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OPTIMIZED operator COMPARTMENT

FINAL REPORT

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16. Abstract This project required the application of modern human engineering technology to effect a reduction of human error and a reduction of accidents associated with underground mining equipment. These kinds of accidents have been growing in number and have been related to a variety of underground electric face equipment. The general problem was to integrate and extend past research efforts that has applied human engineering technology in the design of safer electric face equipment. The specific problem was to develop optimized operator compartments that could be fitted to the following electric face equipment: Loaders, continuous miners, shuttle cars, roof bolters, face drills, cutters, and scoops. In all, 89 models of various types of underground electric face equipment are included in this study. The drawings are intended to be used as guidelines and not fabrication-type drawings. Three mockups were constructed to illustrate the principles of the optimized operator compartments.

17. Key Words and Document Analysis. 17a. Descriptors

Coal mining, underground
Electric face equipment
Safer design
Loaders
Continuous miners
Shuttle cars
Roofbolters
Facedrills
Cutters
Scoops

17b. Identifiers/Open-Ended Terms

Coal mining, underground
Human Engineering
Operator's compartments

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DISCLAIMER STATEMENT

"The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies of the U. S. Interior Department's Bureau of Mines or of any other branch of the United States Government."

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SECTION 1

INTRODUCTION

Underground coal mining is traditionally hazardous. Although many danger-prone human activities are now performed by mechanized equipment, this mechanization has itself brought new dangers to the underground mining industry, and the loss of life and limb has caused increased concern for mine safety. The 1969 Federal Coal Mine Health and Safety Act has precipitated a great deal of safety-related research on the part of the Government, industry, and private agencies. Much of this safety research has been focused on the new and varied man-machine interfaces caused by increased mechanization. Recent projects in this area have dealt with standardized controls, emergency shutdown capabilities (panic bars, strike plates, self-centering controls, "dead man" controls), and machine operator protective devices (fully enclosed cabs, canopies, side rails).

There was a need for integration of the findings of current and past projects to move rapidly toward the smooth, orderly implementation of standardized operator work station designs for underground mining equipment.

The problem to be solved by this project required the application of modern human engineering technology to effect a reduction of human error and a reduction of accidents associated with underground mining equipment. These kinds of accidents have been growing in number and have been related to a variety of underground electric face equipment. The general technical problem was to integrate and extend past research efforts that had applied human engineering technology in the design of safer electric face equipment. The specific problem was to develop optimized operator compartments which could be fitted to the following electric face equipment:

1. Loaders
2. Continuous Miners
3. Shuttle Cars
4. Roof Bolters
5. Face Drills
6. Cutters
7. Scoops

When the human engineered operator compartment design is implemented, change or compromise will be required of many concerned mining industry-related individuals and organizations (operators, coal associations, manufacturers, unions, the Bureau, etc.). During the course of associated recent research efforts, tradeoffs have been made among such factors as safety, economy, user acceptability, reliability, and ease of servicing and maintaining. As a consequence, recent efforts to optimize various aspects of mining equipment are not "perfect" or "optimal" as viewed from any single vantage point, e.g., the operator, the manufacturer, the mine owner, or the human factors expert.

Several of these compromises for "optimized" operator compartment design have been made explicit. The following assumptions have served as guidelines for the working objectives and limitations of this effort:

1. Optimized operator compartment designs must be capable of being fitted to existing equipment, as well as new equipment, without requiring significant machine modifications (i.e., without requiring modification of frame members or operator work platforms).

2. Compartment designs must safely and comfortably accommodate through the ninety-fifth percentile man (i.e., from small equipment operators to operators as tall as 6'2").

3. The canopy and panic bar designs (including materials) resulting from previous USBM contracts are directly applicable to this effort.

4. Manufacturers' canopy designs are directly applicable to this effort.

5. The principles and design recommendations presented in this report are the result of military and industrial human engineering studies and operational field experience. Functional principles of control design as well as specific control design recommendations are presented. It is felt that the implementation of these recommendations will result in cost-effective gains in both safety and production. This study does not eliminate the need for future research when new or unique problems result from changes in current underground coal mining technology.

6. An effort has been made to take into account the cost of implementing each recommendation compared to the potential safety gain resulting from such implementation. The position taken was not "safety at any cost," but rather the more pragmatic position of "safety within the limits of being practically implemented." Tradeoff studies were performed in an effort to document the relative strengths and weaknesses of the various recommendations in terms of: (a) economy, (b) acceptability, (c) safety, and (d) human factors priorities.

The major product of this project is the set of seven drawing packages illustrating the recommended design guidelines for the operator compartments. These drawings are included in separate volumes as Appendices A through G.

The project was completed in four sequential phases. Each activity of these phases is described in depth in subsequent sections of this report. The flow of the entire project is depicted in Figure 1-1.

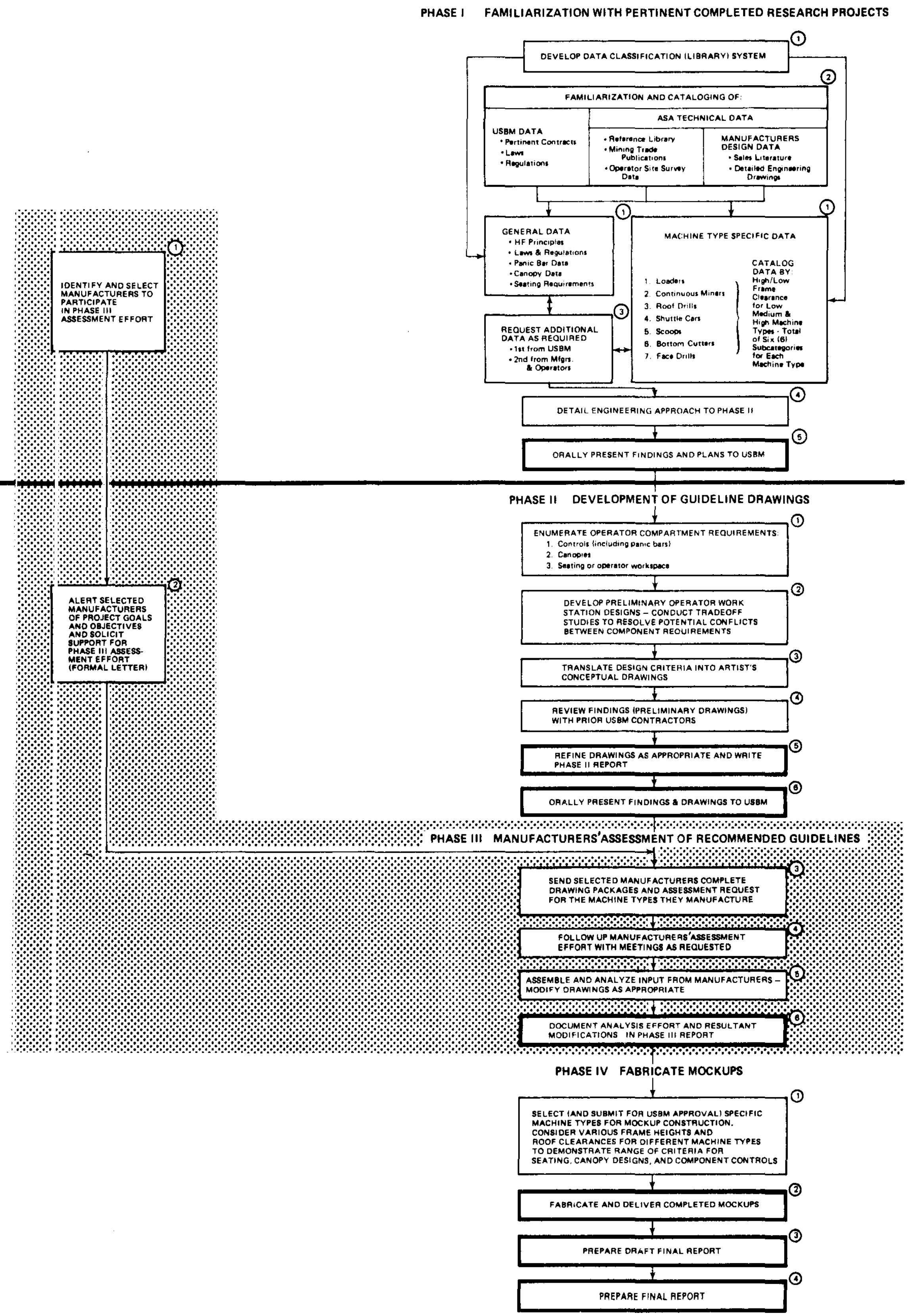


Figure 1-1. General Sequence of Activities for the Project

SECTION 2

PHASE I ACTIVITIES

Familiarization With Pertinent Completed Research Projects

The sequence of the Phase I activities is illustrated in Figure 2-1. These activities were primarily review and classification tasks that provided the framework for the balance of the project.

Section 2.1 Develop Data Classification System

The data classification system that was developed served several functions, many of which had a direct impact on the decisions and activities of later phases. The primary functions of the data classification system were to:

1. Guide in the identification of existing data pertinent to the development of optimized operator compartments and indicate areas in which additional data were required.

2. Provide the framework for a meaningful data storage and retrieval system.

3. Indicate certain potential commonalities among models of the same kinds of machines and between different kinds of machines. The identification of such commonalities was important because highly similar components needed to be analyzed only once.

The development of the data classification system was relatively straightforward. At the highest level, two major data classes were proposed: one for (a) general data applicable to all electric face equipment, and another for (b) data applicable to specific machines. The elements of these two major classes are identified as follows.

A. The general class contained data pertinent to all electric face equipment, and included the following general subclasses:

1. Human factors principles

2. Underground coal mining laws, regulations, operational policy, and practice

3. General panic bar design criteria

4. General canopy performance criteria

PHASE I FAMILIARIZATION WITH PERTINENT COMPLETED RESEARCH PROJECTS

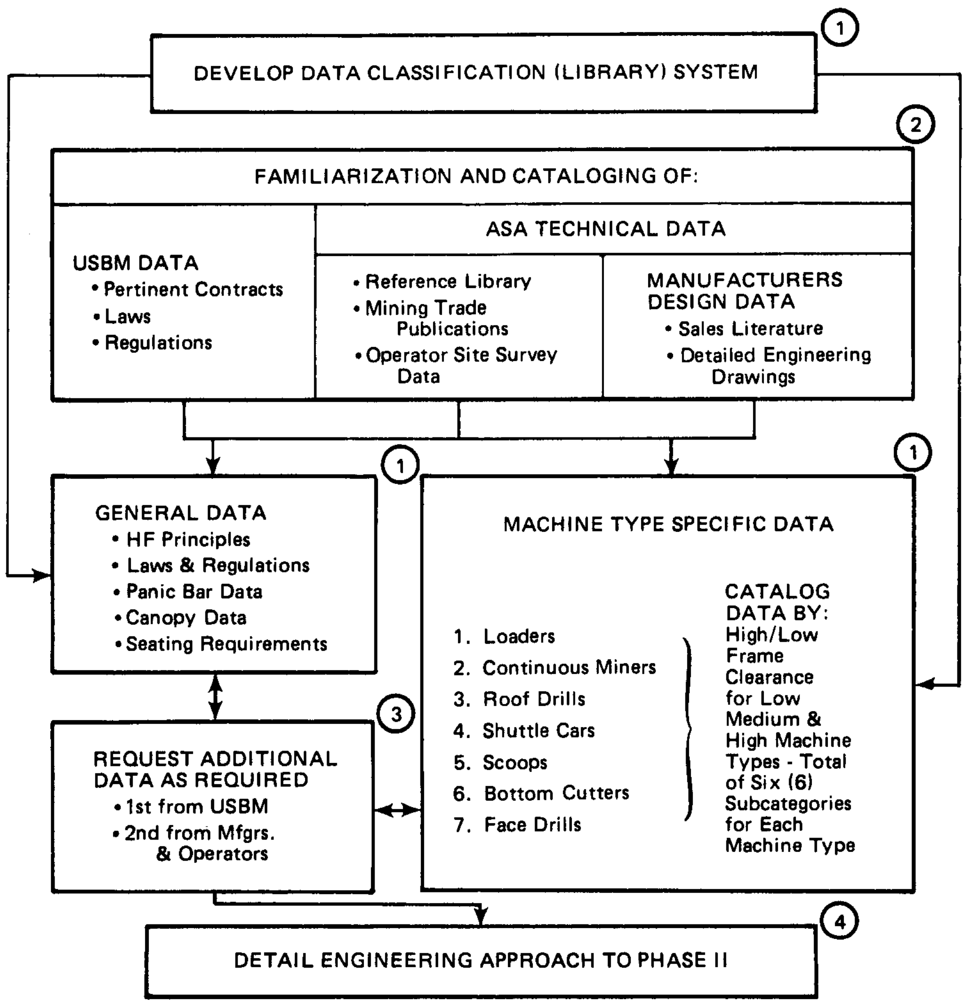


Figure 2-1. Sequence of Activities for Phase I

5. General seating requirements

6. Environmental considerations

7. Personnel safety equipment requirements

B. The specific machine class was complex and consequently made up the largest portion of the data classification system. The initial classification effort focused on machine frame height. Data specific to each machine were classified according to machine frame height into one of the following three categories:

High - Frame heights from 49 to 84 inches
Medium - Frame heights from 37 to 48 inches
Low - Frame heights from 20 to 36 inches

Section 2.2 Cataloging of Existing Research Data

Much of the information necessary for this project was readily available from the Bureau data sources. The data were reviewed and entered into the data classification system described above. Data were obtained from the following sources:

1. USBM Data Sources

    a. USBM Past Research Projects (Contracts)

        (1) P0323093, Standardization of Continuous Miner Control Configurations, June 5, 1972, Applied Science Associates, Inc.

        (2) H0220033, Standardization of Controls on Front-End Loaders, January 1973, Bendix Corporation, Aerospace Systems Division.

        (3) H0220031, Design and Development of Protective Canopies for Underground Low Coal Electric Face Equipment, Including Shuttle Cars, October 1973, Bendix Corporation, Navigation and Control Division.

        (4) H0242020, Survey on Protective Canopy Design, April 1974, Bendix Corporation, Navigation and Control Division.

        (5) H0133031, Panic Bar Study, January 1974, Bendix Corporation, Aerospace Systems Division.

(6) H0230021, Standardization of Controls for Underground Electric Face Equipment, June 1974, Applied Science Associates, Inc.

(7) H0242028, Design and Development of Protective Canopies for a Shuttle Car, Loader, and Roof Drill, January 1974, Bendix Corporation, Navigation and Control Division.

b. Current Federal and State Laws and Regulations

(1) "Federal Metal and Non-Metal Mine Safety Act of 1966."

(2) "Federal Coal Mine Health and Safety Act of 1969."

(3) Federal Register, Part II, Volume 38, Number 167, dated 29 August 1973. An update of a and b above.

(4) Schedules 2G, 31, and 24.

2. ASA Technical Data Sources

a. Past and Current Project Data. During past and present USBM contract efforts, the contractor had compiled relevant reference material. Of particular interest were the surveys of the current industrial human engineering/ergonomics literature applicable to the men and machines of the underground mining industry. With only a few exceptions, all of this literature was available in the contractor's technical files. The Thomas Register and the past twelve months of relevant trade publications, specifically, Coal Age, Coal Mining and Processing, and the Engineering and Mining Journal were also of value.

b. Manufacturer and Operator Performance and Design Data. During the conduct of past and current USBM contracts, 14 major U.S. manufacturers of electric face equipment and a representative sample of coal operators had been visited and interviewed. During the manufacturers' interviews, the following information was compiled:

(1) Sales literature for the electric face equipment manufactured.

(2) Detailed design specifications and dimensional drawings for both control configurations and work station layout.

(3) Actual control labels. Those neither included on drawings nor clearly shown in photographs were recorded by making hand sketches.

(4) Control characteristics. Where feasible, the interviewers tested, measured, and recorded control characteristics not already documented by the previous steps. These characteristics included:

   (a) Control resistance

   (b) Direction of control motion

   (c) Ratio of control motion to vehicle or tool response

(5) Anthropometric data. The relevant body measurements required for safe, comfortable control operation were available from the control configuration/work station drawings and photographs. For those measurements not available the interviewers measured the equipment and recorded relevant space and reach measurements required for control operation.

The coal operators surveyed were selected on the basis of: (1) the variety of electric face equipment reported in current operation, (2) the size of the mining operation, and (3) the variety of seam heights. During these operational mine site surveys, the interview teams collected the following data:

(1) Operator performance of all control functions was observed and recorded. Particular note was made of operator performance in instances where different machine types interface (e.g., a shuttle car working in conjunction with a continuous miner or loader).

(2) The frequency and duration of use of each control for each specific machine type was recorded on Activity/Control Analysis sheets.

All data compiled as a result of both manufacturer and operator interviews were analyzed and pertinent information entered into the data classification system.

Next, a survey was conducted of the Panic Bar Study, Survey on Protective Canopy Design, and the Standardization of Controls for Underground Electric Face Equipment. This survey established an exhaustive list of all manufacturers' makes and models for the seven machine types being considered. Employing this list, a second survey was conducted which identified those makes and models to be tentatively covered by the study. Those makes and models not included in two or more of the previous studies were eliminated from further consideration. Where necessary, the project staff extended the results of the aforementioned studies in one area (e.g., panic bars, control standards or canopies), but to extend the design guidelines in more than one area for any machine was considered to be beyond the scope of work for this current contract effort.

Finally the data classification system was reviewed, additional data requirements identified, and the classification scheme was completed.

Section 2.3 Selection of Machine Models

A wide variety of machine makes and models currently in use in the mining industry were considered for study. However, as a result of analyzing the data obtained by the methods described above, the following machine models were considered beyond the scope of the study, and were eliminated from further consideration:

1. Those machine models employing dual tool booms. These machines typically employ multiple operator stations. To extend design guideline applications for more than one optimized operator compartment per specific machine was considered to be beyond the scope of the current contract effort.

2. Those machine makes and models of which there were fewer than 25 produced.

The machine makes and models which remained after the elimination process were considered to be representative for the purposes of this study. A complete list of machines is presented in Table 2-1.

Section 2.4 Classification of Machines

The refined classification of machines identified in Section 2.3 is the result of an overlay of three influencing factors. The three factors influencing the classification of machines are: (1) frame height, (2) intended machine seam height application, and (3) human factors engineering

Table 2-1

Identification and Classification of
Selected Specific Machine Makes and Models

COLUMN 1	COLUMN 2	COLUMN 3	COLUMN 4	COLUMN 5	COLUMN 6
Selected Machine Type	Manufacturer	Model	Frame Height Classification	Intended Seam Height Usage Classification	Final Operator Clearance/ Intended Seam Height Usage Classification
Loader	Goodman	968	Medium	Medium; High	Medium and High
	Jeffrey	202	Medium	Medium; High	Medium and High
	Joy	14BU7/8	Medium	Medium; High	Medium and High
	Joy	14BU10-11	Low	Low; Medium	Low and Medium
	Long-Airdox	188	Low	Low; Medium	Low and Medium
Continuous Miner	Jeffrey	120/121L	Low	Low; Medium	Low and Medium
	Jeffrey	120/121 M&H	Medium	Medium; High	Medium and High
	Joy	CM10	Medium	Medium; High	Medium and High
	Joy	CM11	Low	Low; Medium	Low and Medium
	Joy	CM12	Medium	Medium	Medium
	Joy	CM14	Low	Low; Medium; High	Low, Medium, and High
	Lee-Norse	CM26/28	Low	Low; Medium	Low and Medium
	Lee-Norse	CM45	Medium	Medium; High	Medium and High
	Lee-Norse	CM48	High	Medium; High	Medium and High
	Lee-Norse	CM265	Low	Low; Medium	Low and Medium
	NMSC	3080	Medium	Medium; High	Medium and High
Shuttle Car	Galis	5L	Low	Low; Medium	Low/ Medium
	Galis	6L	Low	Low; Medium	Low and Medium
	Galis	10L	Medium	Medium; High	Medium/ High

Table 2-1 (continued)

COLUMN 1	COLUMN 2	COLUMN 3	COLUMN 4	COLUMN 5	COLUMN 6
Selected Machine Type	Manufacturer	Model	Frame Height Classification	Intended Seam Height Usage Classification	Final Operator Clearance/ Intended Seam Height Usage Classification
Shuttle Car (cont.)	Goodman	6632	Low	Low; Medium	Low and Medium
	Joy	10SC-22	Medium	Medium	Medium
	Joy	18SC-5	Low	Low	Low
	Joy	18SC-6	Low	Low; Medium	Low/ Medium
	Joy	21SC	Low	Low	Low
	Joy	21SC-B	Low	Low; Medium	Low/ Medium
	NMSC	Lokar 28/30	Low	Low	Low
	NMSC	Torkar 40	Low	Low; Medium	Low/ Medium
	NMSC	Torkar 48	Medium	Medium; High	Medium/ High
	NMSC	Torkar 60	High	Medium; High	Medium/ High
Roof Bolter	Fletcher	DO	Low	Low; Medium; High	Low and Medium/ High
	Fletcher	LTDO	Low	Low; Medium	Low and Medium
	Galis	300	Low	Low; Medium	Low/ Medium
	Galis	320	Medium	Medium; High	Medium and High
	Long-Airdox	LRB-5A	Low	Low; Medium	Low/ Medium
	Long-Airdox	LRB-15	Low	Low; Medium; High	Low and Medium/ High
	Wilcox	WRDA/WRDO	Low	Low; Medium	Low/ Medium
Face Drill	Galis	460	Low	Low; Medium; High	Low and Medium/ High
	Galis	4100	Low	Low; Medium; High	Low and Medium/ High

Table 2-1 (continued)

COLUMN 1	COLUMN 2	COLUMN 3	COLUMN 4	COLUMN 5	COLUMN 6
Selected Machine Type	Manufacturer	Model	Frame Height Classification	Intended Seam Height Usage Classification	Final Operator Clearance/ Intended Seam Height Usage Classification
Face Drill (cont.)	Joy	CD-81-A	Low	Low; Medium; High	Low and Medium/ High
	Long-Airdox	TDF-24	Low	Low; Medium; High	Low and Medium/ High
	Schroeder	CDB-2000A	Low	Low; Medium; High	Low and Medium/ High
Cutter	Goodman	2500	Low	Low; Medium; High	Low/ Medium and Medium/ High
	Joy	15RU	Medium	Medium; High	Medium/ High
	Joy	15RU6/5A	Low	Low; Medium; High	Low/ Medium and Medium/ High
	Joy	16RB-3A	Low	Low	Low
Scoop	Jeffrey	404/405/406	Medium	Medium; High	Medium/ High
	Kersey	24S	Low	Low; Medium	Low and Medium
	S&S	CX-1	Low	Low; Medium; High	Low/ Medium and Medium/ High
	S&S	CX-2	Low	Low; Medium; High	Low/ Medium and Medium/ High
	S&S	74	Low	Low; Medium	Low and Medium
	S&S	86	Low	Low; Medium; High	Low/ Medium and Medium/ High
	S&S	88S	Low	Low; Medium; High	Low/ Medium and Medium/ High
	Elkhorn	AR4	Low	Low; Medium	Low and Medium

considerations usually resulting from operator clearance requirements. Frame height is defined here as the distance from the lowest machine member (i.e., wheels, cats, etc.) to the highest point on the machine frame, excluding canopy structure. Intended seam height usage is the intended use for a selected machine, as stated in manufacturer's advertising literature.

The classification system was reviewed and analyzed. After analysis, the frame height class cutoffs were established as follows:

1. The bottom cutoff point for the low frame height class was 20 inches in order to include machines with very low frame heights.

2. The top cutoff point for the medium frame height class was set at 37 inches.

The machines identified in Section 2.3 were then classified using the system described above. Table 2-1 indicates the frame height classification.

Next, a review of manufacturers' advertising and engineering literature was conducted in order to determine the manufacturers' intended seam height application ("low," "medium," or "high") for the selected machines under consideration. Manufacturers' intended seam height application for the selected machines is indicated in Table 2-1. Almost without exception, manufacturers indicated at least dual seam height application. In comparing the two classifications, the following observations were made: (1) classification by frame height and by manufacturers' intended seam height are almost always the same in the lowest category, (2) in addition to the lowest category, manufacturers almost always claim intended seam height application in the next highest seam height application category, and (3) if the frame height category is "low," manufacturers sometimes claim intended seam height application in all three seam height application categories.

Next, operator clearance requirements as determined by past human factors engineering research [see Section 2.2, USBM Past Research Projects, Items (1) through (7), and in particular Item (4) H0242020, Survey on Protective Canopy Design] were considered relative to the intended seam height usages for machines. Operator clearance is defined as the distance between the lowest portion of the operator's body (when in the typical operator position) to the bottom of the lowest overhead obstruction (usually the lowest portion of the underside of the canopy). For a given seam height (lowest clearance--smallest distance between the lowest roof obstacle and highest bottom at any given point), the operator clearance can most often be obtained by subtracting the following distances from the seam height:

1. Machine ground clearance*
2. Frame thickness of the operator platform*

*For machines equipped with operator platforms.

3. Canopy thickness
4. Clearance between canopy and mine roof

The final classification of machines included operator clearance requirements and the intended seam height usages for the machines. Using this final classification scheme, the selected machines were assigned to one of five distinct classifications: low, low/medium, medium, medium/high, and high. An explanation and an example of each of the final classification cases follow:

Case 1--Machine Classified in a Single Class as Low, Medium, or High. In cases where the manufacturer indicated that a machine was intended for use in only one seam height (e.g., NMSC Lokar 28/30 Shuttle Car for low seam heights, or Joy CM-12 Continuous Miner for medium seam heights), the machine was placed in its respective classification as low or medium. There are no cases in which a manufacturer indicated that a machine was intended to be used only in high seam heights.

Case 2--Machine Classified in More Than One Class as Low, Medium, or High. In cases where the manufacturer indicated that a machine was intended to be used in more than one seam height (e.g., Lee-Norse CM 265 Continuous Miner for low and medium seam heights, or Galis 320 Roof Bolter for medium and high seam heights) and analysis indicated that operator clearance requirements could be greatly improved by using a separate design for the higher seam height application, the machine was simultaneously placed in two or three classifications as low and medium, as medium and high, or as low, medium, and high.

Case 3--Machine Classified in a Single Class as Low/Medium or as Medium/High. In cases where the manufacturer indicated that a machine was intended for use in more than one seam height (e.g., Long-Airdox LRB-5A Roof Bolter for low and medium seam heights, or Galis 10L Shuttle Car for medium and high seam heights) and analysis indicated that operator clearance requirements could not be greatly improved by using a separate design for the higher seam height application, the machine was classified as low/medium or as medium/high.

Case 4--Machine Classified in More Than One Class as Low and Medium/High. In cases where the manufacturer indicated that a machine was intended for use in all three seam height applications (e.g., Joy CD-81-A Face Drill for low, medium, and high seam heights), and analysis indicated that a combination of the operator clearance conditions explained in Cases 2 and 3 existed, the machine was placed in both low and medium/high categories.

Case 5--Machine Classified in More Than One Class as Low/Medium and Medium/High. In cases where the manufacturer indicated that a machine was intended to be used in all three seam height applications (e.g., Goodman 2500 Cutter for low, medium, and high seam heights), and analysis indicated that a combination of the operator clearance conditions explained in Case 3 existed, the machine was placed in two classifications--low/medium and medium/high.

Most of the selected machine models fell into more than one of the intended seam height/operator clearance categories. For example, a Joy CM-14 Continuous Miner was classified three times--as Joy CM-14 low, Joy CM-14 medium, and Joy CM-14 high. The final classification yielded a total of 89 machine categories of which 24 machines were classified as low, 13 were classified as low/medium, 24 were classified as medium, 18 were classified as medium/high, and 10 were classified as high.

Section 2.5 The Engineering Approach to Phase II

Through the use of the classification system, similarities between machines were easily identified. Such work station commonalities as power panel similarities, similar seating requirements, control commonalities, canopy commonalities, were also identified. The classification system provided a convenient basis for identification of those operator compartment requirements which are common across all machines and those which are unique.

SECTION 3

PHASE II ACTIVITIES

Development of Guideline Drawings

The objective of the Phase II activities was to produce a complete set of drawings that would illustrate the concepts and design of "optimized" operator compartments. These drawings are not intended to be working engineering drawings, rather they should serve as a guideline for potential implementation. Figure 3-1 indicates the sequence of activities undertaken in Phase II.

Section 3.1 Optimized Operator Compartment Requirements

The primary purpose of the optimized operator compartment is to increase operator safety and to decrease the likelihood of operator injury during emergency conditions, in a manner which is both cost-effective and practical in application. Past research efforts have indicated a variety of optimized operator compartment requirements which can be enumerated as follows:

1. An optimized operator compartment should, within the existing environmental conditions and from a human factors engineering viewpoint, provide the operator with:

    a. The best possible protection from the dangers involved during roof falls and accidental rib contact without increasing the likelihood of operator entrapment.

    b. The best possible control configurations, including electrical panels and panic bars.

    c. The best possible vision.

    d. The best possible comfort and convenience.

    e. Enough volume or room to accommodate operators ranging in size to the ninety-fifth percentile of the general population (i.e., approximately 6'2").

    f. A methane monitor.

PHASE II   DEVELOPMENT OF GUIDELINE DRAWINGS

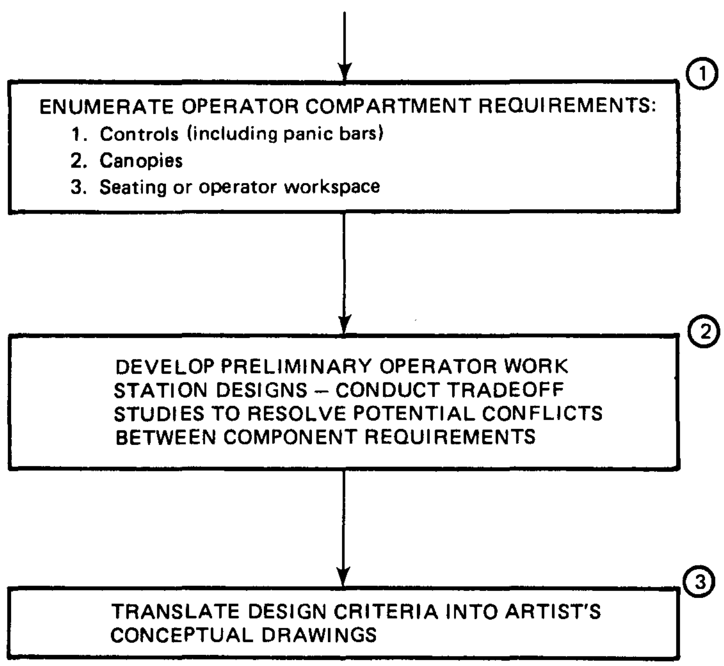


Figure 3-1. Sequence of Activities for Phase II

2. Although minor changes in existing operators' platform dimensions are permitted, the optimized operator compartment must be basically accommodated on the existing operator's platform.

Section 3.2 Development of Operator Work Station Designs

The operator work station designs for each of the machines were developed as follows. First, the engineering drawings for the machines were subjected to a review in order to determine the dimensional parameters and to evaluate the feasibility of optimized operator compartment installation without major machine modification. Next, preliminary hand drawings of the operator's work station illustrating rear view, side view, and top view were made. The existing operator work station requirements, and the location of machine frame members, critical access openings and enclosures, and other potential obstructions were identified during the drawing of these illustrations.

While making the drawings, the operator seating positions were tentatively established. Attempts were made to afford the operator maximum comfort and convenience within the physical confines of the compartment. Standardized controls designed during past research efforts were positioned in the operator's work station. Next, all operator reach requirements involved in the operator/control interface were analyzed. After analysis, the relative positions of the controls were finalized and methane monitors were added to the operator's compartment. The engineering details for the installation of panic bars were incorporated in accordance with the findings of past research.

Section 3.3 Development and Adaptation of Canopy Designs

Canopies intended to give the operator optimum roof fall and rib contact protection were designed for each of the compartments. In cases where canopy designs were already completed by manufacturers, they were integrated directly into the applicable optimized operator compartment design. In cases where canopy designs were not available for the operator's compartment applicable to the machine under consideration, the findings of past canopy research were used as guidelines in the development of new canopy designs.

Next, operator vision requirements were considered. In some cases, modifications to the existing canopy designs were necessary in order to improve operator visibility. Modifications of existing canopy designs for visibility considerations were most frequently employed when developing canopy designs for machine models which fell into the "low" category. Finally, operator seating and positioning requirements were analyzed. Needs for operator comfort, control, and field of vision were identified and integrated into the designs. This total integration process generated a preliminary optimized operator compartment design for each specific machine.

Section 3.4 Translation of Design Criteria Into Artists' Conceptual Drawings

A complete drawing package was created for each of the 89 optimized operator compartment designs derived by the methods explained above. The attachment points illustrated in each optimized operator compartment conceptual design package were also designed and included in the design packages. The contents of a typical conceptual design package are discussed in detail in the following section.

Section 3.5 Description of Conceptual Design Package Layout

Each conceptual design package is comprised of seven or eight drawings. If the specific machine in a particular package incorporates a hydraulically adjustable canopy, an eighth drawing is added to the package to provide the details for the proposed hydraulic cylinders. Those design packages with manually adjustable or fixed canopy designs contain seven drawings per package.

The arrangement and technical content of a conceptual drawing package is outlined in Figure 3-2, and each drawing is described as follows:

Drawing A isometrically illustrates the interrelationships between the canopy designs, standardized controls, electrical panels and panic bars.

Drawing B illustrates the location of the proposed optimized operator compartment on its respective selected machine by top (B_1) and side (B_2) views.

Drawing C illustrates the optimized operator compartment side dimensions, including attachment points. Drawing C is drawn at approximately 1/16-inch scale.

Drawing D illustrates the optimized operator compartment from a rear view, including attachment points. Drawing D is drawn at 1/16-inch scale.

Drawing E illustrates the optimized operator compartment in dimensional plan view, including attachment points. Drawing E is drawn at 1/16-inch scale.

Drawing F illustrates the electrical control power panel for the machine under consideration, in front view.

Drawing G illustrates:

1. The interrelationships between the frame of the machine and the major structural or support members of the proposed operator compartment.

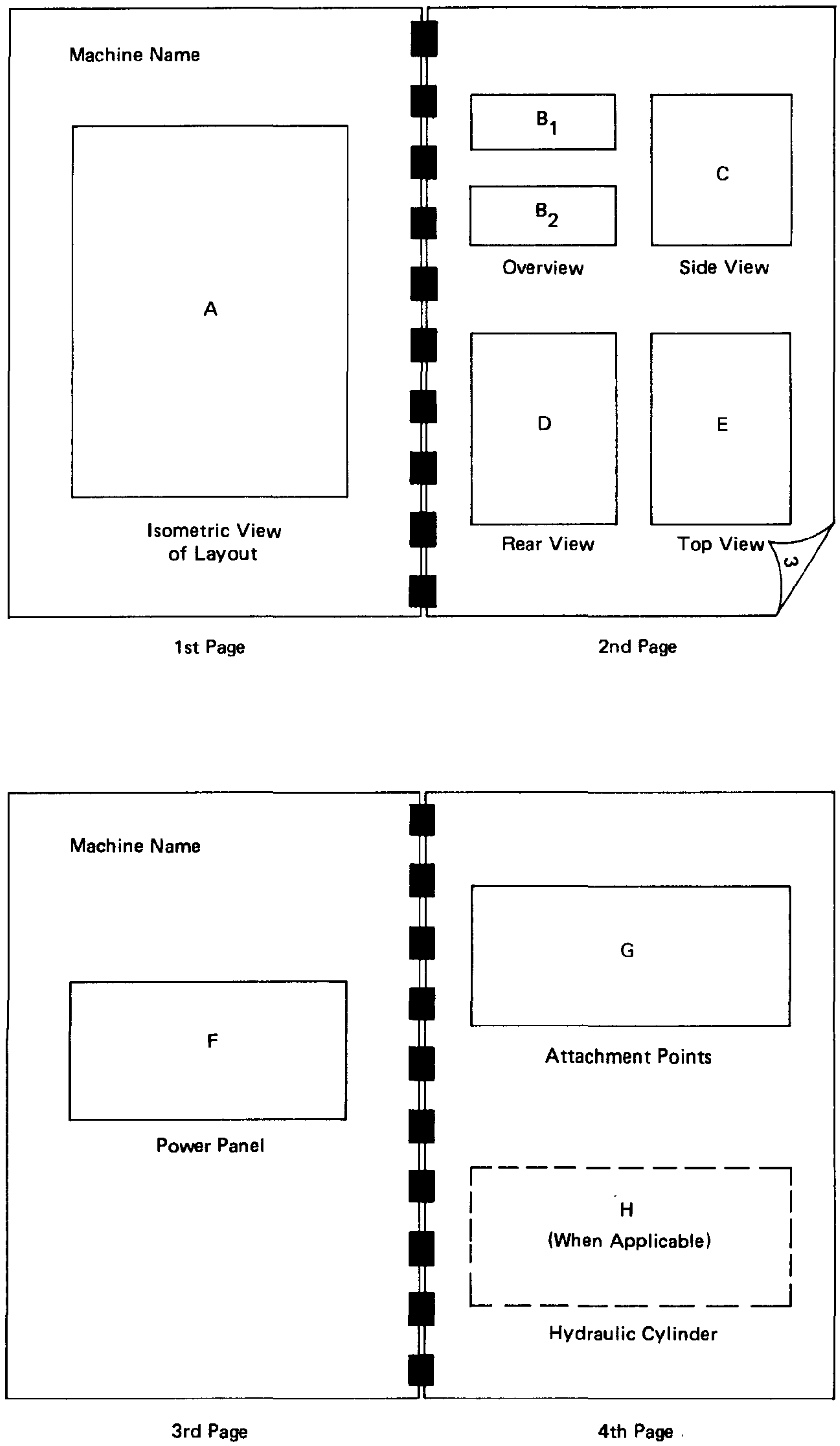


Figure 3-2. Layout for Conceptual Design Packages

2. The dimensional details of the attachment points and the attachment technique employed, by top and front view are shown.

Drawing H illustrates the dimensional details of a typical hydraulic cylinder used to control canopy elevation on the compartments employing hydraulic canopies.

The conceptual design packages for each of the 89 proposed optimized operator compartments are organized and bound by machine type. These are presented in separate appendices accompanying this report. Conceptual design packages within each volume are arranged alphabetically by manufacturer. The remainder of Section 3 presents design descriptions of three major components of optimized operator compartments: canopy design, operator seating requirements, and panic bar requirements.

Canopy Design Results

Section 3.6 Description of Canopy Designs

The recommended canopy designs share a great degree of design commonality. These canopy designs share commonalities in general construction, structural material requirements, top structure, post structure, and attachment. Most of the structural information for canopy design is available in other reports. Canopy post structure information is presented here.

The recommended canopy post structures for all machines fall into one of three categories: (1) hydraulically adjustable, (2) manually adjustable, and (3) fixed. The general design parameters and intended applications for each of the three recommended post structures follow:

1. Hydraulically Adjustable Post Structures

    a. It is recommended that the canopy fixtures employed on roof bolters be capable of being raised to the roof during drilling and bolting operations in order to afford the operator maximum operating clearance. Consequently, hydraulically adjustable post structures were recommended for roof bolters.

b. Due to the variety of seam heights in which shuttle cars regularly travel, frequent regulation of the canopy height is required. Consequently, hydraulically adjustable canopies are recommended for shuttle cars.

c. Hydraulically adjustable canopy designs are used for machines classified for low seam applications.

2. Manually Adjustable Post Structures. Manually adjustable post structures are utilized in canopy designs for all machines except roof bolters employed in medium seam height applications. In medium seams, the canopy fixture/roof interface is not nearly as critical as in low seams, but adjustment of canopy fixture height is still considered to be essential because the frame to roof clearance is often marginal.

3. Fixed Post Structures. Fixed post structures are utilized in canopy designs for all machines except roof bolters intended for use in high seams. In high seams, the canopy fixture/roof interface is not as critical, consequently fixed post structures were utilized since they proved to be the most cost-effective solution.

Operator Seating/Positioning Designs

Past research efforts have indicated that the distance from the top of the machine frame to the top of the canopy fixture must be between 11.5 inches and 19.5 inches if operator vision and comfort requirements are to be met. As a consequence, the resulting operator clearance requirements were major factors influencing the design of the compartments.

Some human factors engineering considerations such as operator reach requirements and the positioning of controls were not greatly affected by operator clearance requirements. Other human factors engineering considerations such as operator vision, operator head clearance, and operator seating/positioning were at times greatly affected.

The influence of operator clearance requirements on compartment design increased greatly and focused on the area of operator seating/positioning for the lower seam height machines. Consequently, when the operator seating/positioning requirements are observed with each position presenting a lower operator silhouette than the design before it, the seating designs are also changed. The progression of operator seating/positioning designs is described as follows.

Case 1--When the operator could be easily positioned well above the floor of the compartment, tractor-type seating with a backrest was recommended. This arrangement was used in high or medium/high machines.

Case 2--If the operator could be positioned above the floor of the compartment but clearance limitations precluded the possibility of placing the operator in an upright position, tractor-type seating without a backrest was recommended.

Case 3--In cases where operator clearance requirements had a significant effect on compartment design and the operator could barely be positioned above the floor of the compartment, low profile seating was recommended.

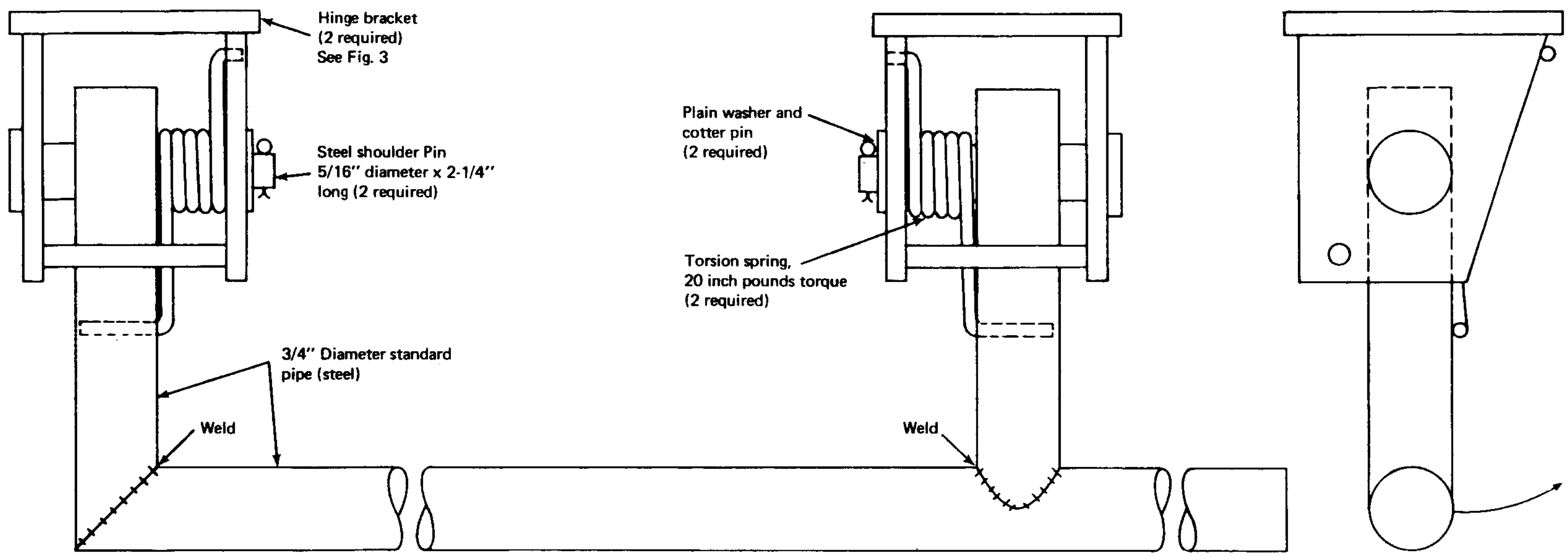
Case 4--When operator clearance requirements precluded the possibility of placing the operator on the floor of the operator compartment, a floating skid or pan was recommended.

Panic Bar Findings

Panic bars are defined in this report as operator-actuated controls designed to be used under emergency conditions which, when activated, deenergize the tram mode of the machine. During the course of activities described in an earlier section, it was discovered that the "Type 1" panic bar design proposed in a previous study could be incorporated into the optimized operator compartment designs. The "Type 1" panic bar design basically resembles the "emergency exit" activators found on fire doors in many public and commercial buildings. Figure 3-3 shows the general construction drawing for the "Type 1" panic bar activator, while Figures 3-4 and 3-5 respectively illustrate the dimensional and welding details and the hinge bracket details.

The "Type 1" panic bars are employed in two basic activation designs, designated "bar/strike plate-activated" and "lever system-activated." Figure 3-6 illustrates a bar/strike plate panic bar design, and Figure 3-7 illustrates a lever system panic bar design. In the bar/strike plate design, strike plates are activated directly by a steel bar which is an integral portion of the strike plate. In the lever system design, the main power off pushbuttons are activated by the panic bar by means of a lever system which consists of two interacting levers.

Regardless of their form of activation design, "Type 1" panic bars can be applied to all of the machines included in this study by employing four design variations of a single basic design illustrated in Figures 3-8 through 3-11.



NOTE: Panic bar may be mounted hinge down, depending on installation requirements.

Figure 3-3. General Construction Drawing for "Type 1" Panic Bar

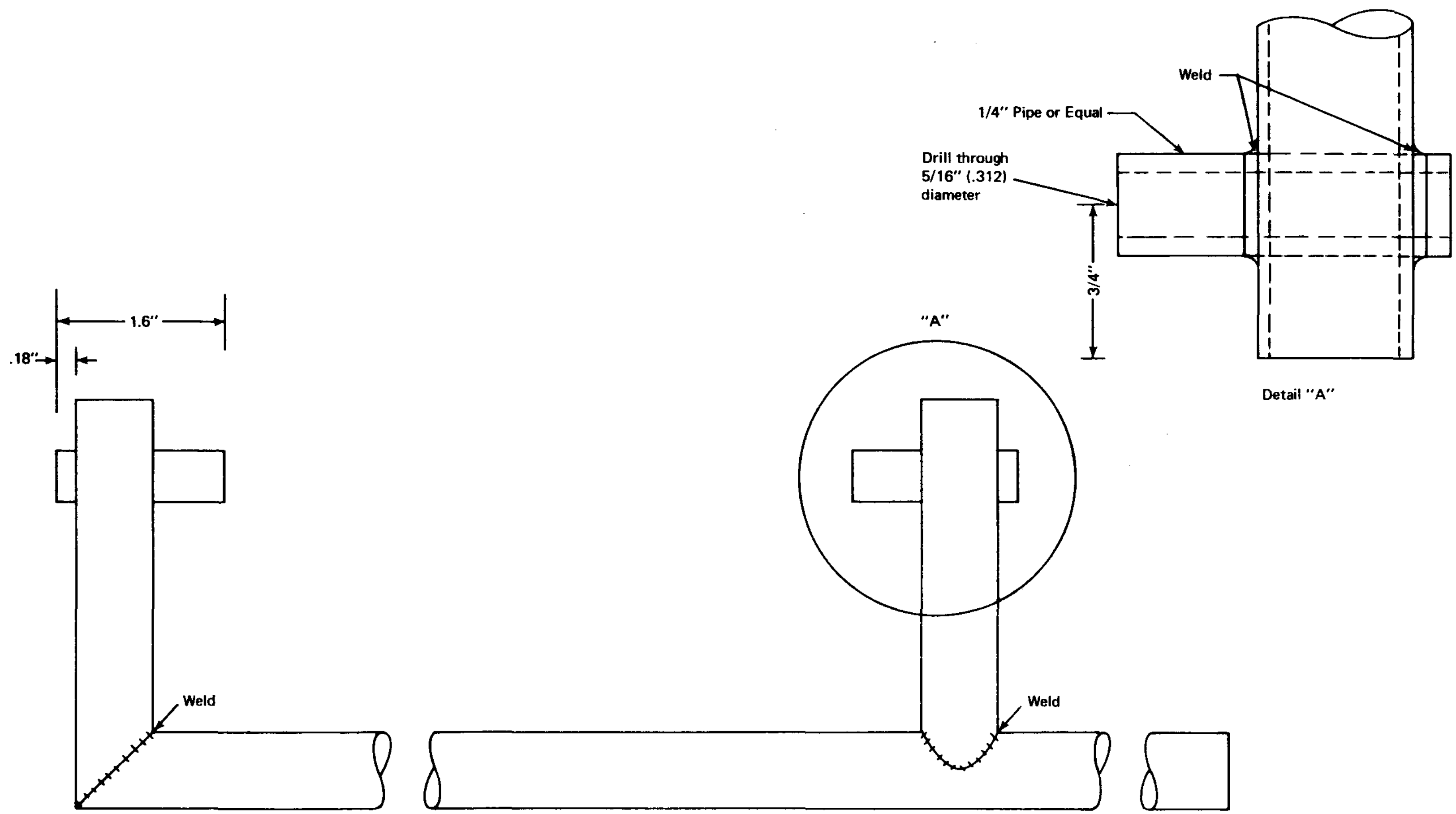


Figure 3-4. Dimensional and Welding Details for "Type 1" Panic Bar

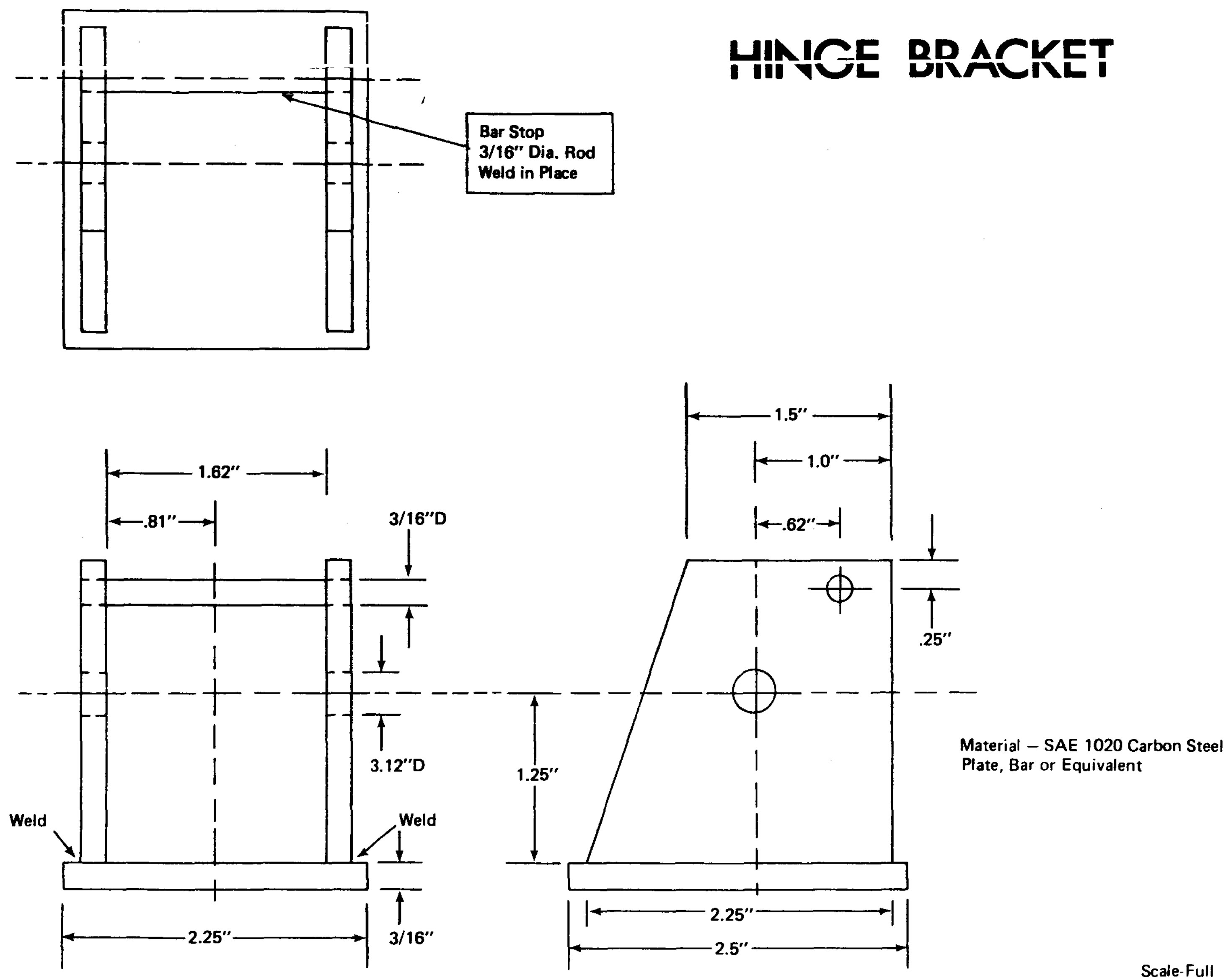


Figure 3-5. Hinge Bracket Details for "Type 1" Panic Bar

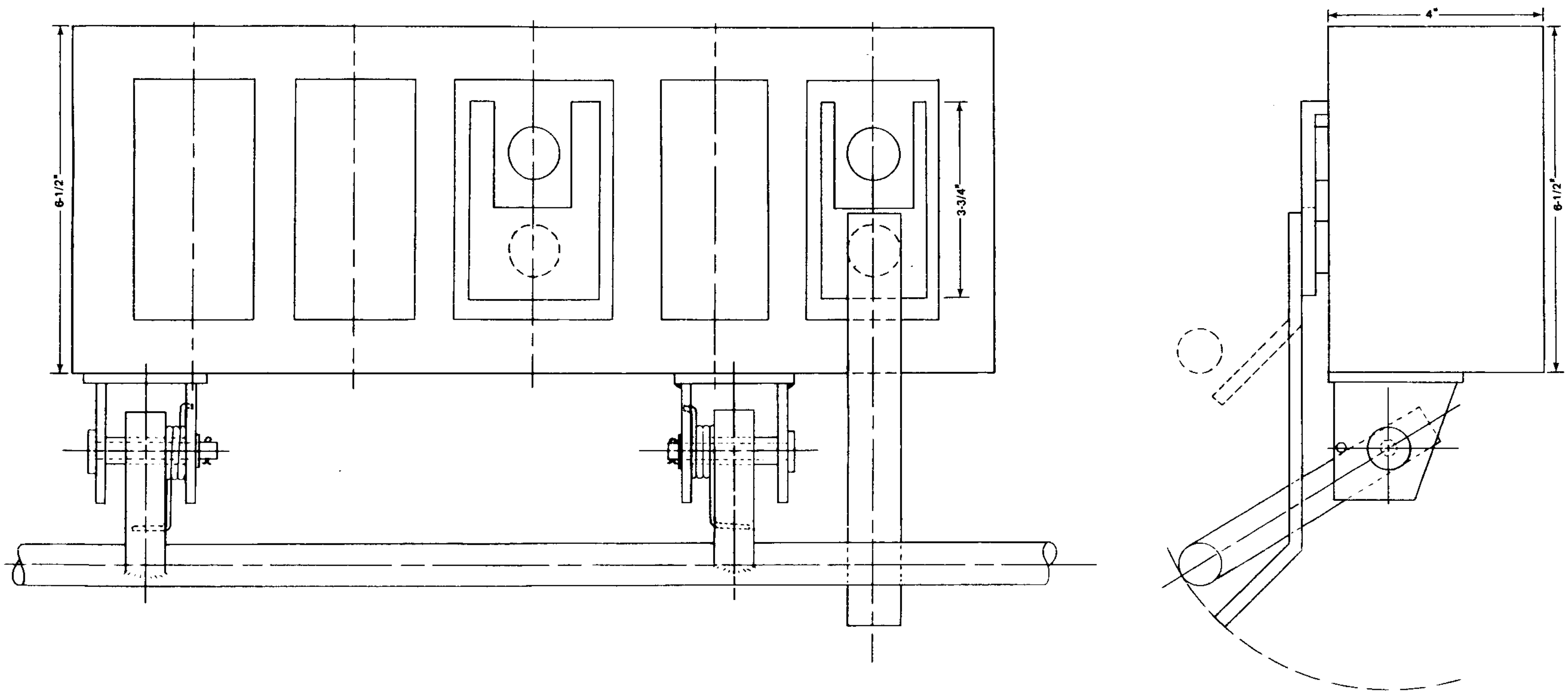


Figure 3-6. Bar/Strike Plate-Activated Panic Bar Design

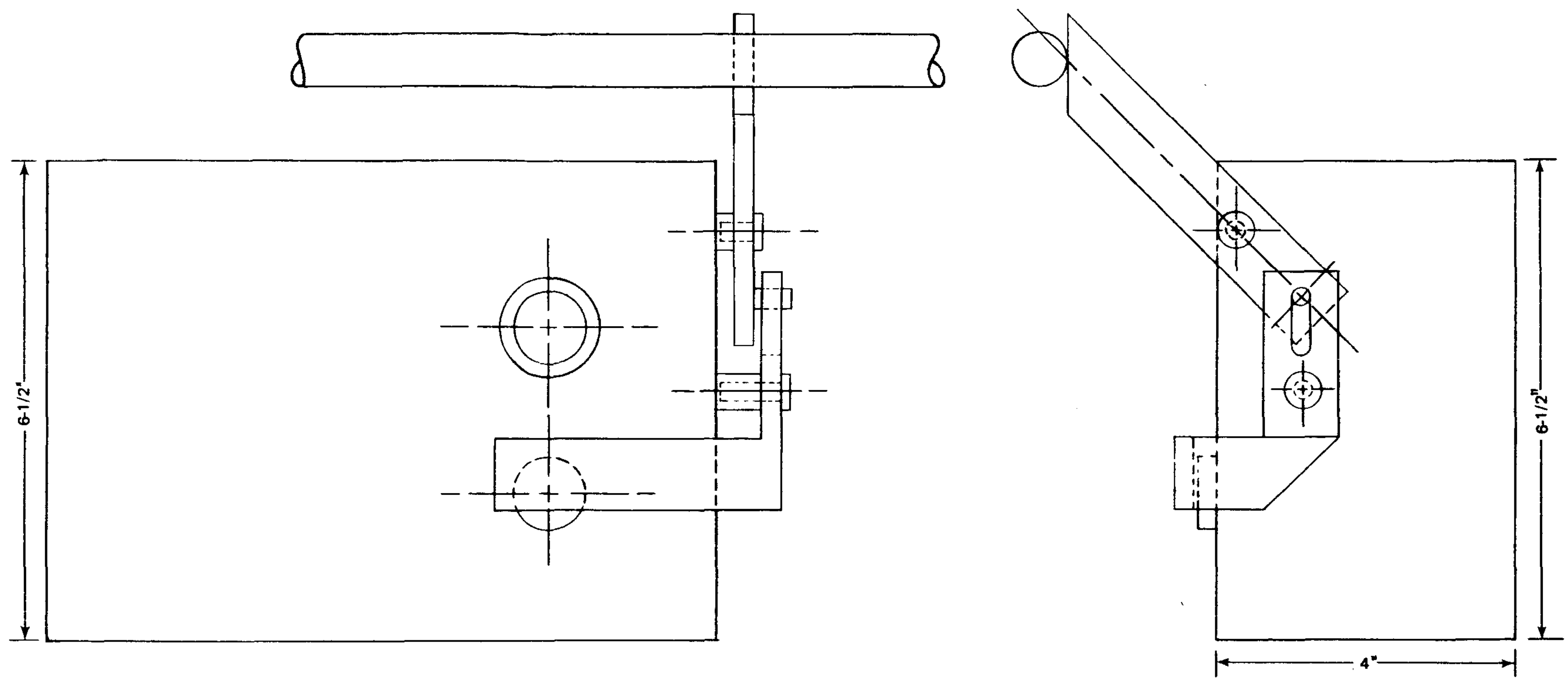


Figure 3-7. Lever System-Activated Panic Bar Design

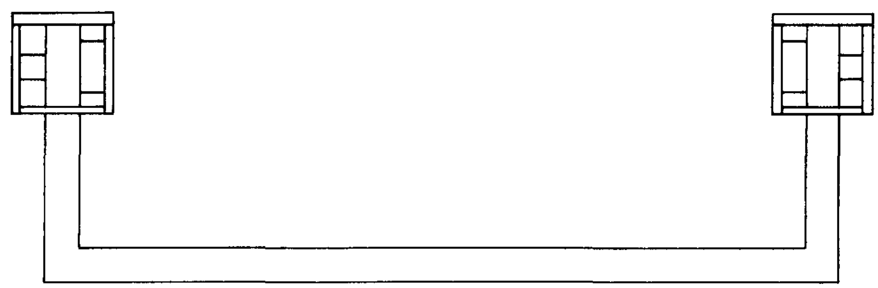


Figure 3-8. "Type 1" Panic Bar
Without Bar Extensions

Figure 3-9. "Type 1" Panic Bar
With Front Bar Extensions

Figure 3-10. "Type 1" Panic Bar
With Rear Bar Extensions

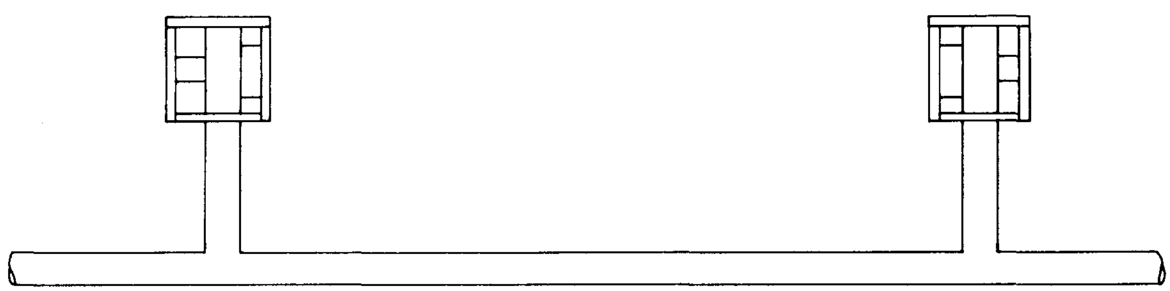


Figure 3-11. "Type 1" Panic Bar With
Front and Rear Bar Extensions

Section 3.7 Relevant Requirements for Panic Bar Fabrication

The following panic bar design requirements are considered to be a relevant summary of previously proposed requirements and current regulations and are included for the convenience of the reader.

1. General Definition, Purpose, and Function

    a. A panic bar is a rigid, bar-type actuation device which when coupled to: (a) an existing pushbutton emergency stopswitch, (b) an existing lever emergency stopswitch, or (c) an additional and separate electromechanical emergency stopswitch will deenergize the tramming motors of the self-propelled electric face equipment.

    b. The primary function of the panic bar is to deenergize the tramming mode of machine operation, but this should not preclude the deenergization of other systems.

2. General Construction and Human Factors Engineering Criteria

    a. Panic bar design criteria are intended to ensure that the operator will be able to effectively activate the panic bar by simple, rapid, and crude limb (i.e., leg or arm) motions under any reasonably anticipated emergency condition or by body motion should the operator be thrown against the panic bar in the event of rib or roof contact. The operator should not be able to accidentally activate the panic bar under normal operating conditions.

    b. The panic bar designs are standardized as follows: All panic bars employ the same hinge bracket, direction and movement of activation, and type and size of material; all panic bars deenergize equipment via the main power control on the standardized electrical control panel.

    c. The panic bar shall extend a sufficient distance in each direction to permit rapid deenergization of the tramming mode upon contact with any portion of the operator's body. Activation may occur along any portion of the actuating bar.

d. The usable and rigid panic bar section exposed to the operator shall be rounded so as to preclude physical danger to the operator. Cables are not acceptable to this requirement.

e. The application of a force of not more than 15 pounds, applied to a quadrant, ± 45 degrees from horozontal to any point along the length of the panic bar shall result in deenergization of the tramming mode. Maximum panic bar activation movement shall be 2 inches.

f. The panic bar shall be separated from all other controls by a minimum of 2 inches. In addition, the panic bar shall be in a position so as to physically project a minimum of 2 inches beyond any structure or control within 4 inches of it. This requirement is intended to permit the operator ready access to the panic bar under emergency conditions and to provide clearance so actuation of the panic bar will not cause accidental actuation of adjacent controls.

g. If located in front of valve bodies or starter boxes, the panic bar shall be of bolt-on construction.

h. All panic bars should be color coded RED to aid in rapid identification and to minimize inadvertent operation. The panic bar assembly should be coated with a good grade of metal primer and final finished with red enamel paint that is suitable for finishing metal.

i. The panic bar shall not be used to reenergize the tramming mode. Instead, a distinctly separate control and operation shall be required to reenergize the tramming mode.

j. Dead man switches, levers or pedals, and self-centering controls cannot be assumed to be acceptable substitutes for panic bars.

3. Material Requirements

a. Low carbon steels (SAE 1020, 1025), hot or cold rolled steep pipe, or steel tubing are recommended as materials for panic bar fabrication.

b. Where additional supports are recommended in the installation of the panic bar in order to improve its position relative to the operator, freedom of material choice is provided. The supports may be pipe, bar stock, angle iron, channel, etc., whichever is most readily available. However, the supports must be sturdy and free of sharp edges and corners.

SECTION 4

PHASE III ACTIVITIES

Manufacturers' Assessment of Recommended Guidelines

During Phase III, the guideline drawings of manufacturer-specific machines produced in Phase II were sent to the specific manufacturers for their assessment. Manufacturers of machines listed in Table 2-1 comprised the list of companies that were requested to participate in the assessment. The sequence of activities for the Phase III tasks is presented in Figure 4-1.

Drawing packages illustrating the "optimized operator compartment" design guidelines for specific machine models were mailed to selected manufacturers. The drawings were packaged so that each manufacturer received drawing sets for his equipment only. Each manufacturer was asked to markup the drawings and comment on the design guidelines. The comments and notes made by the manufacturers were charted and reviewed. A response was prepared for all of the manufacturers' comments. Comments warranting changes in the drawing packages were noted and the drawings were modified accordingly.

Section 4.1 Problem Areas Identified By Assessment Effort

The analysis of the manufacturers' responses resulted in the identification of several problems in the design packages. A short discussion of some of these problem areas is presented in the following paragraphs.

The location of fire controls on the operator's platform was often mentioned as a design weakness. In this case, manufacturers' concern centered around the possibility of the control becoming jammed or covered with coal and consequently being ineffective during emergency conditions. After careful consideration, the design guidelines for these controls were changed to indicate more suitable positions for the fire controls.

The use of separate controls for the main power and pump motor on-off functions was also frequently questioned by manufacturers. They stated that present design practices employ a single control for both of these machine functions. In this case it was felt that the intended purpose of the main power switch is to energize the machine from its power source, while the intended purpose of the pump motor switch is to key only the pump motor. Based on this assumption, it was recommended that these controls remain as illustrated in the conceptual drawing packages.

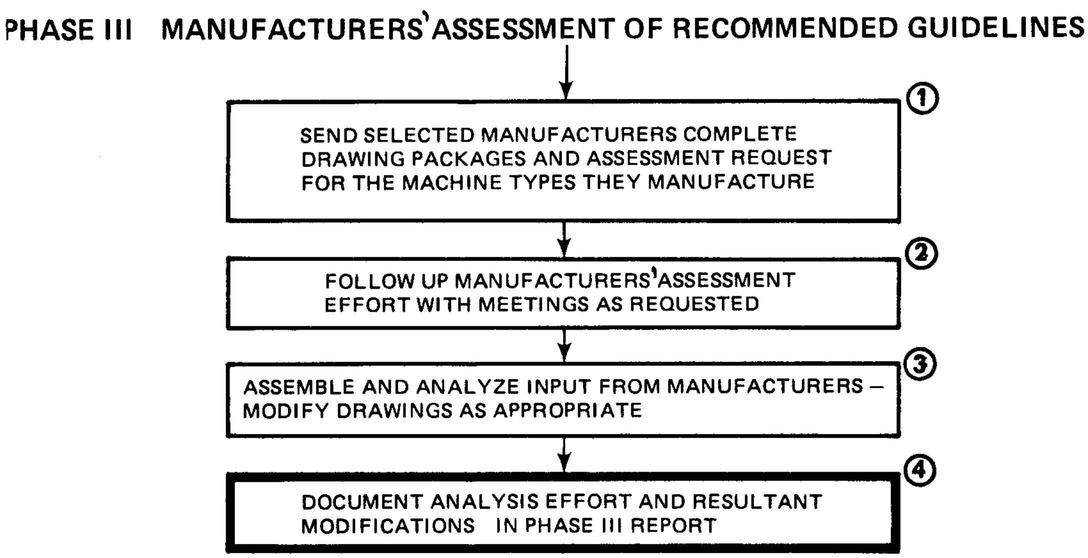


Figure 4-1. Sequence of Activities for Phase III

Some manufacturers felt that certain panic bar designs were unnecessarily complex. Those panic bar designs were reviewed and consequently redesigned.

Some manufacturer comments indicated concern about the recommendations for linkage technologies and hardware implementation. These comments were addressed to the designs for power panel implementation. The specific choice of hardware and linkage implementation was beyond the scope of the current project. It should be noted that the power panels illustrated are not necessarily intended to be electrical panels.

Manufacturers felt that the volume or space allotted for the hydraulic valves was inadequate for implementing the recommended control configurations. Dependent on the appropriate coupling designs, adequate volume and space exists for implementation of the recommended controls, and it is suggested that the controls remain as shown in the conceptual drawing packages.

Section 4.2 Drawing Revisions and Documentation

On the basis of the individual comments and/or the cumulative effect of a number of similar comments, changes in the drawing packages were made. The final compartment guidelines are illustrated in the conceptual drawing packages. These drawings are grouped and bound separately according to machine type and accompany this report as Appendices A through G.

SECTION 5

PHASE IV ACTIVITIES

Mock-Up Fabrication

In order to illustrate the principles of the human engineered operator work stations developed and recommended by this project, three nonfunctional full-scale mock-ups were constructed as Phase IV of the project. The criteria for selecting specific machine types for mock-up fabrication were based on the various frame heights, roof clearances, and control requirements for the equipment under investigation. The goal was to illustrate the range of major equipment components such as seats, canopy designs, panic bar designs and control components. Equipment was selected which illustrates a variety of requirements so that a wider range of operator compartment components would be demonstrated. Through the selection process, the machines listed below were chosen for mock-up construction.

1. Jeffrey 120L Continuous Miner for low roof clearance conditions with adjustable canopy capability.
2. Joy 14BU-7/8 Loader for high clearance.
3. National Mine Service Torkar 48-48 for medium and high roof clearance conditions with two canopy configurations.

Photographs of the completed mock-ups are presented in Figures 5-1 through 5-3.

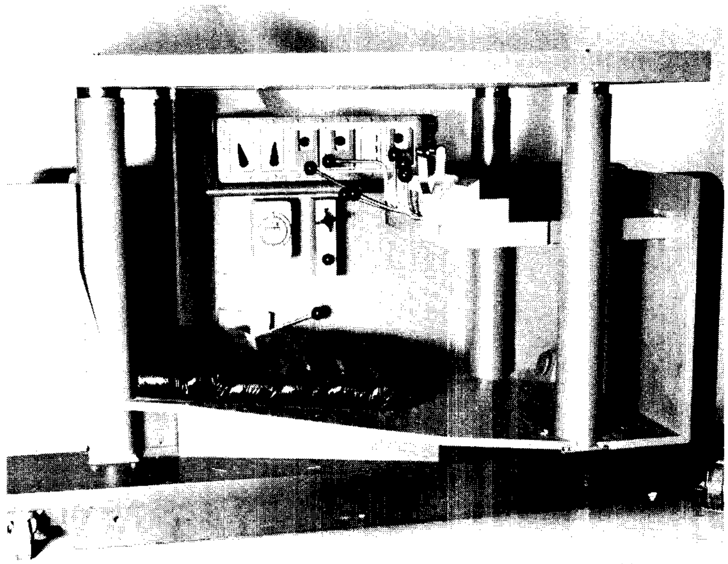


Figure 5-1a. Canopy in lowest position

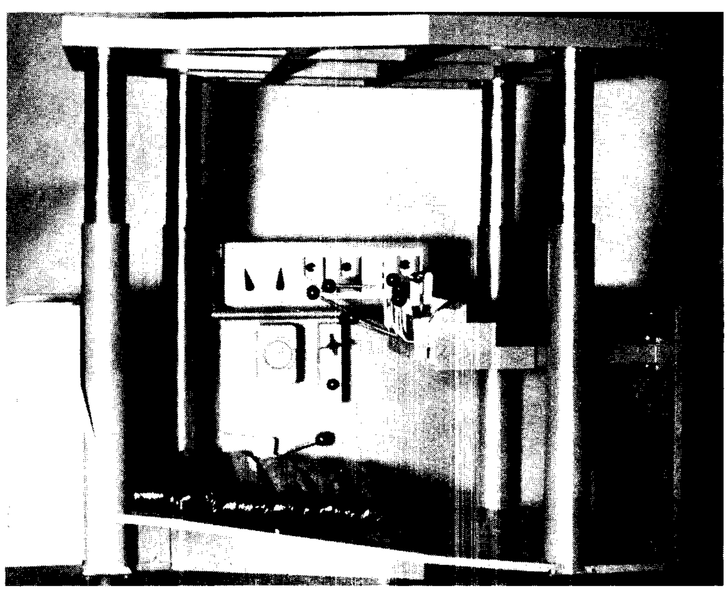


Figure 5-1b. Canopy in fully raised position

Figure 5-1. Mockup of Jeffrey 120L Continuous Miner for low roof clearance conditions with adjustable canopy capability

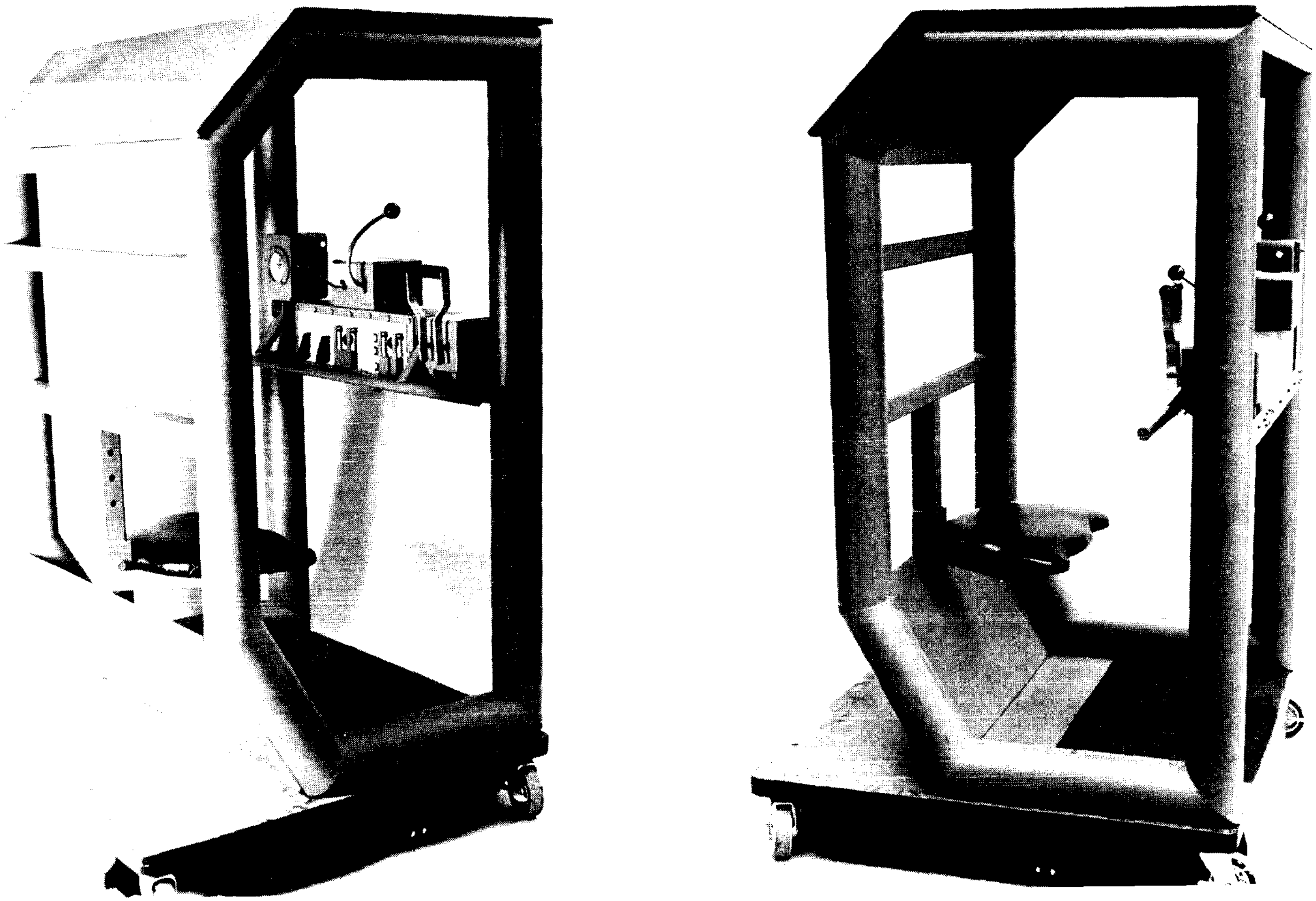


Figure 5-2. Two views of Joy 14BU-7/8 Loader mockup for high clearance

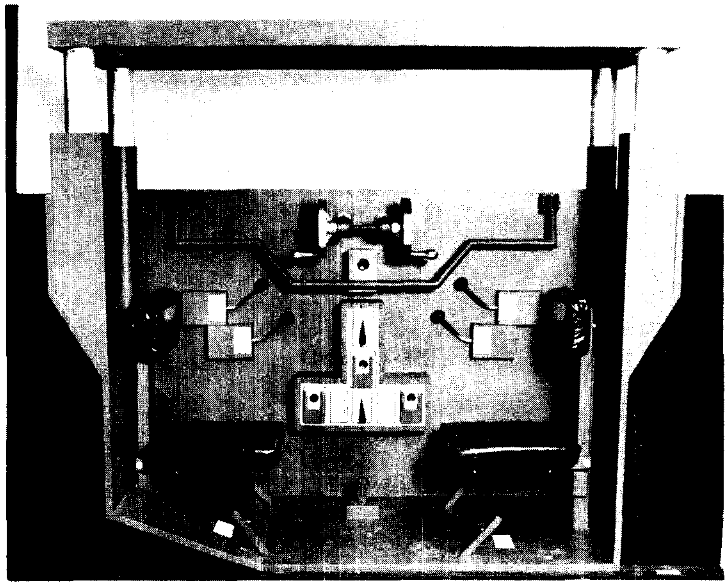


Figure 5-3a. Four-post canopy design

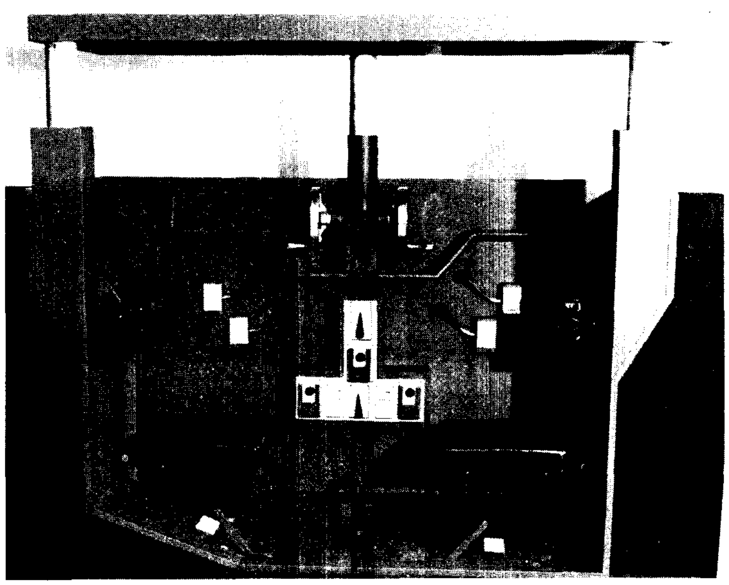


Figure 5-3b. Three-post canopy design

Figure 5-3. Mockup of National Mine Service Torkar 48-48 for medium and high roof clearance conditions with two canopy configurations for one compartment

SECTION 6

SUBJECT INVENTIONS

As required by the "Patents and Inventions Article" of the General Provisions, Appendix B, of Contract No. H0242033, there have been no inventions or patent applications occurring during the conduct of this study.