting machines in use today requires the operator to work in a confined space in close proximity to pinch points associated with the drill boom arm and drill head.

SOLUTION: A device should be installed at the drill head raise pinch-point locations that would stop the hydraulic oil flow to the drill head feed cylinder upon activation, thereby causing immediate stopping of the boom before serious injury could occur. This could be accomplished with the use of an activation device, located at the drill head pinch point, connected to a hydraulic valve in the drill head lift jack circuit. Care must be taken that the activation device is located properly and does not in itself create a pinch point. Prudent design measures will assure activation of the hydraulic valve prior to the travel in the actuation arm being expended. This valve should also be detented. A similar device is being installed on mast-feed bolting machines being manufactured at this time. Technology exists to implement this system and can be made to the bolters in-mine. (See Appendix D.)

BACKGROUND: A solution to this problem was attempted by strategically locating electrical panic switches in the general area of the drill head/boom arm pinch point.

Committee members evaluated a J. H. Fletcher Model DDO roof bolter which had been modified by a coal company by moving a tape switch panic bar to a position on the drill boom. The panic bar shut off power to the machine when activated. Tests at the mine showed that the boom would continue to raise approximately 8" after deactivation at slow-feed raise speed and travel approximately 18" after deactivation at fast-feed raise speed. This is due to the wind down of the electric motor which continues to turn the hydraulic pump during wind down. This amount of travel could still permit the fatal, crushing injuries noted in the recent roof-bolter accidents. In light of this finding, attempts to arrest movement of the drill head raise in an emergency situation must focus on a more positive means of quickly stopping movement, such as blocking the hydraulic flow to the drill head raise circuit.

PROBLEM NO. 3: Roof-bolter operators are exposed to potential crushing injuries resulting from work positions located in a pinch point between the drill boom and/or canopy and the coal rib when positioning the boom prior to drilling.

SOLUTION: Auxiliary control levers for both the canopy raise/lower and boom swing functions can be retrofitted on existing machines and positioned in such a manner as to eliminate the pinch point created by the swinging drill boom. Program Policy Letter No. P94-V-3 allows that "controls that position the drill station canopy, such as canopy raise, canopy lower, boom swing levers, etc. are not required to be located under a canopy, provided these controls are located on the machine in such a manner that they are operable from under supported roof." By raising the canopy and swinging the boom toward the rib from an outby set of levers, the operator has been removed from the pinch point. This modification can be effected on a retrofit basis with currently available technology.

BACKGROUND: In order to position the drill head prior to drilling a bolt hole, the bolter operator may be exposed to a pinch point while swinging the boom. Contributing factors to the severity of this exposure may be the speed of the drill boom swing function and the inaccessibility of the canopy raise and boom swing controls located under the lowered drill station canopy. The inaccessibility of these controls may be further compounded by the mining heights which force the operator into a severely cramped and awkward work position.

PROBLEM NO. 4: Inadvertent actuation of controls while machine operators were positioned in pinch-point areas of the drill head have been contributing causes of numerous fatal and nonfatal accidents.

SOLUTION: Prevention of inadvertent actuation of controls can be provided by guarding, multiple movement control features, or by other equivalent protection means. Guarding should provide a barrier to prevent accidental contact of controls from the operator's body or foreign objects. A well-designed guard should have certain characteristics:

(a) Be installed so as to impose no restrictions, discomforts, or difficulties for the worker. However, it must not require delicate adjustment for use or move out of alignment easily.

(b) Automatically move into or be fixed into place.

(c) Be designed specifically for the machine, type of operations to be conducted, and the hazards which are present.

(d) Require minimum maintenance.

(e) Not constitute a hazard.

Multiple movement control lever features should be designed to prevent the chance of a control being fouled in an on/activated position. A multiple movement control is defined as a control that requires two distinct motions to activate a machine function. The control lever must facilitate an easy actuation due to frequent control movement requirements as a result of the number of roof bolts that are installed during a typical working shift. (See Appendix E for a sketch of a typical control guard.)

BACKGROUND: Several guards retrofitted on machines in the field were observed by committee members. These guarding options were considered to serve the intended purpose.

PROBLEM NO. 5: Observations of roof-bolting operations indicated that the bolter operators were inadvertently positioning their limbs or head over the boom arm during bolt installation. This appears to be a result of the lack of awareness of the pinch point, in that there is no reference point to alert the operator of the danger area.

SOLUTION: Provide a means for the operator to continuously identify the perimeter of the safe operating area adjacent to the drill boom. One such means may be to attach short streamers to the underside of the canopy, visible to the operator but which do not impair overall visibility. Also, any such means should not create a tangle hazard by being placed near rotating components.

BACKGROUND: Earlier discussion of the pinch point created by a rising drill boom focused on removing the operator from this area during a specific work function, such as engaging the fast-feed control. However, it is also recognized that, due to the cramped work area and constantly shifting

positions within this area, there may be times when slight, subtle movement has placed the operator in a pinch point.

PROBLEM NO. 6: Detented drilling controls remain in the position they were set when the equipment operator removes his/her hand from the control and may expose an operator to serious hazards.

SOLUTION: Drilling controls such as drill feed, rotation, and swing should be self-centering. This retrofit action can be easily accomplished in the field.

BACKGROUND: Although self-centering drilling controls have been standard on new roof-bolting machines since an industry-wide manufacturers' decision in 1985, detented drilling controls continue to be used despite MSHA's efforts to discourage their use. Despite the virtual universal practice of self-centering valve spools for all drilling controls, the committee's underground evaluation did include the observation of detented drilling controls on a roof bolter. The manufacturers' earlier decision was made in recognition of potential hazardous situations resulting from detented drill feed and rotation controls. Detented drill feed could result in feed rates incompatible with drilling rates for the strata, resulting in broken drill steels. Also, if the operator became entangled in moving machine components, the use of detented controls would not allow for the deactivation of the control function simply by releasing the control lever.

PROBLEM NO. 7: Numerous accidents have occurred where the operator's glove or clothing became entangled in a rotating drill steel.

SOLUTION: A reliable means of securing the rotating drill steel(s) and bolt tightening wrench in the drilling head should be provided to permit the operator to drill holes and install bolts without stabilizing the tools by hand. Additionally, a means of pulling stuck drill steels from the roof/rib should be provided.

BACKGROUND: To eliminate this hazard, a means is necessary to provide for hands-off drilling operation. This problem is well recognized and several devices are available to retrofit machines with this capability. These include deep chuck drill heads and/or drill steel retainers.

PROBLEM NO. 8: In performing roof- and rib-bolting operations with mast-type bolters with on-board drill stations, it is difficult for the operator to retrieve a drill steel or install resin and the bolt into a hole without climbing out onto the mast to reach the hole. Two fatalities occurred when the operator positioned himself in a hazardous location to retrieve a stuck drill steel.

SOLUTION: Mast-type machines with on-board drill stations used in angle bolting operations create a reach dilemma; therefore, these machines should be provided with resin insertion tools and a positive means of drill steel retrieval on board the machine that are accessible from the operator's position.

Such aids should eliminate the need for the operator to extend his body into a pinch point or climb onto the boom.

BACKGROUND: Although it is possible for the operator to reach the hole without climbing out onto the mast by repositioning the boom, this action takes considerable time and makes it very difficult to realign the boom to properly engage the wrench on the bolt. Another option is to have a helper using a ladder install the resin and bolt. This positions the helper in a dangerous position between the boom and the rib. The operator is thus presented with the dilemma of how to safely reach the hole to install the bolt and resin without slowing down the bolting process.

PROBLEM NO. 9: Bolter operators have experienced inadvertent actuation of controls due to different roof-bolting-machine control layouts on identical make and model bolting machines in use at the same mine.

SOLUTION: Roof-bolting machines of the same model with similar control layout and machine response should operate identically, at least on a mine basis.

BACKGROUND: There are no requirements to have the machine control layout the same on the same model machine. The bolter operator may have to operate a different bolting machine of the same make and model; however, the machine handle control layout or function could be different. This could create the potential for the operator to accidentally activate the wrong function.

Also, accidents have occurred due to bolting-machine control lever response changes made by operators because of the operator's individual preference. Lever activation could be exactly opposite from what a different operator would anticipate.

PROBLEM NO. 10: Machine control malfunctions may have contributed to two fatalities. The mechanical linkage of one control interfering with another control may have caused an unexpected machine movement.

SOLUTION: A pre-operational inspection should be made prior to machine startup. This inspection should include:

Prior to machine startup: A visual inspection of the control levers should be conducted, checking for loose, damaged or missing parts, such as pins, C-clips, or cotter keys. All control levers should be operated to ensure they move freely and smoothly and return to the neutral (off) position when released. Visually inspect all guards to ensure that they are in place and maintained in good condition. Notify assistant or any other personnel in the immediate area that the machine will be started.

After machine startup: Test all panic bars for proper operation. Slowly operate every control valve to ensure that it controls the proper function in the proper direction and at normal speed.

FUTURE MACHINE PERFORMANCE FINDINGS

The following findings are offered for consideration in the future design of roof-bolting machines:

(a) Locate controls to position operator outside the drill boom pinch-point area.

(b) Isolate/group controls by corresponding speed or machine function.

(c) Increase spacing between control levers to improve gloved hand access.

(d) Provide automation of drilling and bolting functions or other means to provide absolute isolation of the operator from pinch points and other hazards.

(e) Provide bolt bending apparatus where necessary.

(f) Provide a pressure switch to allow energization of boom raise controls only after a drill steel/bolt/wrench is installed in drill head.

(g) Provide a "light curtain" to disarm machine functions if corresponding pinch point is penetrated by operator.

(h) Provide a neutral interlock to ensure all controls are in neutral position on machine startup.

(i) Provide control sequencing of machine functions through programmable logic controls.

(j) Provide industry-wide accepted distinct and consistent knob shapes and relative handle lengths to identify corresponding control function.

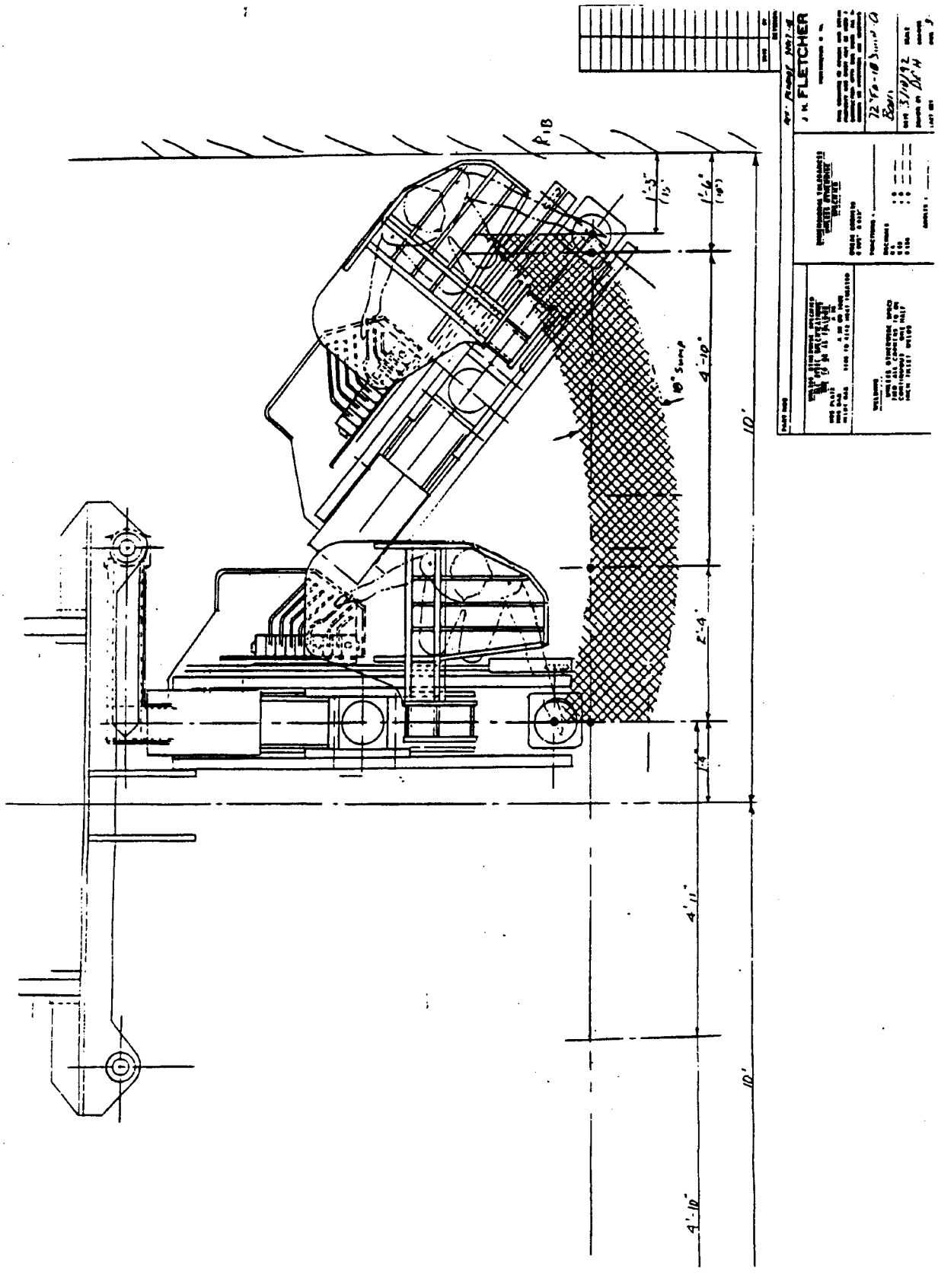
(k) Provide an ergonomically designed operator platform at the drill station regardless of seam height or mining condition.

(l) Address the arrangement and shielding of machine lights to eliminate glare that could interfere with machine operation.

(m) Address means to eliminate pinch point between canopy and drill boom, e.g., provide a stop block to maintain clearance between the canopy and drill boom.

(n) Standardize machine control lever movement and corresponding machine function movement.

APPENDIX A



APPENDIX B

DRILL HEAD FEED RATES

The values presented below are averages for the individual models identified. Data on certain machine models included test data from several machines; however, for a few machine models, data from a single machine is presented due to their limited popularity/availability. Corporate averages were established by raw averaging of data from the models listed. Data was not normalized by population of individual models.

All numbers provided indicate speeds in inches per second as measured at the drill head. FF indicates fast feed and SF indicates slow or regular feed.

Fletcher

(Mast-type machine) DDR	FF↑	18	
	FF↓	22	
	SF↑	5	
	SF↓	12	
DDO	FF↑	21	
	FF↓	28	
	SF↑	9	
	SF↓	13	
LTDO	FF↑	24	
	FF↓	23	
	SF↑	6	
	SF↓	5	
Roof Ranger II	FF↑	23	
	FF↓	24	
	SF↑	7	
	SF↓	9	
Fletcher Corporate Averages	FF↑	22	
	FF↓	24	
	SF↑	7	

	SF↓	10

Long-Airdox
(includes Lee-Norse and Simmons-Rand)

RD 25 2A	FF↑	12
	FF↓	12
	SF↑	9
	SF↓	12
LRB 15A	No Fast-Feed Feature	
	SF↑	8.4
	SF↓	
LN TD-2	FF↑	16
	FF↓	
	SF↑	8
	SF↓	
Simmons-Rand TD1SL	FF↑	16
	FF↓	
	SF↑	8
	SF↓	
Simmons-Rand SR-200A	FF↑	19
	FF↓	
	SF↑	8
	SF↓	
Long-Airdox Corporate Averages	FF↑	16
	FF↓	12
	SF↑	8
	SF↓	12

Eimco
(includes FMC and Galis)

300	No Fast-Feed Feature	
	SF↑	10
	SF↓	18
3510	No Fast-Feed Feature	
	SF↑	10

		SF↓	
Eimco Corporate Averages	SF↑	10	
		SF↓	18

Fairchild

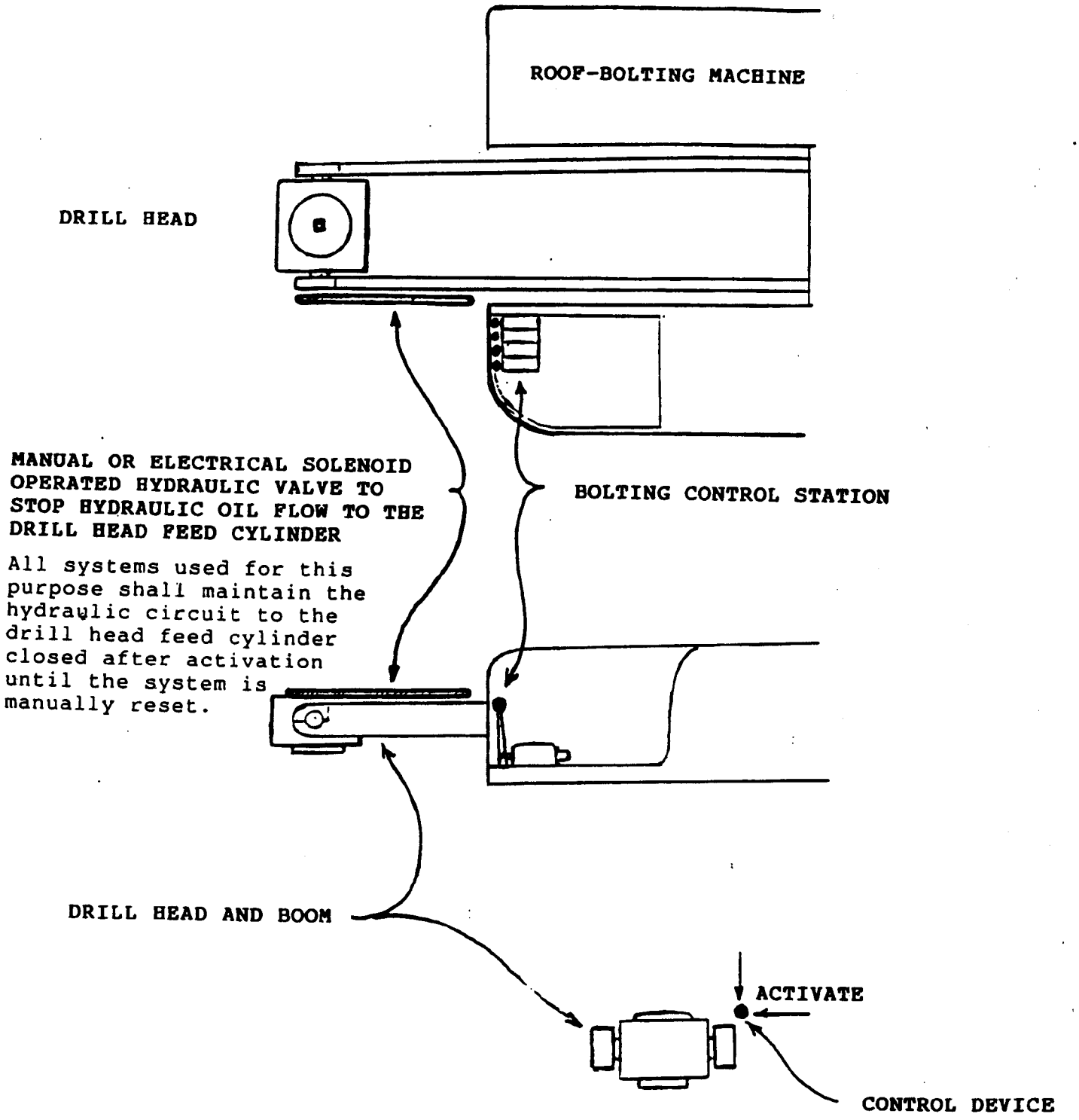
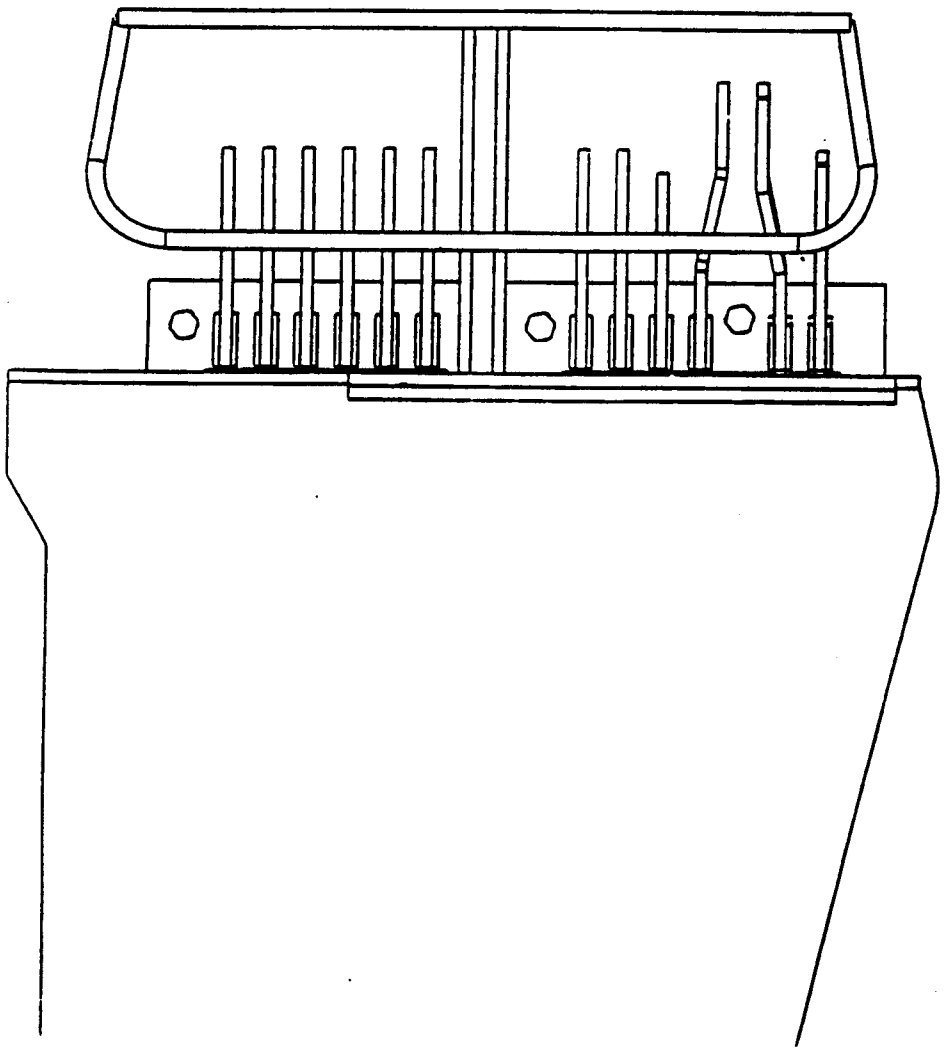
J-4	No Fast-Feed Feature	
	SF↑	8
	SF↓	>8
J-6	No Fast-Feed Feature	
	SF↑	8
	SF↓	>8

APPENDIX C
ROOF BOLTER CONTROL RELATED FATALITIES (1984 - PRESENT)

NO.	DATE	MINE ID	MANUFACTURER	MODEL	MINE/COMPANY NAME	MINE HT.	DESCRIPTION OF ACCIDENT
1	12/13/84	0100759	Eimco	320a	North River Mine No. 1; North River Energy Co.	54"	Helper's head caught between boom and mine roof while operator at controls
2	02/08/86	4002880	Fairchild	WRDA-J6-6600	No. 3 Mine; H. Cameron Coal Company	42"	Operator riding bolter, accidentally hit boom raise lever; operator's head caught between boom and roof
3	05/10/86	4406123	Royal	RM1978	No. 1 Mine; Weststar Coal Company, Inc.	32"	Operator leaned over drill head, accidentally hit boom raise lever; operator caught between drill head and roof
4	08/19/88	4200098	Lee-Norse	TD-2-43	King No. 4 Mine; United States Fuel Company	78"	Victim caught between boom and ATRS while drilling
5	08/15/89	1516287	Simmons-Rand	TD-2-30	Black Oak No. 7 Mine; Golden Oak Mining Co. L. P.	48"	Boom raise lever accidentally engaged during maintenance, boom raised ATRS; operator caught between ATRS and roof
6	08/28/89	4406375	Fletcher	DDO-15-A	Triple C No. 1 Mine; Clinchfield Coal Co.	46"	Operator's head caught between boom and canopy while inserting drill steel in hole
7	12/13/89	1515443	Eimco	300	No. 1 Mine; Shelcha Coal Company	30"	Operator leaned over boom, accidentally hit boom raise lever; operator caught between boom and roof
8	02/27/90	1516665	Eimco	300	No. 4 Mine; Jones Branch Coal Co., Inc.	32"	Maintenance worker hit control while changing hydraulic hose, causing boom to fall
9	03/05/92	4601967	Fletcher	DDO-13	No. 14 Mine; Deep Star Mining, Inc.	54"	Operator leaned over boom and accidentally hit boom raise lever; operator caught between boom and roof
10	04/09/92	4002045	Simmons-Rand	TD1-24-2.1E	S&H Mine #2; S&H Mining, Inc.	27"	Operator's head caught between boom and roof while inserting 48" bolt
11	05/27/92	4603805	Fletcher	DDO-15	Martinka #1 Mine; Southern Ohio Coal Co.	72"	Operator caught between drill head and canopy while setting bolter up to install bolts
12	03/26/93	4603374	Fletcher	RR-II	Maple Meadow Mine; Maple Meadow Mining Co.	60"	Victim found with head pinned between boom and canopy
13	05/13/93	1516450	Galis	300	No. 3 Mine; Limousine Coal Company	32"	Repairman crushed between boom and roof when SCSR belt came in contact with controls

14	02/15/94	4200171	Fletcher	HDDR-13	Star Point No. 2 Mine; Cyprus Plateau Mining Corporation	118"	Operator crushed between drill head and machine frame while bolting the rib
15	03/05/94	1102371	Fletcher	HDDR-15	No. 2 Mine; Monterey Coal Company	108"	Operator crushed between drill head and machine frame while bolting the rib
16	03/25/94	4607009	Fletcher	DDO-13	Castle Mine; Elk Run Coal Co., Inc.	60"	Operator crushed between drill head boom and canopy when fast-feed boom lift lever was inadvertently activated

APPENDIX D


ROOF-BOLTING MACHINE
DRILL HEAD
MANUAL OR ELECTRICAL SOLENOID OPERATED HYDRAULIC VALVE TO STOP HYDRAULIC OIL FLOW TO THE DRILL HEAD FEED CYLINDER
All systems used for this purpose shall maintain the hydraulic circuit to the drill head feed cylinder closed after activation until the system is manually reset.
BOLTING CONTROL STATION
DRILL HEAD AND BOOM
ACTIVATE
CONTROL DEVICE

APPENDIX E