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A mining research contract report
August 1990

RESEARCH SUPPORT FOR THE DEVELOPMENT OF SAE GUIDELINES FOR UNDERGROUND OPERATOR COMPARMENTS

Contract H0308110
Society of Automotive Engineers

BUREAU OF MINES
UNITED STATES DEPARTMENT OF THE INTERIOR

DISCLAIMER NOTICE

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

FOREWARD

This report was prepared by the Society of Automotive Engineers, Land and Sea Division, Warrendale, Pennsylvania under USBM Contract number H0308110. The contract was initiated under the Coal Mine Health and Safety Program. It was administrated under the technical direction of the Pittsburgh Research Center with Mr. William J. Wiehagen acting as Technical Project Officer. Mr. Michael Nowicki was the contract administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period of October 1980 to November 1990. This report was submitted by the authors on August 15, 1990.

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EXECUTIVE SUMMARY

This report covers the development of proposed Draft SAE Recommended Practice J1314 entitled "Human Factors Design Guidelines for Mobile Underground Mining Equipment". The initial work began in 1978 with the SAE Off Road Machinery Technical Committee (ORMTC) - Subcommittee 29, Working Group 3. In late 1980, a research contract was obtained with the Bureau of Mines to support development of additional data. Human engineering design criteria were needed to develop operator work stations for underground mining equipment. Contractors compiled accident histories for selected equipment types, prepared task and hazard analyses and defined minimum envelope dimensions. Additional tasks were to recommend location and actuation of controls, define minimum visibility envelopes, and describe guidelines for seating and operator ingress and egress. As of June 1990, a draft of SAE J1314 had been proposed, but not approved by the committee. Revisions to the document are currently underway.

INTRODUCTION

For many years, the operation of underground mining equipment has been characterized as cramped and uncomfortable with poor visibility. Operators often experience difficulties identifying and handling machine controls. The lack of consistent human factors engineering considerations when designing underground compartments is an important contributor to many mining injuries.

To address these concerns, the Bureau of Mines contracted (USBM Contract No. H0308110) the Society of Automotive Engineers (SAE) to develop human engineering guidelines for the design of operator work stations. Many standards and design guidelines have been established for above-ground equipment. These guidelines aid industry in establishing consistent man/machine interface systems. They provide more consistent placement of controls within and across machine types and also accommodate a range of population extremes. Such guidelines do not exist for underground mining equipment. The unique constraints of underground mining do not permit the direct translation and use of existing above ground standards, such as SAE J898, SAE J899 and SAE Draft J1814.

BACKGROUND

SAE is a global society of nearly 60,000 members from diverse engineering fields. The society serves industries that use and manufacture self propelled vehicles for a variety of applications. As an independent technical body, SAE promotes and disseminates technology, standards and engineering practices to the aerospace, automobile, construction, forestry, agriculture and mining industries. SAE engineering standards and practices are consensus documents, written by individual industry experts with related technical experience. These individuals volunteer their time and resources as technical committee members developing engineering standards.

SAE Off-Road Machinery Technical Committee - Subcommittee 29 was established in 1978 to focus on specialized mining machinery. The subcommittee formed a working group to address human factors guidelines for mobile underground mining equipment. The initial work began with the design and placement of shuttle car and roof drill controls. Several meetings were held within the working group to prepare an extensive list of data requirements. The requirements defined and established steering systems, operator controls, fire suppression systems and operator ingress and egress. Committee work proceeded and culminated with a draft Recommended Practice - "Human Factors Guidelines - Roof Drills". Balloting of this document highlighted the need to develop fundamental information such as task and accident/injury analyses. This information could provide a focus for the working group efforts and a baseline for future development of Recommended Practices. Insufficient data and the need for additional human factors expertise prompted the investigation of government funded research.

On behalf of Subcommittee 29, Working Group 3, SAE submitted a proposal to the U. S. Bureau of Mines for contract support. Funds were needed to develop technical information and sustain the activities of the working group. The preparation of these guidelines would be accomplished by organizing a Machine Task Group for each selected machine type. Efforts would include the compilation of accident histories, preparation of task and hazard analyses, definition of minimum operator envelope dimensions, control locations and directions of activation, development of minimum visibility envelopes and minimum criterion for operator ingress/egress and seating. Task group leaders were also identified as key individuals who would lead document preparation and research activities.

Ten different mining machine types were to be reviewed over the two year program schedule. This would include additional data support for the draft roof drill and shuttle car documents and development of human engineering guidelines for continuous miners, loaders, cutters, face drills, personnel carriers, utility tractors, locomotives and scoops. The intent of the contract was to assist development of SAE Recommended Practices and provide a stronger technical base of human factors information than would be possible through the voluntary efforts of Subcommittee 29, Working Group 3.

PURPOSE

The purpose of this report is to summarize the events toward development of human factors guidelines for mobile underground mining equipment. This document provides an overview of the research and committee activities which preceded the current efforts. Presently, an Ad Hoc Group to the SAE Human Factor Technical Committee is developing a consensus standard for the design of underground operator work stations. Following a brief synopsis of the consensus process within SAE, other sections of this report document the research activities used as a basis of the current draft of SAE Recommended Practice J1314 entitled "Human Factors Design Guidelines for Mobile Underground Mining Equipment".

This report contains several references to other literature and SAE technical reports. The appendices contain dated information which may not be accurate in current technology. The reader should note that such references and information refer to the data that existed at the time of development. Current versions of the references may contain different data.

CONSENSUS STANDARDS

Whenever a Council/Division within SAE authorizes a committee, subcommittee or working group to initiate, revise or consider repeal of a technical document, notice of such authorization is published in the Automotive Engineering and/or Aerospace Engineering publications. This notice identifies the subject matter or document for discussion and the committee or group's next meeting date. When a draft proposal is completed by the working group, a letter ballot is distributed to group members and any persons who may be directly and materially affected by the proposed draft. Responses to letter ballots are either a waive, an approval or disapproval with comments. The group will strive for full agreement at all levels of balloting. Where full agreement cannot be achieved, consensus is established through the approval of at least three-fourths of the responding committee members. At least one-half of all members receiving a ballot must respond without waiving their vote.

Consensus documents initiated and approved by a working group, are next submitted for subcommittee ballot. Any unresolved disapprovals from the working group or other affected individuals will accompany the letter ballot to the subcommittee. Consensus is also established within the subcommittee and the technical committee by the same procedures. At any point in the document approval process (see Figure 1), a document can be referred back down to the subcommittee or working group level for revision. This is particularly possible if the sponsoring technical committee believes that outstanding disapprovals should be given further consideration.

Approval by the involved technical committee constitutes a recommendation to the Council/Division to approve the document. The technical committee chairperson prepares any necessary information for submission to the Council or Division. The rationale for any performance requirements and the committee's reasons for not accepting any disapproving views are included in the report. The Council or Division will then establish a consensus view of the document. If no disapprovals exist, the document is prepared for publication. However, documents with outstanding disapprovals are referred to the Technical Board for review. Technical documents referred to the Board by a Council/Division or an individual with a dissenting view, are either approved or disapproved by letter ballot. Any persons who wish to oppose the release of a consensus document, may then appeal the Technical Board's decision. The appeal process allows any concerned individuals to present their views in a forum conducted by the Technical Board Chairperson. This forum is held during the subsequent regularly scheduled meeting of the SAE Board of Directors. A final decision is then made after review and discussion with the appealing parties.

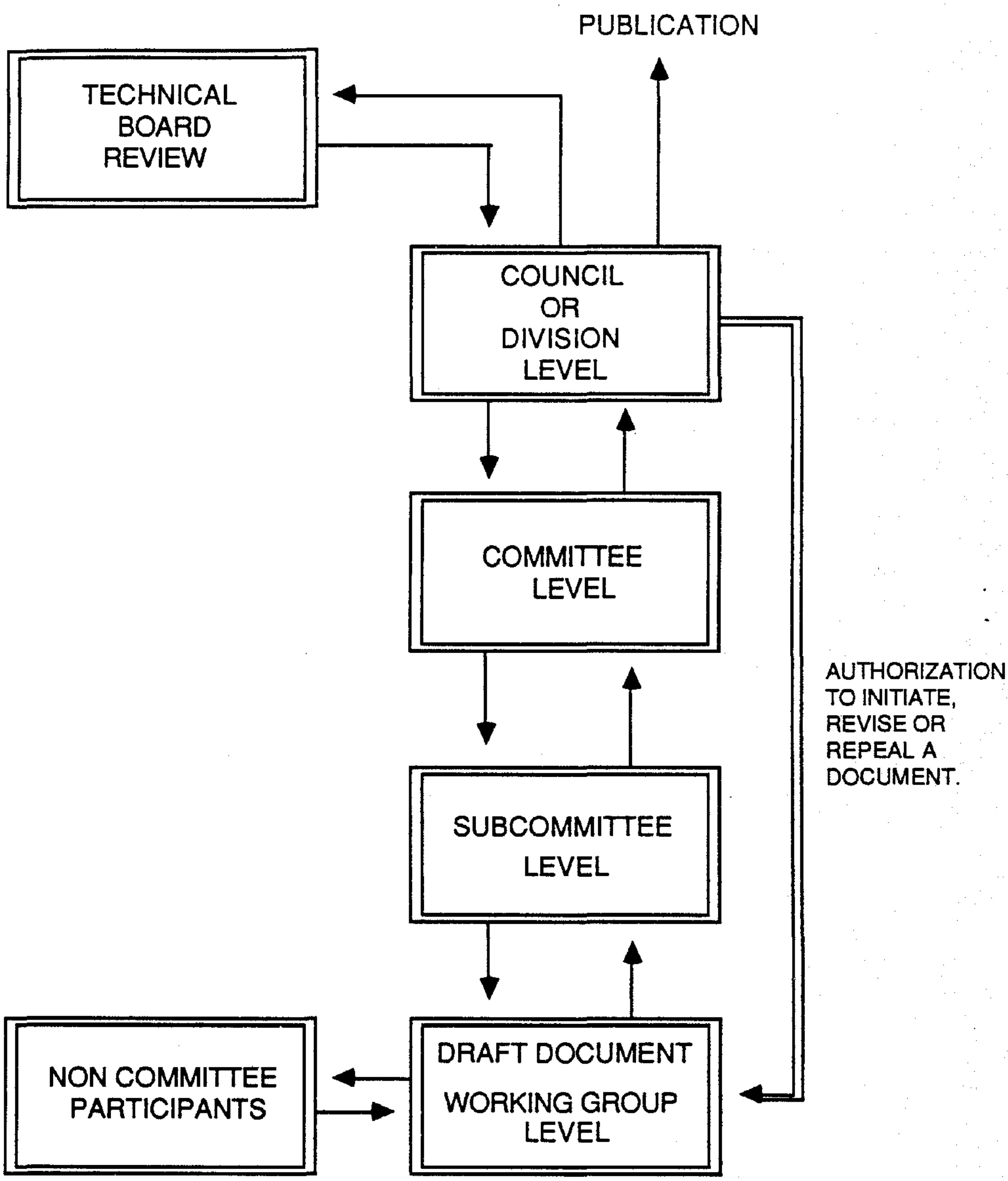

PUBLICATION
TECHNICAL BOARD REVIEW
COUNCIL OR DIVISION LEVEL
COMMITTEE LEVEL
SUBCOMMITTEE LEVEL
AUTHORIZATION TO INITIATE, REVISE OR REPEAL A DOCUMENT.
NON COMMITTEE PARTICIPANTS
DRAFT DOCUMENT
WORKING GROUP LEVEL

FIGURE 1

There are several classifications of SAE technical documents:

SAE Standards: These technical reports are a documentation of broadly accepted engineering practices or specifications for a material, product, process, procedure or test method.

SAE Recommended Practices: These reports are documentation of practice, procedures and technology that are intended as guides to standard engineering practice. Their content may be of more general nature, or they may propound data that have not yet gained broad acceptance. The recommended practice should emphasize the capabilities and limitations of the information contained therein. The technical committee preparing such a report may also add an introductory note stating that the document is intended as a guide toward standard practice and is subject to change; keeping pace with experience and technology.

SAE Information Reports: These reports are compilations of engineering reference data or educational material useful to the technical community.

SAE Draft Technical Reports: A Draft Technical Report may be identical to other Technical Reports except that it has not had consensus approval by the sponsoring Council/Division or the Technical Board.

SAE Research Reports: These reports will provide technical and nontechnical information which may support a technical report or provide information on state of the art technology. Examples include rationale reports, results of round robin or field testing, or compilations of industry research results. These reports have a maximum life of 5 years and cannot be revised or reaffirmed.

Within the context of this research effort, the goal of the subject contract was to utilize the consensus process to develop a Recommended Practice with supporting information that may eventually be accepted as an SAE Standard.

ORDER OF EVENTS

A meeting was held on October 7, 1980 to discuss project goals, summarize activities under SAE Subcommittee 29 (Working Group 3), prepare a management plan, discuss commonalities between the equipment types to be studied, and outline work assignments. Table 1 summarizes the responsibilities of each of the four subcontractors. Figure 2 and Figure 3 addresses the respective project organization and program plan.

Table 1 - Task Group Responsibilities

Project Leader	Machine Types
Bendix Corporation	Continuous Miners and Scoops
Canyon Research	Roof Drills and Personnel Carriers
McDonald Associates	Loaders, Cutting Machines, and Face Drills
Woodward Associates	Shuttle Cars, Utility Tractors and Locomotives

A second and third project coordination meeting were held on November 6, 1980 and March 5, 1981. Several issues were considered including document formats, common vocabulary, data sources, seating studies and possible machines that would not meet the proposed recommended practice. Project leaders agreed that all these issues must be clearly defined in the rationale statement of the draft document.

Following these meetings, each task group began developing a unique draft set of human factors guidelines for the assigned machine types. The guidelines were based upon data collected from varied sources. Appendix 1 offers a sample of the types of data collected by the Bendix Corporation from the manufacturers of scoops and continuous miners. The survey instrument was used to ascertain information on machine job functions, operator and helper tasks, configuration of controls, and display layouts. This information was instrumental in compiling a preliminary draft Recommended Practice for roof drills and a Rationale Statement.

Accident and injury analyses were also performed by the task groups. For example, Canyon Research Group analyzed 43 fatal and over 5,000 nonfatal roofbolter accidents that occurred through the years 1975-1979. Narrative descriptions of over 600 of these accidents were analyzed manually. Appendix 2 provides an example of the type of safety analysis using accident and injury data.

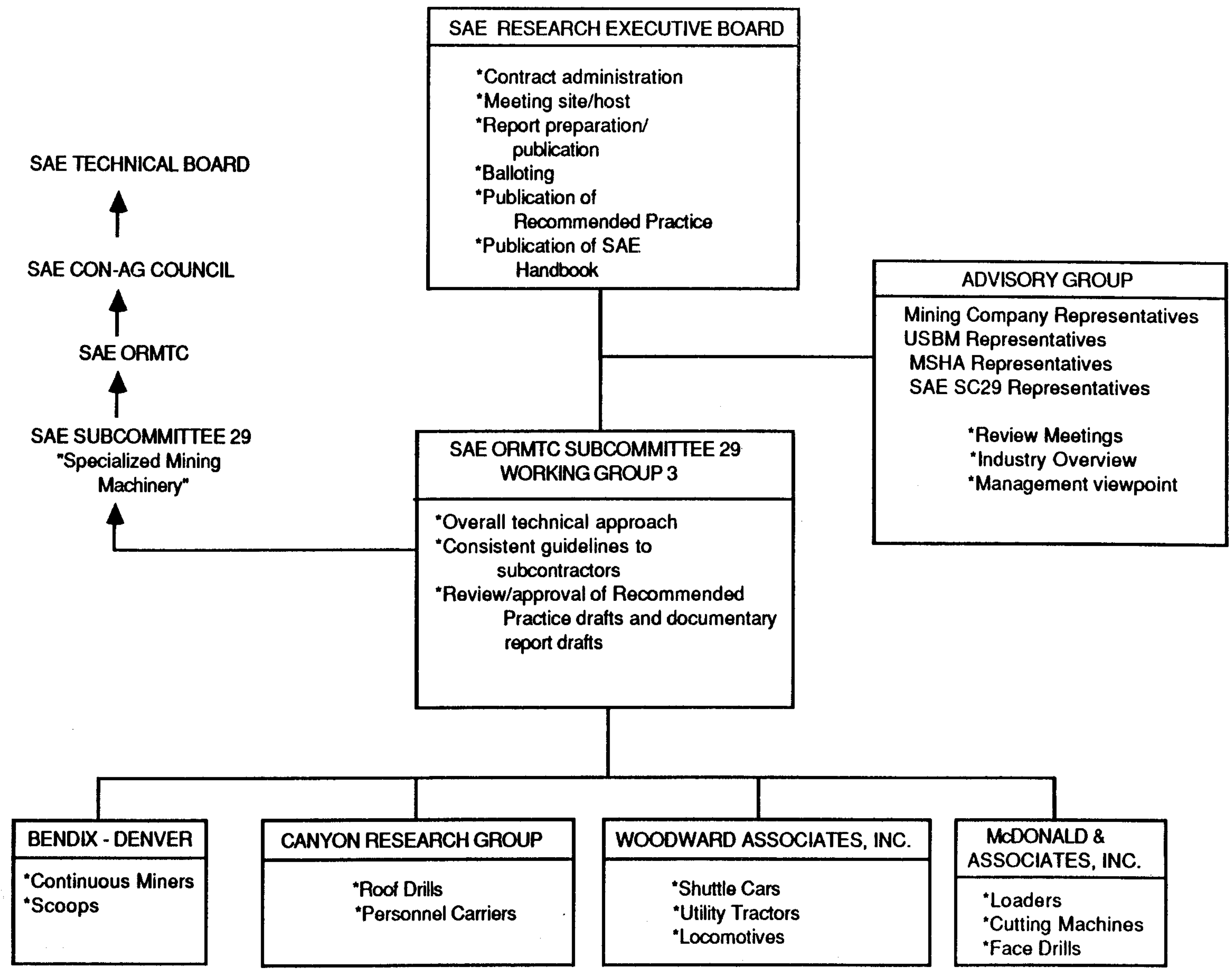


FIGURE 2 - PROJECT ORGANIZATION

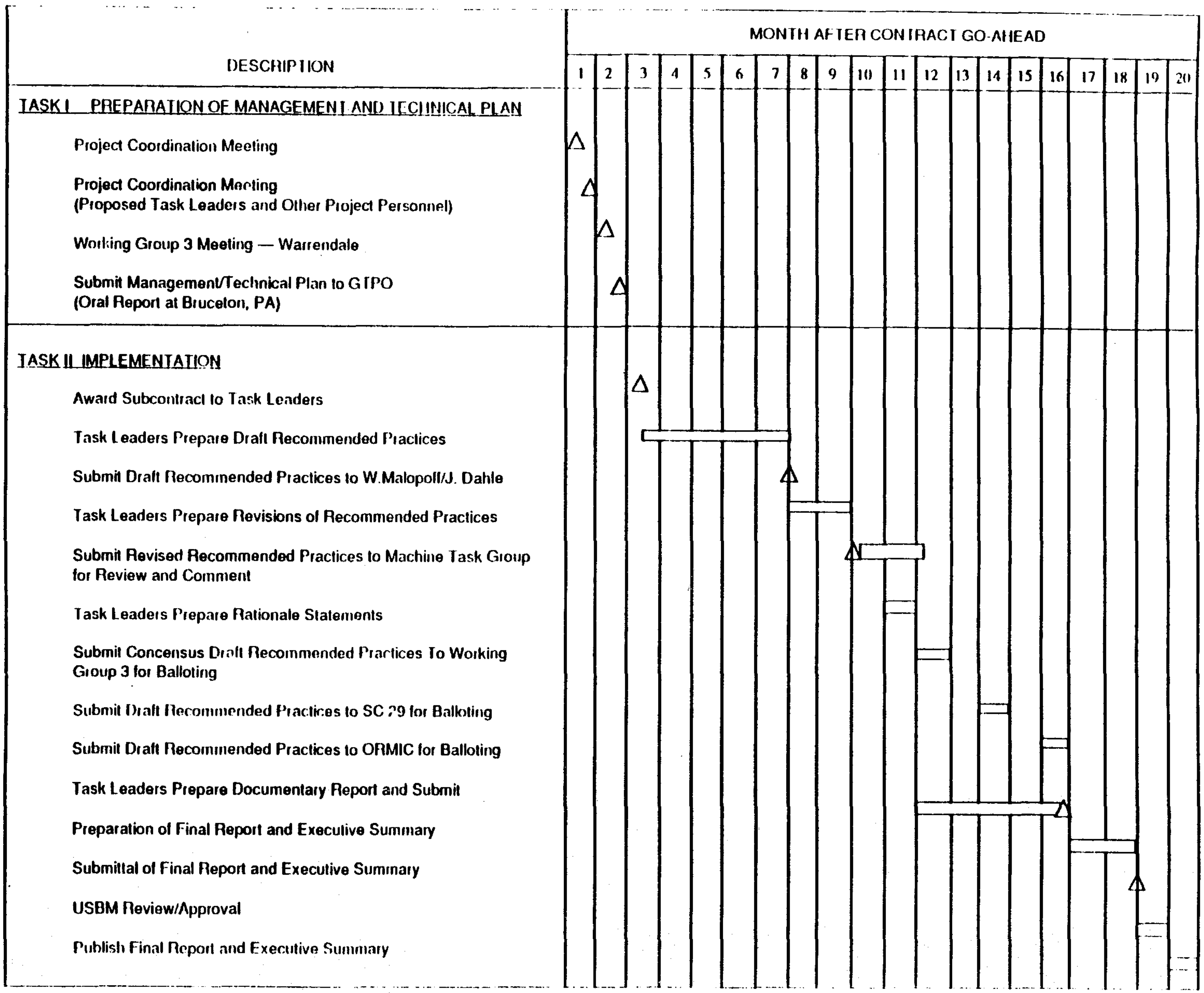


FIGURE 3 - PROJECT SCHEDULE

Project leaders solicited manufacturer and MSHA (Mine Safety and Health Administration) input to the draft documents. McDonald and Associates contacted a number of manufacturers to solicit their comments and inputs. Companies were selected from a MSHA list of manufacturers, the Coal Age Buyers' Guide and the Thomas Register . From this list, an advisory panel was formed for reviewing all work and drafts developed under the project. The panel, which consisted of those described in Appendix 3, reviewed the draft documents for loaders, cutters and face drills. Another example of the type of input received from the manufacturers is illustrated in Table 2. Canyon Research Group sought to classify controls as either primary or secondary based upon their task analyses and interviews with machine users and designers. These types of data and information were included in the Rationale Documents submitted by each of the Project Leaders.

Table 2 - Suggested classification of primary and secondary controls

Control Class	Designation	Agree		Disagree	
		MSHA	Manuf.	MSHA	Manuf.
Tramming controls:					
Left tram	- primary	14	5		
Right tram	- primary	14	5		
Steering	- primary	14	5		
Speed	- primary	14	4		1
Inch tramming	- primary	14	3		2
Cable reel	- secondary	14	5		
Director valve	- secondary	14	5		
Parking brake	- secondary	14	5		
Service brake	- secondary	14	5		
Setting controls:					
Stab jack	- primary	14	5		
TRS lift	- primary	14	5		
Canopy	- primary	12	3	2	2
TRS sump	- primary	10	5	3	
TRS tilt	- secondary	10	4	3	1
Drilling controls:					
Drill rotate	- primary	14	5		
Boom (mast) lift	- primary	14	5		
Drill guide (centralizer)	- primary	14	4		1
Auger clamp	- primary	14	4		
Drill speed	- secondary	12	3	2	2
Impactor	- secondary	12	4	1	1
Bolt torque	- secondary	6	2	7	3
Repositioning controls:					
Boom swing	- primary	12	5		
Boom sump	- primary	12	5		
boom tilt	- secondary	10	4	2	1
Electrical:					
Panic bar	- primary	13	5		
Pump start/stop	- secondary	12	5	1	
Lighting	- secondary	13	5		
Main power	- secondary	13	5		

As work progressed, a meeting was held on January 21, 1982 with all projects leaders in attendance. This meeting provided a basis to review the work of the four task groups and plan for the balloting of the Recommended Practices through the working group. By the following year, draft SAE Recommended Practices for eight of the ten machine types were developed and balloted. Appendices 4, 5, and 6 illustrate the balloted documents for continuous miners, shuttle cars and roof drills respectively. Table 3 provides a summary of the ballot results.

Table 3 -Summary of Balloted Documents

DOCUMENT	BALLOTED	RESULTS		
		Approve	Disapprove	Waive
J1296, Shuttle Cars	9/9/82	10	2	2
J2138, Roof Drills*	11/18/82	8	4	1
J1421, Continuous Miners	9/28/82	6	4	3
J1425, Loaders	10/20/82	4	1	4
J1426, Cutters	10/20/82	4	1	4
J1427, Face Drills	10/20/82	5	1	3
J1429, Personnel Carriers	11/18/82	8	1	2
J1439, Scoops and Ramcars	2/22/83	0	0	0
JXXXX, Utility Tractors	Not balloted	-	-	-
JXXXX, Locomotives	Not balloted	-	-	-

*this document number was formerly J1314 and was changed to avoid confusion with the combined document.

Due to the size of each of the eight individual documents, it was proposed to consolidate the guidelines into a single design guideline. A subcontract was awarded to the Essex Corporation to; (1) review incomplete draft guidelines/supporting materials and attempt to complete them with the materials/data available, and (2) consolidate existing guidelines into a single document and draft a Recommended Practice for submission to SAE. The draft Recommended Practice (J1314) is contained in Appendix 7. This combined document was completed by Essex in October of 1984 and balloted through SAE Subcommittee 29 - Working Group 3 in December, 1984. The results of the balloting indicated three (3) Approvals, six (6) Disapprovals, and six (6) No Replies. The general consensus was that the document needed additional refinement, was too lengthy, and should be more performance oriented.

An Ad Hoc Group to the SAE Human Factor Technical Committee - SC1 was then formed to address the needed revisions. The task force met for the first time in August of 1985. The group questioned whether such a document was still needed in industry, and if so, how to organize the task force to address specific issues. Several mining standards were available, however, they primarily addressed surface mines. The task force agreed that human engineering guidelines for underground operator compartments were still needed in industry. Initial work assignments focused on anthropometric data, operator enclosure sections, control reach for varying positions and seating. Several subsequent meetings were held and are outlined in Table 4.

Table 4 Ad Hoc Group - Meeting Schedule

MEETING DATE	LOCATION
March 5, 1986	Bruceton, Pennsylvania
April 28, 1987	Pittsburgh, Pennsylvania
September 17, 1987	Milwaukee, Wisconsin
October 7, 1988	Warrendale, Pennsylvania
February 1, 1990	Pittsburgh, Pennsylvania

During these meetings, the group addressed several issues on technical content. The group chose to delete certain anthropometric data that could also be found in SAE J898; 'Control Locations for Off-Road Work Machines'. Other anthropometric data was still needed, however, for prone and crawling positions. A review of SAE Draft J1814; 'Operator Controls for Off-Road Work Machines' was also conducted to gather applicable data. After additional revisions, a schedule was developed with the intention to complete the document by October of 1988. However, seating criteria was not completed and caused additional delays in revising the combined document.

APPENDIX 1

Date

MINING MACHINE

MANUFACTURER'S DATA FORM

Manufacturer's Name

Address

Telephone Number

Person(s) Contacted and Title

GENERAL CHARACTERISTICS OF DOCUMENTED MINING MACHINE

Machine Type

Model

General Characteristics

(Attach blueprints, advertising, or other pertinent literature, if available)

MINING MACHINE

STANDARDIZATION* QUESTIONNAIRE

	Question	(Check One) Yes	No	Uncertain
	Controls			
1.	Do you think control occurrence should be standardized (i.e., certain controls should always be provided as standard equipment, while others are offered as optimal equipment)?			
2.	Do you think control location should be standardized (i.e., the same controls should be placed in the same general location or zone from one machine to another)?			
3.	Do you think control types should be standardized (i.e., the same controls should be placed in the same general location or zone from one machine to another)?			
4.	Do you think control direction of motion should be standardized (i.e, the control should move left to cause the machine or equipment to move left)?			
5.	Do you think control actuation should be standardized (i.e., the control movement should always be proportional to the rate or distance of tool or vehicle movement or, in other cases, actuation of a control should only turn some function ON or OFF)?			
6.	Do you think control labeling should be standardized (i.e., for control nomenclature and/or direction of motion, etc.)?			
7.	Do you think control shape should be standardized?			
8.	Do you think control color, should be standardized?			
9.	Do you think control size should be standardized?			
10.	Do you think control forces should be standardized?			
11.	Do you think control extent of travel should be standardized?			
12.	Do you think control layout (i.e., interrelationships) should be standardized?			

* Standardization should generally be understood to refer to a range of design solutions (i.e., for control location, a control might be located anywhere within a one foot square zone, but not within another zone). Information from this questionaire will be used to determine which types of standardization measures should be incorporated into the proposed recommended practice.

	Question	(Check One) Yes	No	Uncertain
	Displays			
13.	Do you think display occurrence should be standardized (i.e., certain displays should always by provided as standard equipment, while others are offered as optimal equipment)?			
14.	Do you think display location should be standardized (i.e., the same displays should be placed in the same general location or zone from one machine to another)?			
15.	Do you think display types should be standardized (i.e. the same displays should be placed in the same general location or zone from one machine to another)?			
16.	Do you think display labeling should be standardized (i.e., for control nomenclature and/or direction of motion, etc.)?			
17.	Do you think display size should be standardized?			
18.	Do you think display layout (i.e., interrelationships) should be standardized?			

* Standardization should generally be understood to refer to a range of design solutions (i.e., for control location, a control might be located anywhere within a one foot square zone, but not within another zone). Information from this questionaire will be used to determine which types of standardization measures should be incorporated into the proposed recommended practice.

	Question	(Check One) Yes	No	Uncertain
	Workspace Layout			
19.	Do you think operator station layout (i.e. operator position relative to door or control panels) should be standardized?			
20.	Should minimum cab dimensions be recommended in the design guidelines?			
21.	Do you think emergency exit points should be standardized?			

General Comments

Prepared By: ________
Phone Number: ________
Machine Type: ________
Model: ________

TASK ANALYSIS FOR MINING MACHINE OPERATOR

FUNCTION	OPERATOR TASK	COMMENTS	CONTROLS	DISPLAYS/FEEDBACK

e attach any available task analysis applicable to this piece of equipment.

TASK ANALYSIS FOR MINING MACHINE OPERATOR (Continued)

Machine Type: ________

Model: ________

FUNCTION	OPERATOR TASK	COMMENTS	CONTROLS	DISPLAYS/FEEDBACK

tional pages if necessary.

Machine Type: ________

MINING MACHINE VISIBILITY REQUIREMENTS

1. List in order from most important to least important all areas around the machine or parts of the machine which you feel from your experience the operator <u>must</u> see from the cab to conduct safe operations.

    1.

    2.

    3.

    4.

    5.

2. List all areas around the machine or parts of the machine which you feel should reasonably be visibility design goals that are not included in the list above.

    1.

    2.

    3.

    4.

    5.

3. Comments on visibility requirements:

LIST OF MACHINE CONTROLS, THEIR FUNCTIONS
IMPORTANCE, AND LOCATION

PREPARED BY: ____________________

MACHINE TYPE: ____________________

PHONE NUMBER: ____________________

MODEL: ____________________

A. FUNCTIONS AND IMPORTANCE

	CONTROL	FUNCTION	Check One			
			CO*	IO	R	S
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						
13.						
14.						
15.						
16.						
17.						
18.						
19.						
20.						

* Legend: CO = Continuously Operated; IO = Intermittently Operated; R = Routine; S = Function That Affects Safety

B. LOCATION

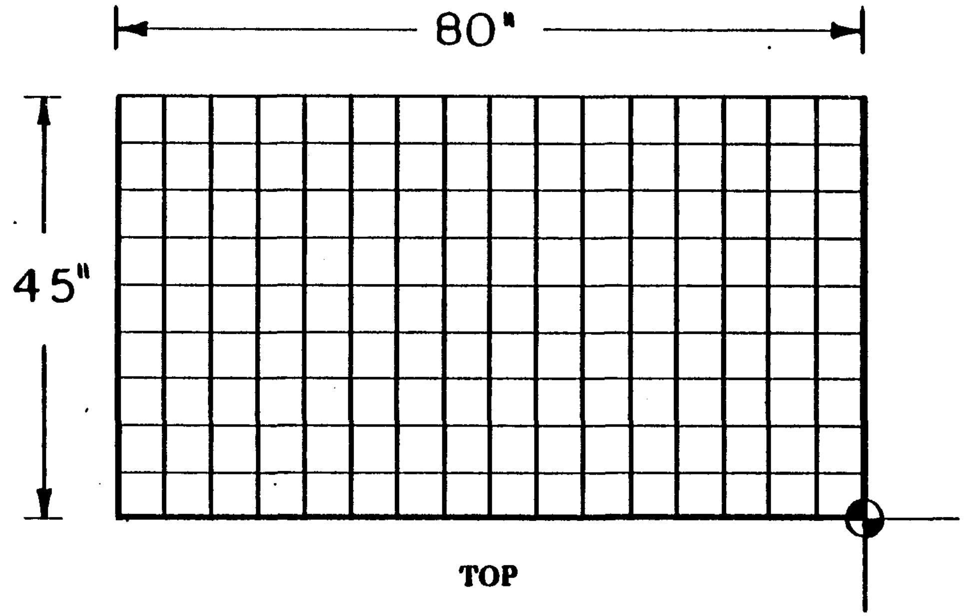
Using the numbers from the list above, plot the location of each control by writing its number in the appropriate place on each view of the workspace diagram on the next page.

MACHINE TYPE: __________

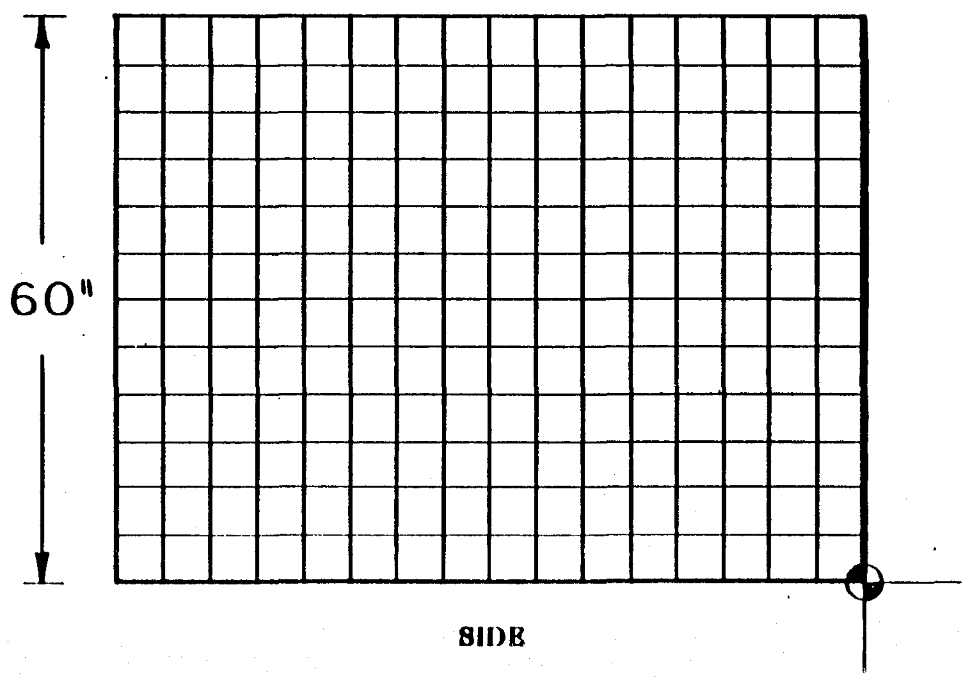
MODEL NUMBER: __________

MINING MACHINE WORKSPACE DIAGRAM

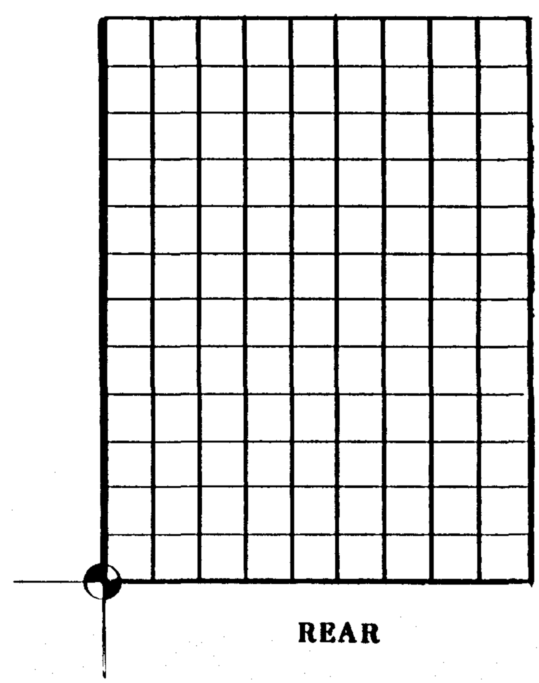
1. Draw the cab workspace in all three views starting from the indicated reference point.
2. Draw the seat location in all three views.
3. Give important dimensions in inches (note that grid squares are 5" x 5").
4. Plot component locations by number as instructed on the previous page.



TOP



SIDE



REAR

DETAILED DESCRIPTION OF EACH MACHINE CONTROL

PREPARED BY: ____________________ MACHINE TYPE: ____________________

PHONE NUMBER: ____________________ MODEL: ____________________

CONTROL	TYPE*	PLANE OF ORIENTATION		SIZE**	DISPLACEMENT RANGE	FORCE	STANDARD OR OPTIONAL (CHECK ONE)		DIRECTION OF MOTION	RESULTS OF MOTION
		HORZ.	VERT.				S	O		

* **Control Type Legend:**

BF = Button, Foot Push
BH = Button, Hand Push
CR = Crank
HC = Handle, Cylindrical
HT = Handle, "T"
KB = Knob, Bar
KH = Knob, High Torque
KP = Knob, Pull
KR = Knob, Rotary
KS = Knob, Slide
LB = Lever, Ball Grip
LC = Lever, Cylindrical
PA = Pedal, Accelerator
PB = Pedal, Brake
SK = Switch, Key
SR = Switch, Rocker
ST = Switch, Toggle
SL = Switch, Lever
WH = Wheel, Hand
WT = Wheel, Thumb

** **Control Size Legend:**

ᴵ – Length
Diameter
W = Width
x · Cross Section
H = Height

MINING MACHINE
CONTROL LABELING

PREPARED BY: ____________________ MACHINE TYPE: ____________________

PHONE NUMBER: ____________________ MODEL: ____________________

LABEL	CONTROL	MEANING	REMARKS

MINING MACHINE
CONTROL CODING METHODS

PREPARED BY: ____________________ MACHINE TYPE: ____________________

PHONE NUMBER: ____________________ MODEL: ____________________

CODING METHOD*	CONTROL	CODED CHARACTERISTICS	REMARKS

* Control coding methods in the first column may include:

Shape	Extent of Travel
Color	Location
Size	Direction of Travel
Force	Other (Please Specify)

SAFEGUARDS AGAINST INADVERTENT MACHINE CONTROL ACTIVATION

PREPARED BY: ____________________ MACHINE TYPE: ____________________

PHONE NUMBER: ____________________ MODEL: ____________________

(NOTE: Identify all controls which could introduce hazards if NOT properly operated.)

CONTROL	DESCRIBE MEASURES WHICH COULD BE RECOMMENDED TO PREVENT INADVERTENT OR CARELESS CONTROL ACTIVATION

LIST OF MACHINE DISPLAYS, THEIR FUNCTIONS
IMPORTANCE, AND LOCATION

PREPARED BY: ____________________ MACHINE TYPE: ____________________

PHONE NUMBER: ____________________ MODEL: ____________________

A. FUNCTIONS AND IMPORTANCE

NO.	DISPLAY	FUNCTION	CM*	IM	R	S
A.						
B.						
C.						
D.						
E.						
F.						
G.						
H.						
I.						
J.						
K.						
L.						
M.						
N.						
O.						
P.						
Q.						
R.						
S.						
T.						

* CM = Continuously Monitored
R = Routine

IM = Intermittently Monitored

S = Presents Information Critical to Safety

B. LOCATION

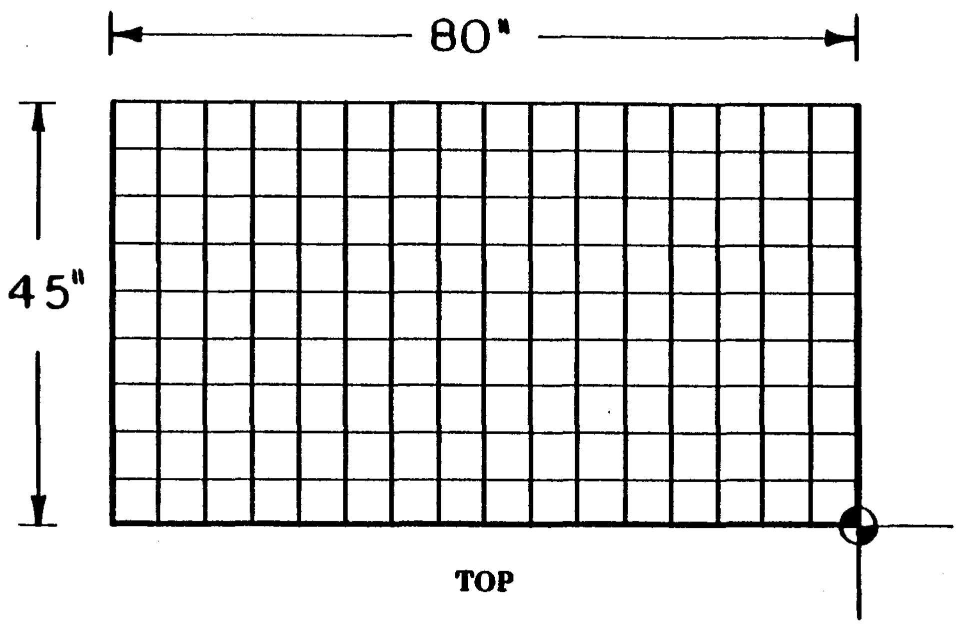
Using the Letters above to represent the displays, please plot the location of each display by writing its letter in the appropriate place on each view of the attached workspace diagram.

MACHINE TYPE: __________

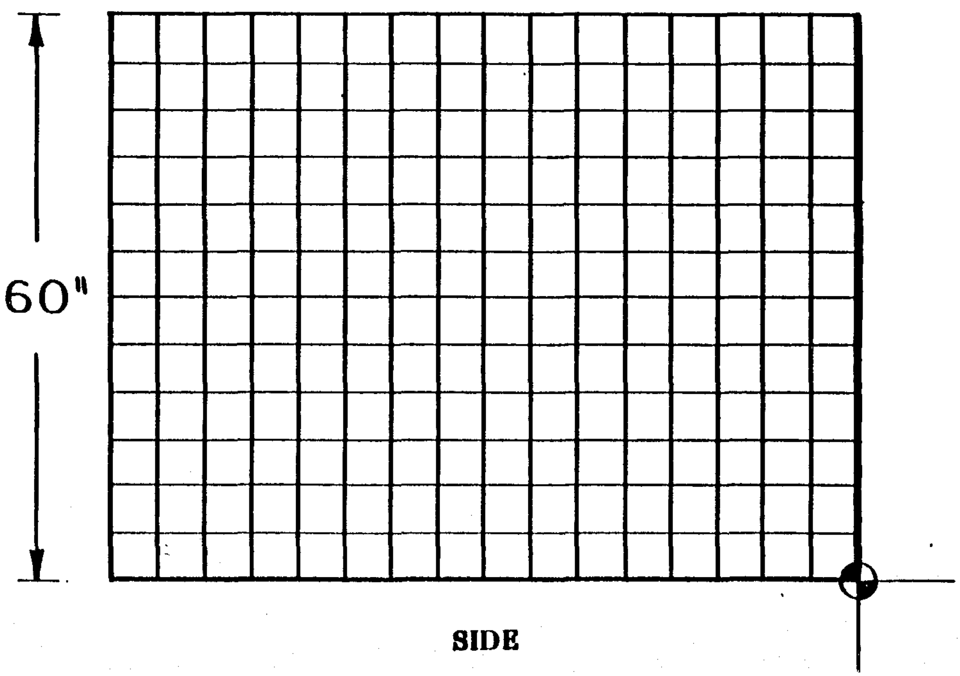
MODEL NUMBER: __________

MINING MACHINE WORKSPACE DIAGRAM

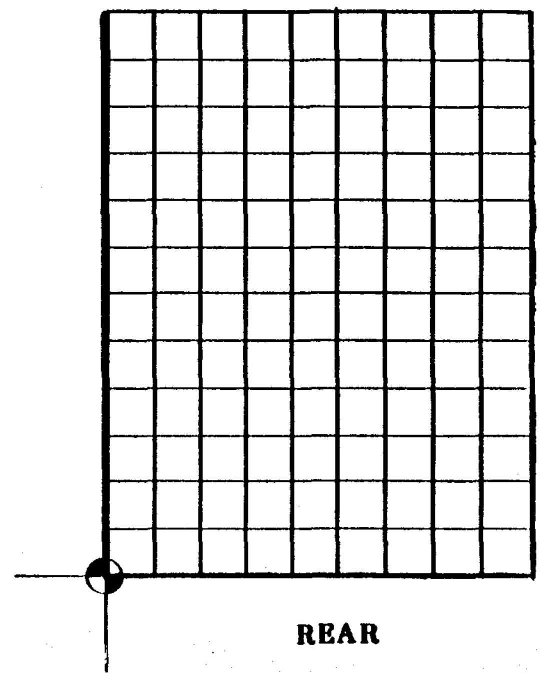
1. Draw the cab workspace in all three views starting from the indicated reference point.
2. Draw the seat location in all three views.
3. Give important dimensions in inches (note that grid squares are 5" x 5").
4. Plot component locations by number as instructed on the previous page.



TOP



SIDE



REAR

DETAILED DESCRIPTION OF EACH MACHINE DISPLAY

PREPARED BY: ____________________ MACHINE TYPE: ____________________

PHONE NUMBER: ____________________ MODEL: ____________________

DISPLAY	TYPE		MANUFACTURER	MODEL #	SIZE	SCALE RANGE	DIRECTION OF INDICATOR MOTION	REMARKS
	DIGITAL	ANALOG						

MINING MACHINE
DISPLAY LABELING

PREPARED BY: ____________________ MACHINE TYPE: ____________________

PHONE NUMBER: ____________________ MODEL: ____________________

LABEL	DISPLAY	MEANING	REMARKS

Machine Type: ____________

Model: ____________

MINING MACHINE SEAT DATA

1. Is there a seat? Yes No
2. Is the seat adjustable? Yes No
3. If adjustable, provide the following information:
   - a) Range of fore-aft travel ______ in.
     - Travel increment ______ in.
   - b) Range of vertical travel ______ in.
     - Travel increment ______ in.
   - c) Range of seat back inclination (from vertical) ______ °
     - Inclination increment ______ °

NOW, SET ALL PARTS OF THE SEAT AT THE MIDDLE OF THEIR ADJUSTMENT RANGES AND PROVIDE THE FOLLOWING INFORMATION:

1. Consider the seat pan:
   - a) Seat pan length ______ in.
   - b) Seat pan width at narrowest part ______ in.
   - c) Height (from floor to front edge of seat pan) ______ in.
   - d) Set pan inclination (from horizontal) ______ °
2. Is there a seat back? Yes No

   If so, please provide the following information
   - a) Seat back width ______ in.
   - b) Seat back length ______ in.
   - c) Seat back inclination (from vertical) ______ °
3. Are there any arm rests? Yes No

   If so, please provide the following information:
   - a) Arm rest length ______ in.
   - b) Arm rest width ______ in.

c) Arm rest height ________ in.

d) Minimum arm rest separation (measured from inside edges) ________ in.

e) Arm rest inclination (from horizontal) ________ °

f) Are the arm rests adjustable? Yes No

If so, please describe the nature and ranges of the adjustment(s):

____

____

4. Is a seat belt provided? Yes No

5. Is a shoulder harness provided? Yes No

6. Is a headrest provided? Yes No

If so, please provide the following information:

a) Headrest length ________ in.

b) Headrest width ________ in.

c) Is the headrest adjustable? Yes No

If so, please describe the nature and range(s) of the adjustment(s):

____

____

PREDICTIVE RELATIONSHIPS FOR ESTABLISHING INTERIOR CAB DIMENSTIONS

In order to explore and define the interrelationships that serve to determine the necessary dimensions of an operator's cab space, a systematic study using plastic drawing board manikins was conducted. In this study, three different percentile manikins (95% male; 5% male; and 5% female) were employed. These manikins were designed, patented, and thoroughly documented for the USAF by Kennedy (1980) and were based on 1985 projections from a large set of anthropometric dimensions (NASA, 1978). Each manikin was modified for mining cab design work by adding a mining cap and cap lamp to it. Each manikin was systematically positioned under various interior cab heights (see Figures 1, 2 and 3) to establish the baseline relationship between cab height and cab length.

During the study, several assumptions were made to assist in placing the manikins under each selected interior cab height. Since, in many mining design situations, a canopy is often required, a constant two inches of clearance between the operator's cap (or cap lamp) and the canopy underside was maintained. Previous work by Bendix had suggested that at least two inches of clearance was desireable in moving machinery with low canopies. For baseline purposes, the seat pitch was fixed at 10° and the seat pan length was fixed at 16 inches. The seat reference point was placed at 1 inch above the cab floor. The angle between the manikin's foot and lower leg was fixed at 95° (the midpoint of the generally recommended range of 90° to 100° - see Morgan, et al., 1963). Finally, for purposes of standardization, the manikin's head was kept in contact with the rear wall of the cab in all cab layout configurations.

The baseline relationship for predicting interior cab length from interior cab height was found to be quadratic in form for all three percentile manikins. A quadratic regression equation was fitted to each manikin's data points -the resulting degree of fit being extremely high (refer to the next section for the actual equations). Figure 4 presents the predictive equation lines for the 5% female, 5% male, and 95% male in bold face. The prediction lines shown for other percentile operators were derived by interpolation using the standard normal distribution. This figure should prove useful in helping designers establish the cab length necessary for a given range of operators. One would enter the figure with the needed cab height and read the cab length needed off the appropriate percentile curve. The 95% male drives the upper limit of cab length. If a designer is constrained to a given cab length, the figure can be used to derive the necessary cab height using the 95% male line as the reference line (if 95% male is to be accommodated).

Many other factors can work and interact with interior cab height to determine the necessary cab length. To address these issues, further work was done using the 95% manikin. Variables examined were: altering the operator's knee angle to shorten the needed leg room; altering the operators foot angle to minimum; and altering the seat pitch itself. Figure 1 shows some of the work done to address these factors. Figures 5 and 6 show the predictive equation lines

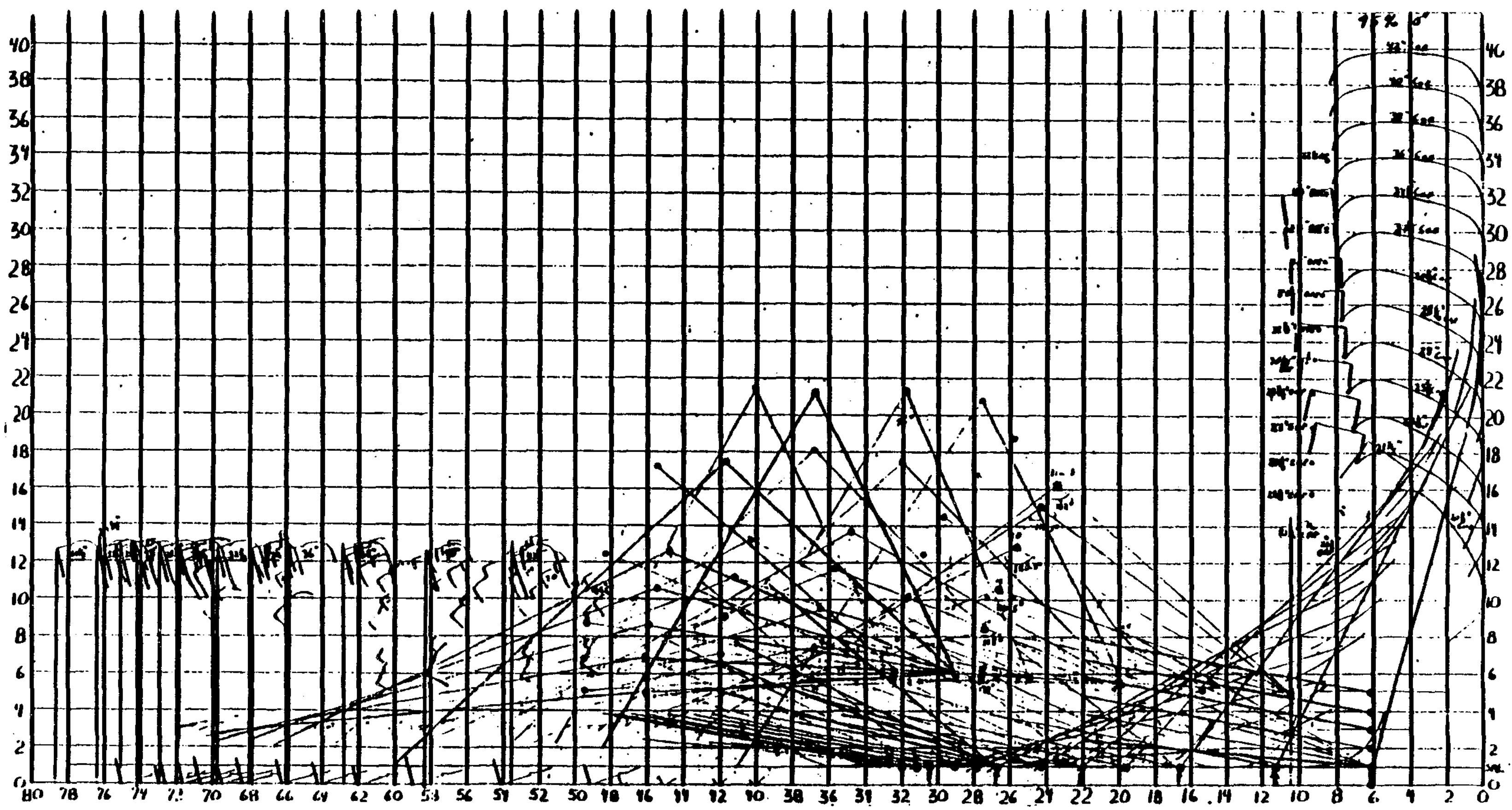


Figure 1. Work Space Position Layouts for 95% Male.

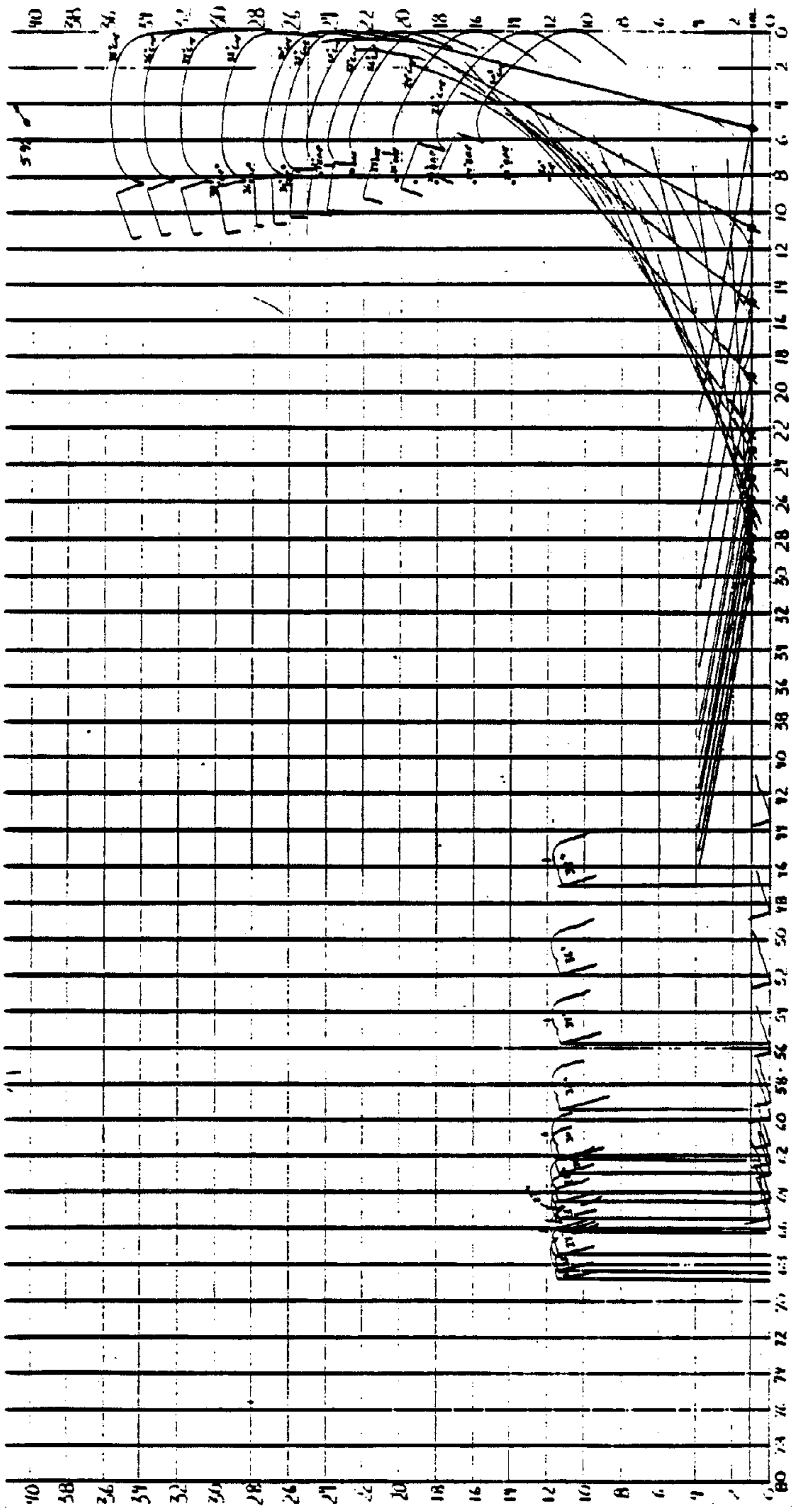


Figure 2. Work Space Position Layouts for 5% Male.

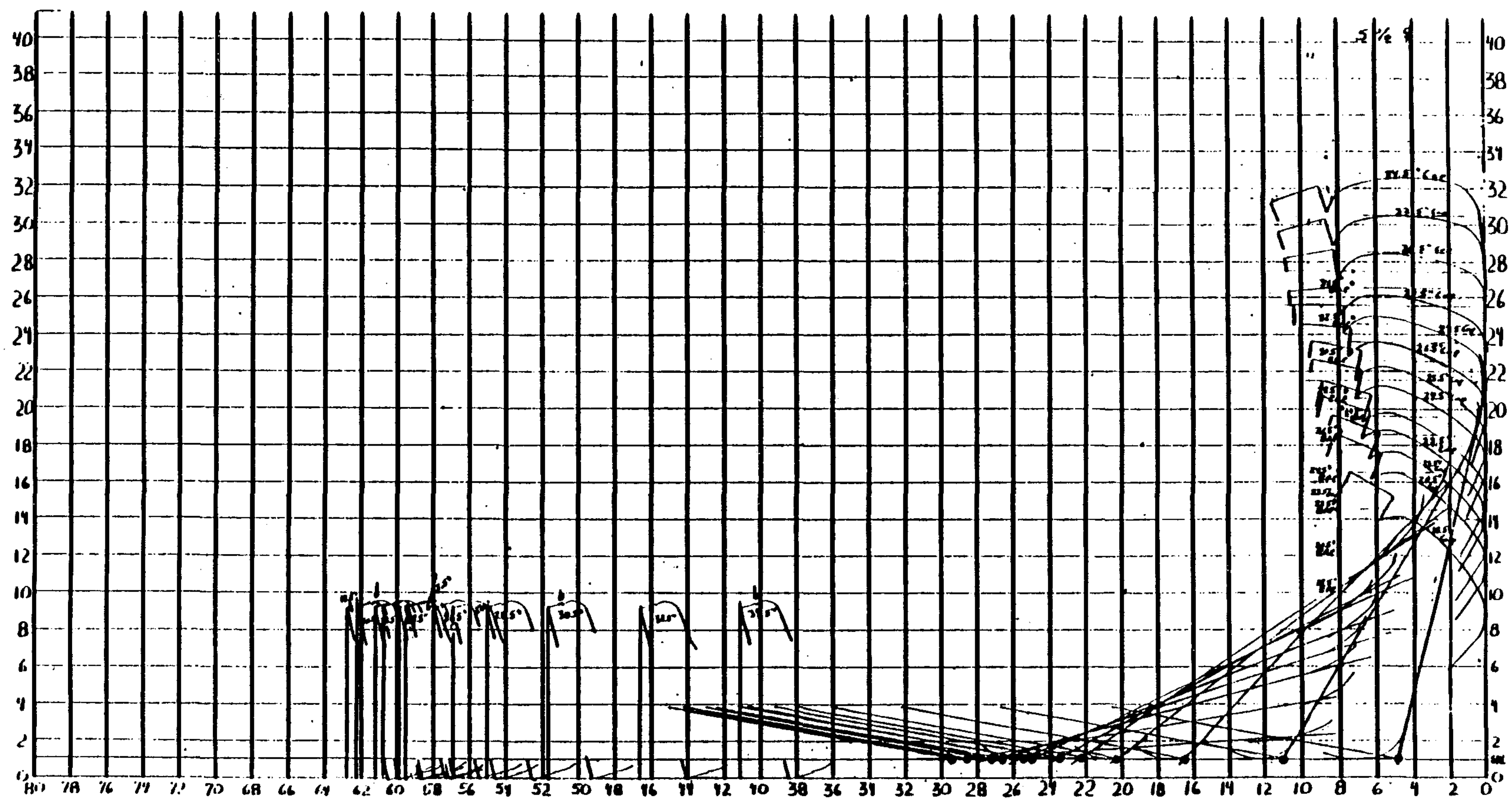


Figure 3. Work Space Position Layouts for 5% Female.

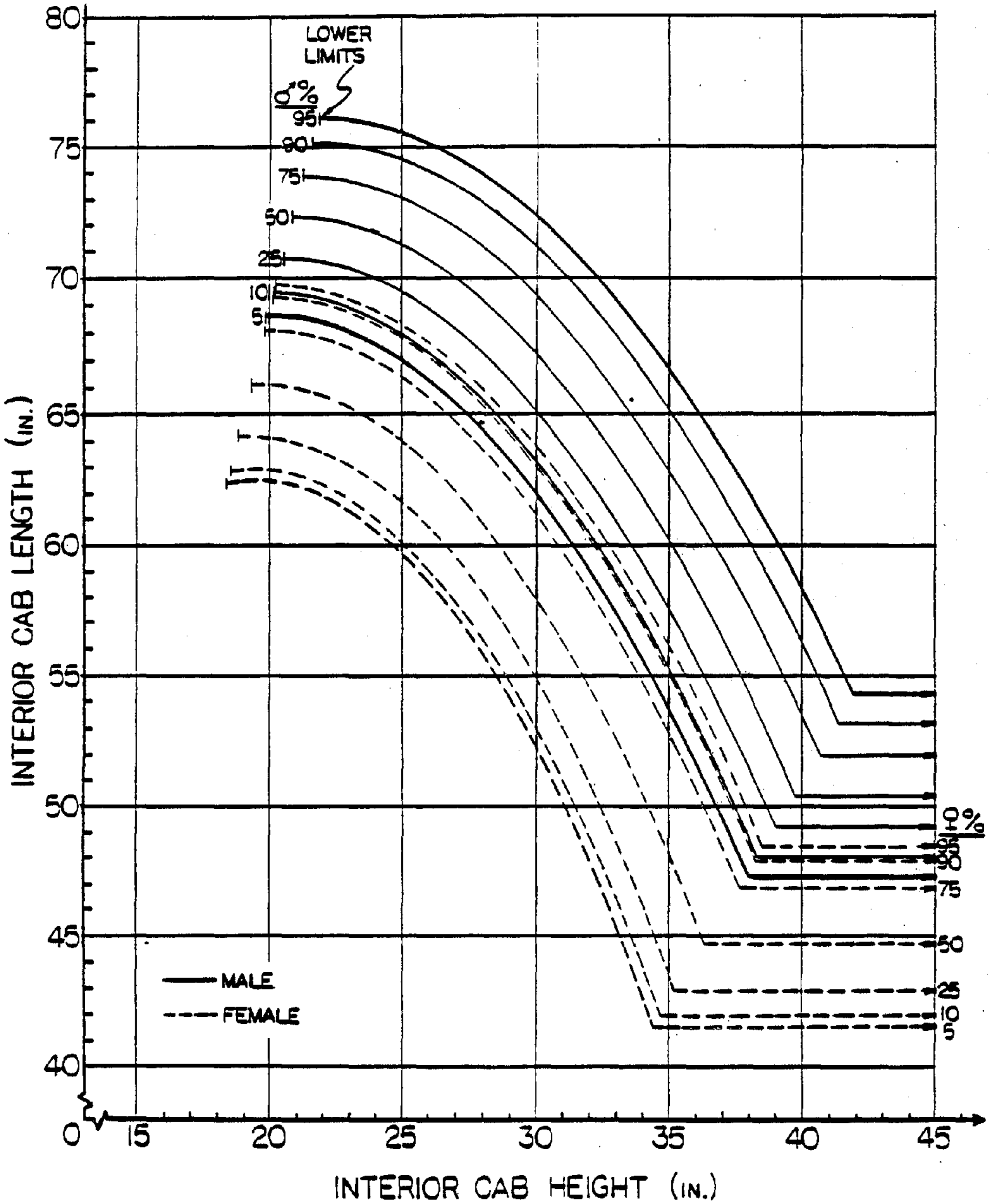


Figure 4. Prediction lines for establishing interior cab length from interior cab height (assuming 2" cap clearance) for various percentile operators.

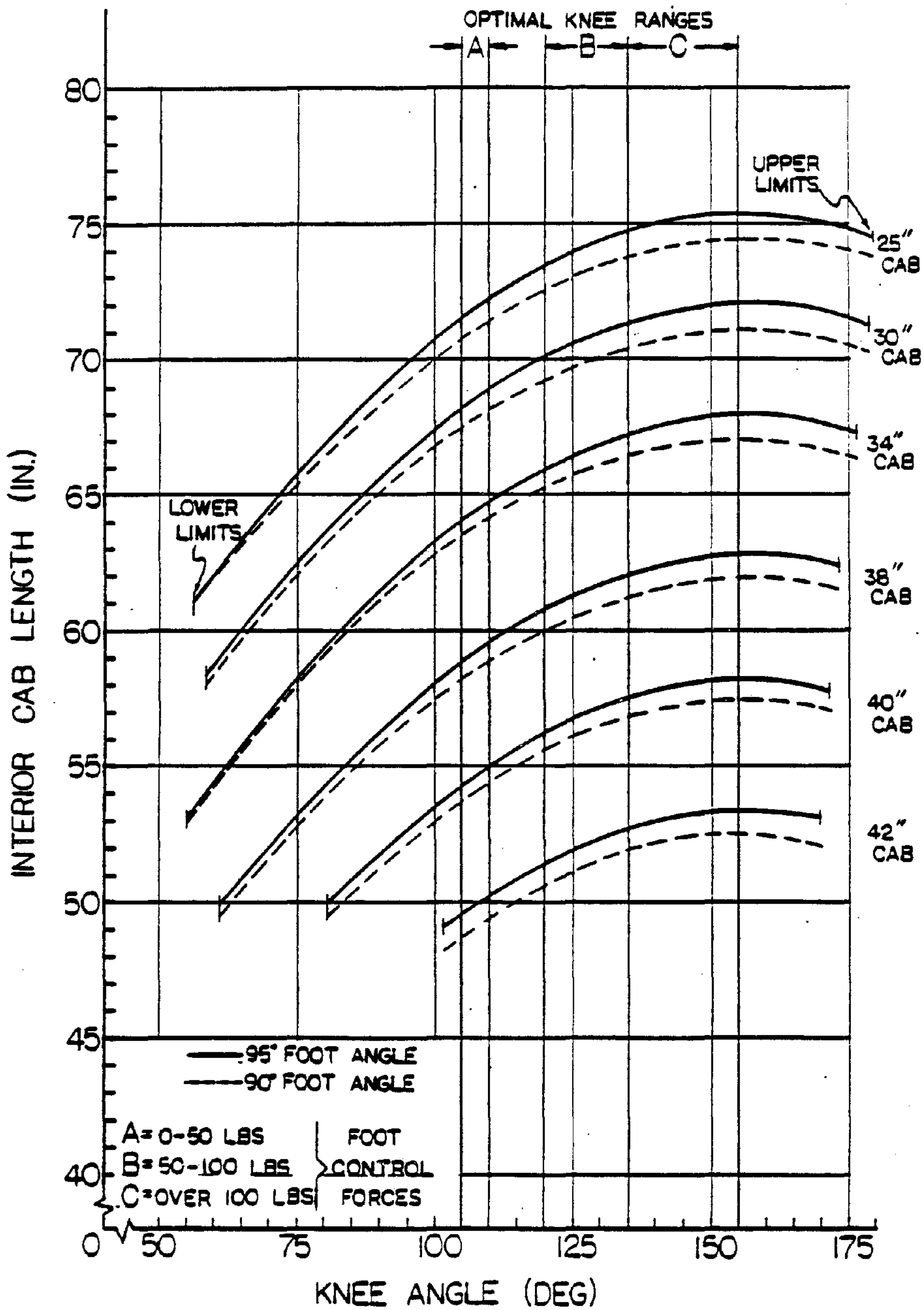


Figure 5. Prediction lines for altering interior cab length by changing knee angles and foot angles in various interior cab heights (assuming 2" cap clearance).

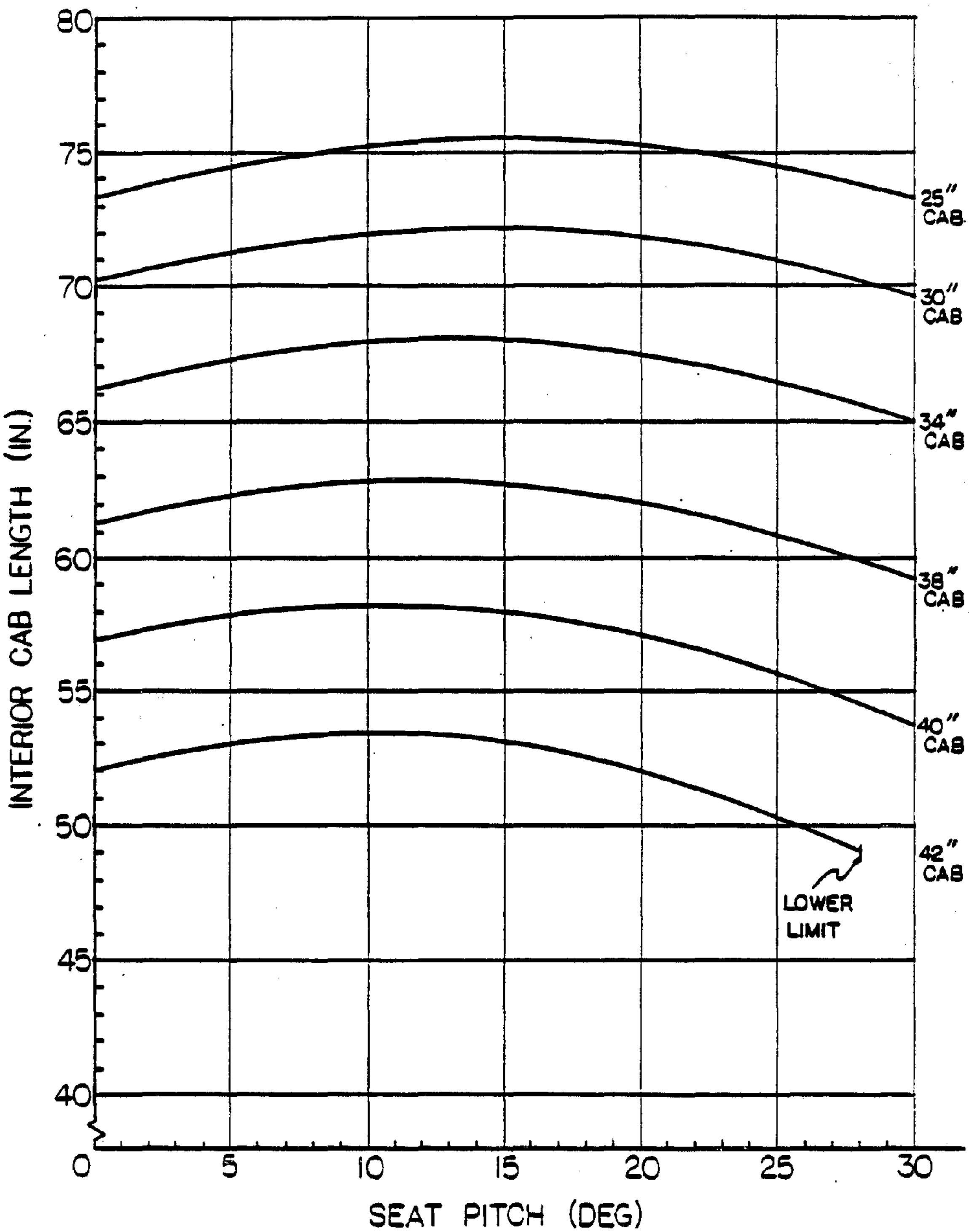


Figure 6. Prediction lines for altering interior cab length by changing the seat pitch for various interior cab heights (assuming 2" cap clearance).

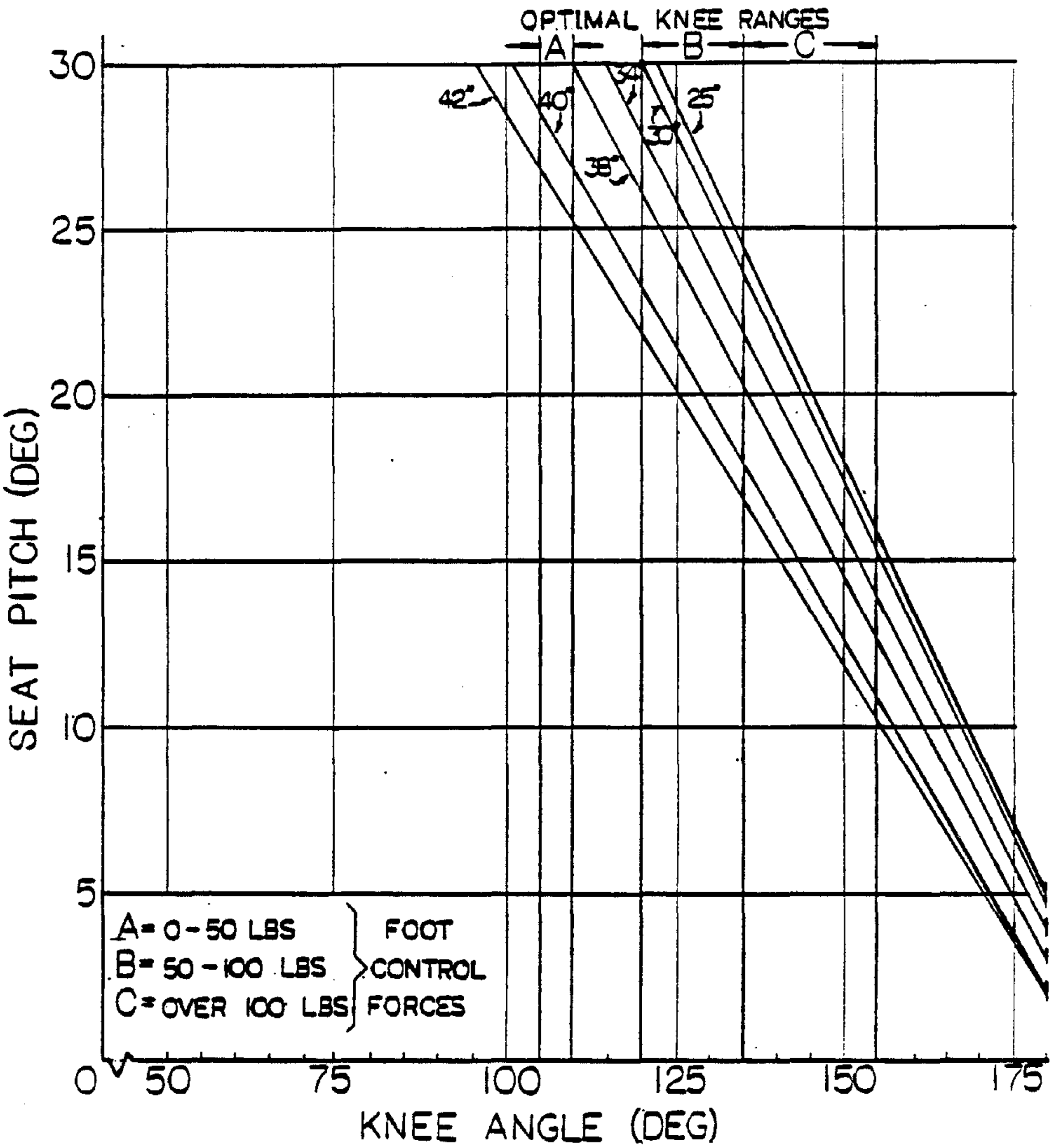


Figure 7. Relationship between seat pitch angle and knee angle for various interior cab heights (assuming 2" cap clearance).

(again quadratic in form - refer to the next section) for changes in knee angle, foot angle, and seat pitch, respectively. The prediction lines were fitted for several representative interior cab heights. As can be seen in Figure 5, changes in knee angle do not reduce needed cab length by any substantial amount until the knee angle reaches about 120° - 125°. Changes in foot angle gain a maximum of about 1 inch in cab length reduction, but only for the larger knee angles. Figure 5 also shows the recommended optimal knee angle ranges needed if foot controls of various forces are to be used (see Van Cott & Kinkade, 1972). For strong force foot controls (over 100 lbs. as would often be true for tramming foot controls in mining machines), a relatively large knee angle (more than 135°) is needed. As can be seen in Figure 6, seat pitch changes do not greatly influence needed cab length until the upward pitch reaches about 20° - 25°.

Figure 7 shows the predictive relationship between knee angle and seat pitch angle. This relationship is strongly linear as might be expected (see the next section for the actual equations). The optimal knee angle ranges are also shown in this figure. Thus, this figure can help one determine what seat pitch should be used for a given foot control force and interior cab height.

All of these figures (4 through 7) can be used jointly to determine the cab length necessary to accommodate a given range of operators. These figures are predictive so the results they yield should be considered as ideal. They will serve to assist the designer in understanding the interrelationships involved in cab dimensioning under different types of constraints and in establishing design criteria and goals.

It should be noted that all possible driving factors in cab space dimensioning have not been addressed here. For example, if a headrest is provided for the operator, the additional space for the headrest must be accounted for by extending the cab length. Beyond a certain point (preliminary indications are 10 inches above the floor), raising the seat reference point (SRP) will reduce the needed cab length. However, raising the SRP to this level begins to approach a more normal seating posture and there are many sources (e.g., Van Cott & Kinkade, 1972) that address normal seating design parameters. Another factor not accounted for is the extension in cab length needed if foot pedals are required. The distance traveled by the pedal during depression as well as the pedal mechanism dimensions themselves will require that the cab length be longer than what the figures here would predict.

QUESTIONS ABOUT THE FIGURES IN THIS SECTION

1. Are Figures 4, 5, 6 and 7 useful in helping you understand some of the human factors that determine cab dimensions?

2. Which figures should or should not be included in the guideline? Why?

3. How might you use these figures to design a cab? Give examples.

PREDICTIVE EQUATIONS FOR WORKSPACE CRITERIA

Nomenclature

ICL	=	Interior Cab Length from back wall (inches)
ICH	-	Interior Cab Height from floor to canopy (inches)
KA	=	Knee Angle (degrees)
SP	=	Seat Pitch (degrees)
^	=	Predicted value
FA	-	Foot Angle (degrees)

Assumptions

- 2 inch cap clearance
- Seat reference point 1 inch above floor
- Seat pan pitch is initially 10°
- Seat pan length is fixed at 16 inches
- Angle between foot and lower leg (foot angle) is 95°
- Operator's head always contacts cab rear wall
- Operator range is 95% male through 5% female

Adjustments to Equations Based on Assumptions

- Alter seat pitch angle (corresponding knee angle change also occurs - See Figure 7)
- Alter permissible cap clearance (this will change the effective interior cab height)
- Elevate knee to decrease knee angle (defined as the angle between the hip-knee and knee-ankle links)
- Elevate or lower seat reference point
- Alter foot angle

Predicting Cab Length from Cab Height Within Assumptions

a) 95% Male: $\widehat{ICL} = 50.2953 + 2.3564\,(ICH) - .0539\,(ICH^2)$

$R^2 = .996,\ n = 12$

b) 5% Male: $\widehat{ICL} = 41.0652 + 2.7222\,(ICH) - .0674\,(ICH^2)$

$R^2 = .999,\ n = 12$

c) 5% Female: $\widehat{ICL} = 26.4472 + 3.6751\,(ICH) - .0968\,(ICH^2)$

$R^2 = .998,\ n = 12$

(Other curves defined by interpolation using normal distribution)

Adjusting Cab Length for Changes in Knee Angle and Foot Angle (for Selected Cab Heights)

Cab Height	Foot Angle	Equation $[R^2; n]$
42"	95°	$\widehat{ICL} = 16.5321 + .4715\ (KA) - .00151\ (KA^2)$ [.997; 6]
	90°	$\widehat{ICL} = 14.6962 = .4911\ (KA) - .00157\ (KA^2)$ [.999; 6]
40"	95°	$\widehat{ICL} = 23.4074 + .444\ (KA) - .00142\ (KA^2)$ [.998; 6]
	90°	$\widehat{ICL} = 23.1782 + .4398\ (KA) - .00141\ (KA^2)$ [.998; 6]
38"	95°	$\widehat{ICL} = 28.2841 + .4351\ (KA) - .00137\ (KA^2)$ [.999; 7]
	90°	$\widehat{ICL} = 28.8751 + .4187\ (KA) - .00133\ (KA^2)$ [.999; 7]
34"	95°	$\widehat{ICL} - 32.5997 + .4494\ (KA) - .00143\ (KA^2)$ [.999; 7]
	90°	$\widehat{ICL} - 33.2327 + .4342\ (KA) - .00140\ (KA^2)$ [.999; 7]
30"	95°	$\widehat{ICL} - 37.1178 + .444\ (KA) - .00141\ (KA^2)$ [.999; 7]
	90°	$\widehat{ICL} - 37.4576 + .4314\ (KA) - .00139\ (KA^2)$ [.999; 7]
25"	95°	$\widehat{ICL} = 40.3006 + .4451\ (KA) - .00141\ (KA^2)$ [.999; 7]
	90°	$\widehat{ICL} = 41.8131 + .4118\ (KA) - .00130\ (KA^2)$ [.999; 7]

Van Cott and Kinkade (1972) recommend various optimal ranges of knee angles for situations where foot pedals are used and the foot control forces are within certain ranges:

- For foot control forces between 0 and 50 lbs, the optimal knee angle recommended is between 105° and 110°.
- For foot control forces between 50 and 100 lbs, the optimal knee angle recommended is between 120° and 135°.
- For foot control forces over 100 lbs, the optimal knee angle recommended is between 135° and 155°.

Adjusting Cab Length for Changes in Seat Pitch (for Selected Cab Lengths)

a) For 42" Cab: $\widehat{ICL} = 52.0376 + .2713\ (SP) - .01036\ (SP^2)$

$R^2 = .999; n = 6$

b) For 40" Cab: $\widehat{ICL} = 56.8387 + .2519\ (SP) - 0.1137\ (SP^2)$

$R^2 = .998; n = 6$

c) For 38" Cab: $\widehat{ICL} = 61.3214 + .2595\,(SP) - .01095\,(SP^2)$

$R^2 = .995;\ n = 7$

d) For 34" Cab: $\widehat{ICL} = 66.1763 + .2795\,(SP) - .01061\,(SP^2)$

$R^2 = .999;\ n = 7$

e) For 30" Cab: $\widehat{ICL} = 70.1837 + .2666\,(SP) - .00939\,(SP^2)$

$R^2 = .999;\ n = 7$

f) For 25" Cab: $\widehat{ICL} = 73.3324 + .2848\,(SP) - .00946\,(SP^2)$

$R^2 = .999;\ n = 7$

<u>Linear Relationship Between Seat Pitch and Knee Angle (for Selected Cab Heights)</u>

a) For 42" Cab: $\widehat{SP} = 62.8745 - .3400\,(KA)$

$R^2 = .999;\ n = 6$

b) For 40" Cab: $\widehat{SP} = 65.8763 - .3545\,(KA)$

$R^2 = .999;\ n = 6$

c) For 38" Cab: $\widehat{SP} = 74.2034 - .3976\,(KA)$

$R^2 = .998;\ n = 7$

d) For 34" Cab: $\widehat{SP} = 75.9026 - .3994\,(KA)$

$R^2 = .998;\ n = 7$

e) For 30" Cab: $\widehat{SP} = 82.8477 - .4358\,(KA)$

$R^2 = .999;\ n = 7$

f) For 25" Cab: $\widehat{SP} = 84.0399 - .4400\,(KA)$

$R^2 = .998;\ n = 7$

Note that the optimal knee angle ranges for various ranges of foot control forces can be applied to these equations also to define a usable seat pitch.

QUESTIONS ABOUT THE FORMULAS IN THIS SECTION

1. Would it be helpful to know the formulas that give rise to the curves shown in Figures 4, 5, 6 and 7 when designing a cab?

2. Should formulas and figures both be included in the recommended practice? Why or why not?

3. Under what circumstances would you use the formulas?

APPENDIX 2

2. SAFETY ANALYSIS OF ROOFBOLTER OPERATION

The objective of the safety analysis presented below was to give a complete picture of the nature of accidents that occur with roofbolters and to investigate the extent to which accidents are caused by design deficiencies of the roofbolting machine. Several previous studies have been performed of roofbolting accidents. These are summarized in Helander, Elliott, and Krohn, (1981).

For the present study the following data were analyzed: 1. Computer analysis of statistics for roofbolter accidents that occurred through the years 1975-1979. In total, 5,013 accidents were analyzed. 2. Roofbolter fatality reports for the years 1975-1979; there were 43 fatalities. 3. Narrative accident descriptions of 809 roofbolter accidents which accurred from January-September, 1979; 600 of these were analyzed manually.

2.1 Computer Analysis of 5,013 Accidents

The computer analysis researched the MSHA Health and Safety Analysis Center (HSAC) computer files for accidents involving roofbolter machines. The accident data was then sorted with respect to body injury, manufacturer of roofbolting machine, job category, objects inflicting injuries, worker activity at the time of the accident, and the workers job experience in years. A full account of the results is given in Helander, Conway, Elliott, and Curtin (1980).

The analysis produced data that seemed incomplete or inaccurate. For example, the most frequent worker activity during accidents was tramming with 30.6% of the injuries. This result is clearly at odds with the manual (and more accurate) analysis performed by Adkins and Hargraves (1977), who reported 10%. One reason is that safety personnel (in mines and at MSHA) have difficulties reporting subtask activities. This kind of information is certainly more difficult to code than other "matter-of-fact" information such as body part injured and experience at the task. (Often, no subtask is reported at all.) It was therefore decided not to rely on the computer analysis of worker activity but to obtain the information through a manual analysis of the narrative descriptions of the accidents, see 2.3.

2.2 Analysis of Roofbolter Fatalities

HSAC fatality reports are 8 page documents. Since they contain very detailed information, they were considered important to analyze.

During the years 1975-1977, 43 fatalities occurred. The reports were analyzed in order to classify the immediate causes of accidents. The results are shown in Table 2.

Most fatalities occurred as a result of roof and rib falls. These accidents are fairly easy to analyze since, in most cases, there was one primary cause; for example, negligance to install adequate temporary roof support or failure to work under protected roof. The machine related fatalities, however, are more difficult to analyze since the reports rarely provide human factors type information, such as if the operator was confusing controls on the machine or whether the operator had adequate training.

It has often been pointed out that inexperienced workers have more accidents than those with experience (e.g. Theodore Barry and Associates, 1971). Table 3 shows the amount of roofbolting experience at the time of the accidents. Both the accident reports obtained from the computerized HSAC analysis and the fatalities were evaluated. In order to assess the relative risks of accidents as a functional job experience, Adkins and Hargreaves (1977) estimate of operator job experience was used. Although the sample is small (107 workers), it is the most accurate available and was therefore used for calculations of accident involvement as a function of job experience.

As can be seen from Table 3, roofbolter operators with one year of experience or less constituted 19% of the population and incurred 55% of the accidents. The relative risk of accident can be calculated: 55/19 = 2.89. In contrast, roofbolter operators with more than 10 years of

Table 2. Analysis of roof bolter operator fatalities (1976-1979).

Cause of Fatalities	Number of Fatalities
Roof Fall	32
Rib Fall	5
Machine Design Deficiencies	4
Collison	1
Blasting	1
TOTAL	43

Table 3. Relative risk for fatalities and injury as a function of roof bolter operator experience.

Roof Bolting Experience Years	Bendix Sample (N=107) Percent	Analysis of 43 Fatalities		Analysis of 1212 Injuries	
		Percent of Fatalities	Relative Risk For Fatality (Average=1.00)	Percent of Injuries	Relative Risk For Accident (Average=1.00)
1	19	42	2.21	55	2.89
2	20	14	0.70	28	0.90
3	14	12	0.86	8	0.71
4	10	5	0.50	5	0.50
5-6	11	9	0.82	6	0.54
6-8	6	5	0.83	3	0.50
9-10	6	5	0.83	3	0.50
More than 10	14	9	0.64	3	0.21

experience have a relative accident risk of 0.21. Similar results were obtained for fatalities. During the first year on the job, the relative risk was 2.21. After one year of experience the relative risk dropped to 0.70 and remained stable regardless of increasing experience. It is tempting to speculate that .70 represents a fairly constant level of risk imposed by the mining environment (e.g. machine design, work methods, and the amount of calculated risk that experienced miners accept). Similarly, the increased risk of fatalities and injuries for miners with less than one year of experience can be explained by their lack of familiarity of the system, including what kind of behavior constitutes a "reasonable" amount of risk taking.

2.3 Manual Analysis of 600 Roofbolter Accidents

Computer printouts of narrative accident descriptions were obtained from HSAC for the time period January-September 1979. These reports typically contain a 20-30 word description of the accident. In all, there were 809 accident reports; several were incomplete so only 600 were analyzed. An example of the type of information contained is:

> "While roofbolting, the employee pressed the wrong lever, causing bolter to catch left index finger between roof and bolter, severely lacerating left index finger."

In addition, information is also given with respect to model of roofbolter, job experience, days away from work, etc.

The 600 accidents were analyzed in terms of worker activity, suggested cause of accident, machine part involved, and body part injured. The analysis was performed to obtain an overall assessment of the characteristics of the roofbolting accidents. Specifically, information on machine part involved and body injury were sorted with respect to workers subtask. This task oriented approach was considered to have several advantages: 1. It is a logical point of departure for a human factors analysis. The majority of accidents are considered to be "caused" by human errors. It is therefore essential to know what the operator was doing (right or wrong) at the time of the accident. 2. It has instructional value since results be used for training hazard recognition.

Table 4 shows worker activity at the time of the accident, and Table 5, the suggested cause of the accident.

From Table 4, it can be seen that the most hazardous work activities were drilling, tramming, and inserting bolts. In 14.1% of the accidents, "roofbolting" was reported; since no subtask was suggested, these accidents were not further analyzed.

Table 5 shows that rock fall accounts for close to 25% of the number of accidents. This can be compared to the fatalities where rock fall was by far the dominating cause. The next most frequent category was "struck by machine part", which accounted for 17% This category included most of the drill steel accidents. Unintentional control activation was mentioned for 5.3% of the accidents. This number is probably an under estimation (compare Miller and McLellan, 1975), partly due to the fact that the MSHA accident reporting system does not systematically collect information concerning man-machine design problems. Several of the suggested causes might indicated machine design deficiences such as "caught" and "pinch-point" (8.8%); "activating a machine part, resulting in injury to fellow operator" (4.7%); and "caught on or beneath the machine" (11%). Some of these accidents may be eliminated by design improvements.

Finally, the machine parts involved were analyzed. The drill steel was involved in 12.5% of the accident, the boom in 10.2% and the body frame in 9.4%.

The information in Table 6 suggests that there are several hazardous components on roofbolters. Indeed, even design items installed for safety, such as canopies, ATRS systems, drill guides, and dust boxes, were involved in almost as many accidents as the drill steel. It must be recognized that there are several hazardous components on roofbolters and attempts to make the operation safer by installing safety devices might induce substitution accidents. Obviously, there are trade-off implications in most design modifications. The relatively low percentage of drill steel accidents does not support the commonly held belief that everything can be solved simply by implementing hands-off drilling.

Table 4. Worker activities at the time of the accident.
(January-September 1979)

Activities	Number of Injuries	Percent of Total
Drilling hole	106	17.7
Tramming	85	14.1
Roof bolting used as a general descriptor	85	14.1
Inserting bolt	79	13.2
Manually moving equipment	34	5.7
Walking or standing beside machine	24	4.0
Lowering boom, canopy, TRS, or stabjack	24	4.0
Removing drill steel	24	4.0
Positioning boom or canopy	19	3.2
Performing maintenance	16	2.8
Raising boom or canopy	8	1.3
Assembling bolt	6	1.0
Setting or adjusting parts	6	1.0
Loading supplies	5	0.8
Other smaller categories	29	4.8
Unknown activities	50	8.3
Total	600	100.0%

Table 5. Suggested cause of accident (January-September 1979).

Type of Accident	Number of Injuries	Percent of Total
Rock fall on operator	148	24.7
Struck by machine part	101	16.8
Caught on or beneath the machine	66	11.0
Caught in pinch point	53	8.8
Unintentional control activation	32	5.3
Pinched between rib and machine	28	4.7
Activating a machine part resulting in injury to fellow operator	28	4.7
One operator trams into another operator	20	3.3
Lifting or pulling objects	19	3.2
Struck by flying object	16	2.6
Operator strikes roof	12	2.0
Rib cave on operator	10	1.7
Slip and fall while using the machine	7	1.2
Ruptured hydraulics	4	0.7
Other smaller categories of type of accident	36	6.0
Unknown	20	3.3
Total	600	100.0%

Table 6. Object involved in the accident.
(January-September 1979)

Objects	Number of Injuries	Percent of Total
Drill steel	75	12.5
Boom	61	10.2
Body frame	56	9.4
Canopy, drill station	33	5.5
Roof bolt	23	3.8
Drill pot	22	3.7
Wrench	19	3.2
Temporary jacks	17	2.8
Power cable	16	2.7
Canopy, tram station	15	2.5
Roof bolt plate or wood block	15	2.5
Wheels	10	1.7
Drill clamp or guide	10	1.6
TRS	9	1.5
Forward drill controls	8	1.3
Tram controls	8	1.3
Stabjack	6	1.0
Parts tray	4	0.7
Riding board	3	0.5
Dust box	3	0.5
Less frequently involved objects	59	9.8
No machine parts, such as, rock falls (N=106) and rib caves (N=10)	128	21.3
Total	600	100.0%

For the three most frequent worker activities, the "suggested cause" of accident, machine part involved, and body part injured were cross tabulated, see Table 7. This table, then, provides an overall picture of the complex causes of roofbolting accidents.

There are clear differences in accident causes for the three major subtasks; different parts of the machine are involved and different parts of the body are injured. Under such circumstances, it seems ill-advised that accident prevention measures by MSHA and mine operators should concentrate on two issues (roof fall and drill steel accidents). The cross tabulation in Table 7 suggests that a systematic approach to roofbolter accidents must be taken and investments in accident prevention should address all the different parts of the system. Cost-benefit ratings should then be established for various countermeasures. There are likely to be many solutions to the different hazards; criticality and cost should be considered before one is chosen.

Table 7. Accident analysis of most hazardous roof bolting tasks. Analysis of 600 accidents - 1979

Task	Accident Profile					
Drilling 106 accidents 17.7% of sample	Suggested Cause (Percent)		Machine Part Involved in the Accident (Percent)		Part of Body Injured (Percent)	
	Struck by machine Part	31%	Drill steel	46%	Fingers	25%
	Rockfall	28%	Canopy (drill station	5%	Arm	18%
	Caught on or beneath machine	11%	Drill pot	5%	Hand	12%
	Pinch point	9%	Body frame	4%	Wrist	9%
	Less frequent categories	21%	Wrench	3%	Shoulder	5%
			Less frequent categories	37%	Multiple	5%
					Head	4%
					Eye	4%
					Less Frequent	18%
Tramming 85 accidents 14.1% of sample	Suggested Cause (Percent)		Machine Part Involved in the Accident (Percent)		Part of Body Injured (Percent)	
	Pinched against rib	25%	Body frame (general)	36%	Foot	22%
	Caught on or beneath machine	18%	Canopy (tram station)	11%	Fingers	13%
	Rockfall	14%	Boom	7%	Knees	10%
	Struck by machine part	12%	Tram controls	7%	Back	7%
	Unintentional control activation	10%	Temporary jacks	5%	Ankle	7%
	Less frequent categories	21%	Canopy (drill station)	5%	Multiple	6%
			Less frequent categories	30%	Lower leg	6%
					Hip	5%
					Less frequent categories	24%
Inserting bolt 79 accidents 13.2% of sample	Suggested Cause (Percent)		Machine Part Involved in the Accident (Percent)		Part of Body Injured (Percent)	
	Pinch point	25%	Roof bolt	22%	Fingers	28%
	Struck by machine part	21%	No machine parts involved	17%	Hand	13%
	Rockfall	19%	Roof bolt plate or wood block	15%	Head	9%
	Caught on or beneath machine	10%	Wrench	11%	Foot	8%
	Struck by flying objects	5%	Canopy (drill station)	8%	Arm	6%
	Unintentional control activation	4%	Drill pot	5%	Back	6%
	Less frequent categories	16%	Less frequent categories	22%	Multiple	5%
					Wrist	4%
					Less frequent categories	21%

APPENDIX 3

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10 March 1981

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Warrendale, PA 15096

ATTN: Robert C. Uhl, Staff Engineer
Contract HO 308110

Subj: Quarterly Technical Report No. 1

Dear Mr. Uhl:

This letter is submitted in response to the contractural requirements for a Quarterly Technical Report, Article II, Item C, and covers the period from 1 November 1980 to 28 February 1981.

Reporting Period Activities

During the reporting period, McDonald & Associates personnel attended SAE committee meetings, contacted manufacturers concerning the program, established an advisory committee, visited an equipment manufacturer, conducted a literature search, developed an initial task analysis, and selected baseline anthropometric data. Each of these tasks is discussed separately below.

SAE Committee Meetings

Thus far we have attended three meetings. In the kickoff meeting we established the scope and schedule of the program. McDonald & Associates was assigned to work on the cutter, loader and face drill. The second meeting was with SAE Subcommittee 29 to discuss the program and receive feedback. The third meeting was to review progress and discuss problems with other Working Group members.

Contacting Manufacturers

We contacted a number of manufacturers to alert them to our plans and solicit their comments and inputs. Companies were selected from an MSHA list of manufacturers, Coal Age Buyers' Guide and Thomas Register. The letter in Appendix A was sent to the following manufacturers:

Anderson Mavor	Dowty Corp.
ELMAC Corp.	ESCO Corp.
Goodman Equip. Co.	Ingersoll-Rand Co.
Joy Mfg. Co.	Mescher Mfg. Co.
Paurat GmbH	Tidewater Supply Co.
Victulic Co. of America	Voest-Alpine Intl. Corp.
Wachs, E.H. Co	Westfalia Lunen

Atlas Copco MCT AB	Dresser Industries
FMC Corp.	Mining Development LTD.
Schroeder Mining	Mining Equip. Mfg. Corp.
Torque Tension LTD	Turman (G.B.) LTD
Victor Products	AEC Inc.
British Coal Int'l	British Jeffrey Diamond
Clark Equipment Co.	Curry Mfg. Corp.
Eickhoff America Corp.	Eimco Elkhorn
Eimco Mining Machinery	Fairchild Inc.
J.H. Fletcher & Co.	Herold Mfg. Inc.
Lake Shore Inc.	Long-Airdox Const. Co.
M.A.N. Division	Mining Dev. LTD
Myers Whaley Co.	North Amer. Galis Co.
Owens Mfg. Co.	Dooley Bros.
Epling Mfg. Co. Inc.	Royal Machine Works, Inc.
Sullivan Trail Mfg. Co.	Paul's Repair Shop Inc.
S&S Corp.	Tread Corp.

Establishing An Advisory Group

After sending out the letters, we telephoned all of the major manufacturers of cutters, loaders and face drills to recruit an advisory panel for reviewing our work before submittal to SAE Subcommittee 29. The following individuals have agreed to be on our advisory panel:

Prescott Greene
Chief Product Engineer
Joy Manufacturing Co.
325 Buffalo Street
Franklin, PA 16323

Walter Silks
Design Engineer
Goodman Mining Machinery Co.
4834 South Halsted St.
Chicago, Illinois 60609

William Cobb
Schroeder Brothers Corp.
Nichols Ave.
Box 72
McKees Rocks, PA 15136

Butch Riffe
Design Engineer
Long-Airdox Company
P.O. Box 331
Oak Hill, WV 25901

Willard J. Sickles II
Design Engineer
Acker Drill Co. Inc.
P.O. Box 830
Scranton, PA 18501

McDonald & Associates Inc.
999 Woodcock Road • Suite 103 • Orlando, Florida • 32803 (305) 896-8539

14 November 1980

RE: SAE Recommended Practices On Mining Equipment

Dear Sir:

The Society of Automotive Engineers is currently developing recommended practices for the design of operator stations on self-propelled underground coal mining equipment. Responsibility for development of the recommended practices has been assigned to ORMTC Subcommittee 29, Working Group 3 on Human Factors.

I have responsibility for developing draft recommendations on Face Drills, Undercutters, and Loaders used in conventional underground coal mining. Your company is listed in the Coal Age Buyer's Guide under one of these three headings. If you have an interest in the development of these recommended practices, please contact me as soon as possible. If I have already contacted someone in your engineering staff by telephone, please disregard this letter.

Respectfully yours,

L. Bruce McDonald, Ph. D.
President

LBM/cw

cc: Bill Holopoff
John Dahle
Bob Uhl

APPENDIX 4

OPERATOR'S COMPARTMENTS FOR UNDERGROUND CONTINUOUS MINERS

SAE Recommended Practice

1. PURPOSE

This SAE Recommended Practice has been developed by the Bendix Corporation for Working Group 3 of Subcommittee 29 of the Off-Road Machinery Technical Committee under funding provided by the U.S. Bureau of Mines Contract No. H0308110 titled "Development of SAE Guidelines for Underground Operator Compartments". The objective of this contract was to develop recommended practices applicable to general performance and design specifications related to the human engineering needs of operator stations of ten different pieces of electrically powered underground coal mining equipment including: continuous miners, scoops, roof drills, personnel carriers, loaders, cutting machines, face drills, shuttle cars, utility tractors, and locomotives. The SAE Recommended Practice forms a portion of this contract effort. It is intended as a guide toward standard practice but may be subject to frequent change to keep pace with experience and technical advances.

This recommended practice is a guide to provide human factors design parameters for electrically powered underground continuous miners so that the operator workspace on such machinery may be designed to uniformly comply with accepted standards and practices of the human factors profession.

2. SCOPE

This recommended practice applies to all electrically powered underground continuous mining machines having rotating drum cutting heads. Most of the recommended design practices presented in this document are also applicable to other types of underground continuous miners and may be applied to provide compatability between machine types. This recommended practice includes guidelines for:

* control/display selection and location
* seat design
* visibility requirements
* operator protection
* workstation dimensioning and layout

3. DEFINITIONS

3.1 Anthropometric Definitions

3.1.1 Cap Clearance - The space allowance between the top of the miner's cap and the lower surface of the canopy over his workspace. According to SAE J833 Jan80 this allowance should be at least 2 in. (50 mm) in height. More allowance may be desirable in machinery that is likely to encounter vertical vibration such as that generated by movement at relatively high speeds over rough ground and/or where restraints such as seat belts are not available.

3.1.2 Critical Link - A link dimension upon which elements of a design are based. The number of critical links used to define a particular design should be limited to three or less because each successive link restriction tends to reduce the size of the population that could be accommodated by the design.

3.1.3 Eye Reference Point - A point located on the bridge of the nose and centered between the eyes.

3.1.4 Foot-Lower Leg Angle - The angle between the knee-ankle link and the plane of the bottom of the foot.

3.1.5 Functional Grip - The link distance from the shoulder pivot point to the palm of the hand.

3.1.6 Functional Reach - The link distance between the shoulder pivot point with the shoulder relaxed and the tips of the outstretched fingers.

3.1.7 Functional Reach Extended - The functional reach with the shoulder pivot extended as far forward as possible.

3.1.8 Knee Angle - The angle between the knee-ankle link and the hip-knee link.

3.1.9 Link Points - Points representing the pivot points of the movable joints of the body. The distance between link points are the measurements used to establish design configurations and pivot requirements.

3.1.10 Manikin - A two-dimensional, articulating representation of one view of a human being of known size (percentile) relative to a particular population. Used on a drawing board as a design aid to establish workspace dimensions and link points. For the purposes of this document, two side-view manikins are used: a 5th percentile female manikin having 1st percentile limbs and a 95th percentile male manikin having 99th percentile limbs.

3.1.11 Maximum Grip - The distance at which an operator can grip and operate a control with the shoulder and arm extended to its most forward position.

3.1.12 Maximum Hand and Foot Control Space - An acceptable space reserved for less frequently operated controls which are not needed quickly in emergency situations (from SAE J898 APR80).

3.1.13 Minimum Grip - The closest distance at which an operator can grip and operate a control.

3.1.14 Normal Grip - The distance at which an operator can grip and operate a control without extending the shoulder.

3.1.15 Optimal Foot Control Space - The space where foot controls can be reached most quickly and accurately, and with greatest application of force. This space is considered most desirable (from SAE J898 APR80).

3.1.16 Optimal Hand Control Space - The space where hand controls can be reached most quickly and accurately, and with greatest application of force. This space is considered most desirable (from SAE J898 APR80). The dimensional limits common to both design precentiles and bounded by the areas shown in Figure 1.

3.1.17 Percentile - A number expressed as a percentage (%) which represents the percentage of the population that is equal to or smaller than the dimensions given.

3.1.18 Visual Angle - The angle of a visual target's position relative to a standard horizontal line of sight.

3.2 Control Definitions

3.2.1 Controls - Any mechanism or device used to affect a machine in operation.

3.2.2 Control Forces - The amount of force required to actuate a control.

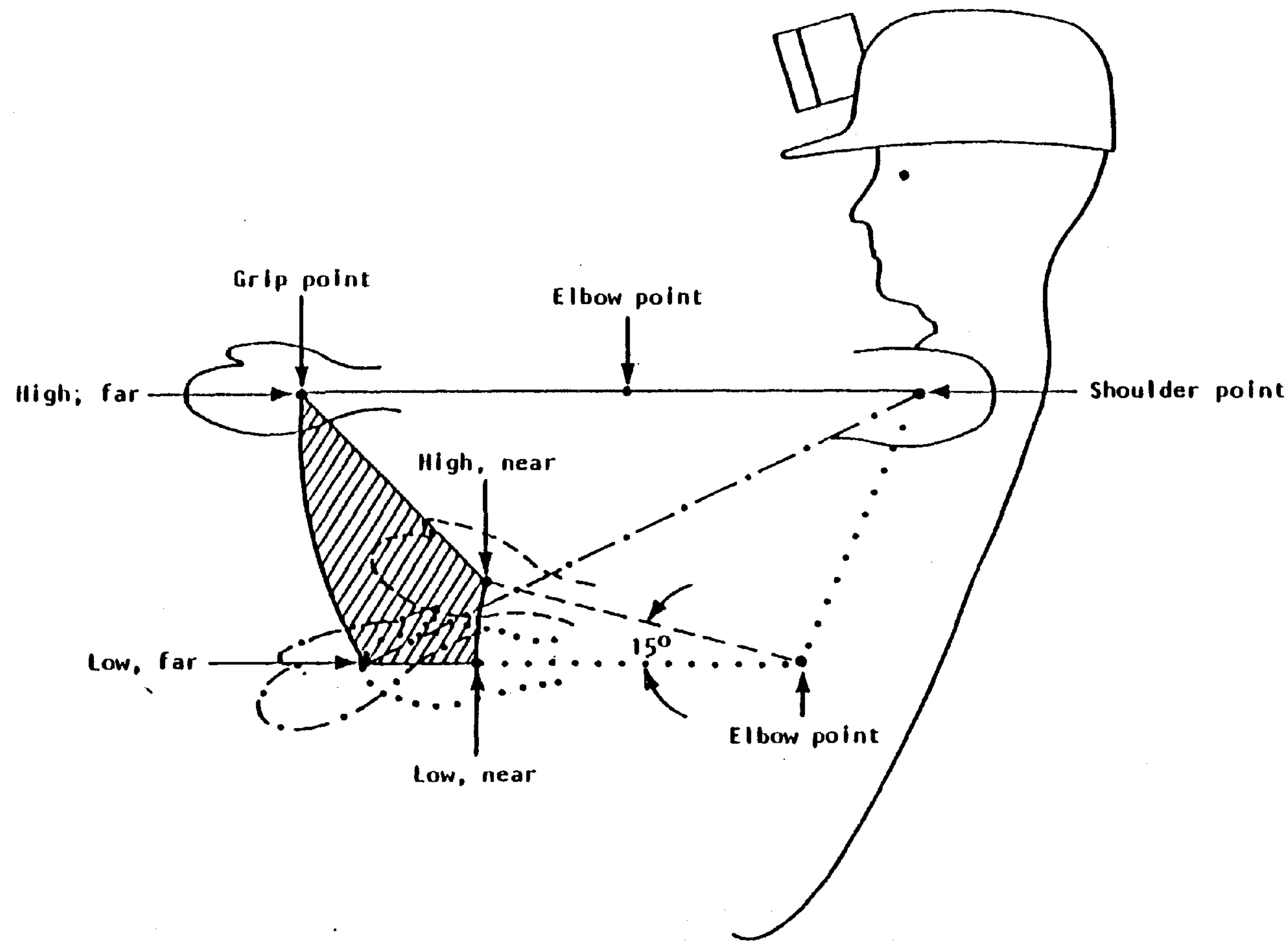


Figure 1. Optional Hand Control Space (Derived from Morgan, Cook, Chapanis, & Lund (1963))

3.2.3 Primary Controls - The most frequently used or critical controls for safety which should be located in the operator's optimal hand or foot control area.

3.2.4 Secondary Controls - Less frequently used controls which should be located in the optimal hand or foot control area whenever possible or otherwise immediately adjacent to this area.

3.2.5 Tertiary Controls - Infrequently used controls that need not be located in or immediately adjacent to the optimal manual control area.

3.3 Display Definitions

3.3.1 Displays - Any mechanism or device that provides the operator with information about the status of the machine, its controls, or its parts. May be visual or auditory.

3.3.2 Primary Displays - Those displays which are most frequently used or which provide critical information related to the safety of the operator or machine. These displays should be located within 30 degrees of normal line of sight. Use of these displays should not require excessive movement of the operator's head or eyes from normal line of sight. (Van Cott and Kinkade, 1972)

3.3.3 Secondary Display - These are frequently used operational displays. Use of these displays may require eye movement from the normal line of sight, but not head movement. (Van Cott and Kinkade, 1972)

3.3.4 Tertiary Displays - These are infrequently used displays such as console power indicators and maintenance displays. Use of thse displays may require operator head movement from normal line of sight. (Van Cott and Kinkade, 1972)

3.4 Workstation Envelope Definitions

3.4.1 Cab - For the purposes of this document, the word "cab" will be considered to be synoymous with "workspace".

3.4.2 Cab Floor - The upper surface of the bottom structure of the operator's workspace.

3.4.3 Canopy - The overhead protective structure covering a mining machine workspace that shields the occupant from falls of objects from the roof of the mine.

3.4.4 Interior Workspace Height - The distance between the cab floor and the lower surface of the canopy.

3.4.5 Interior Workspace Length - The distance between the inside surfaces of the front (foot-most) and rear (head-most) walls or controls defining the longitudinal limits of the operator's workspace.

3.4.6 Interior Workspace Width - The distance between the inside surfaces of the walls, doors, or controls defining the lateral limits of the operator's workspace.

3.4.7 Seat Backrest - The surface of the seat which supports the operator's back.

3.4.8 Seat Headrest - The surface of the seat which supports the operator's head or neck.

3.4.9 Seat Pan - The nearly horizontal surface of the seat upon which the operator sits.

3.4.10 Seat Pitch Angle - The angle between the plane of the seat pan and the plane of the workspace floor.

3.4.11 Seat Reference Point (SRP) - The point where the middle lines of the seat pan and backrest intersect (undeflected cushion). The approximate location of the SRP is 4.0 in. (102 mm) to the rear and 2.2 in. (56 mm) lower than the H-point (adopted from SAE J898 APR80).

3.4.12 Workspace - The total volume of space used by the operator as he controls the machine.

4. OPERATOR WORKSTATION GUIDELINES

4.1 Control and Display Recommended Practice - The control and display Recommended Practice is incorporated into the Workspace Layout Recommended Practice presented in Section 4.5.2. Design of the controls, displays, and workspace is highly interactive. The choice of components or features in one area significantly affects the choices in every other area. It is therefore recommended that layout of the workspace be planned as a unit following the guidelines presented in Section 4.5.2.

4.2 Seat Design Recommended Practice

4.2.1 The operator's seat should be constructed in such a way as to properly support the operator's body and head in any expected operating position or workspace height. Figure 2 shows the recommended geometry for an anthropometrically-adjustable mining machine seat suitable for use in interior workspace heights from 42 inches (fully upright) to less than 26 inches (fully reclined). Table 1 specifies critical seat characteristics for the recommended seat shown in the Figure. Positioning of the seat within the operators workspace is closely related to the recommended practice presented in Section 4.3 "Visibility Recommended Practice".

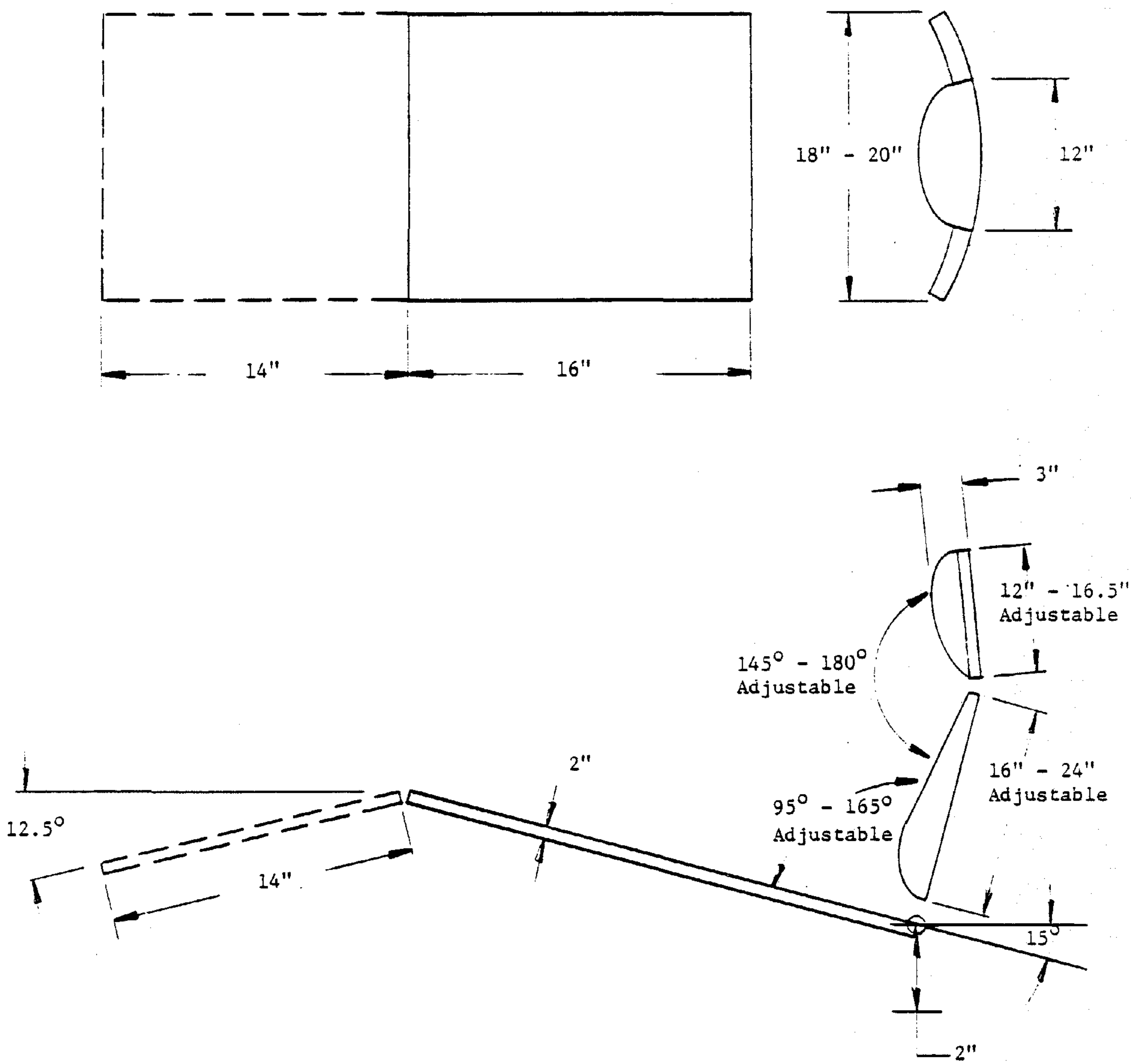


Figure 2. Recommended Operator's Seat Configuration

Table 1. Design Requirements for a Mining Machine Operator's Seat

SEAT PART	FEATURE	RECOMMENDED VALUE OR CHARACTERISTIC	REFERENCE
Headrest	Width	At Least 12 inches	Ayoub, Deivanayagam, & Kennedy (1977)
	Length	12 to 16.5 inches (adjustable)	Hartley, Cooksey, & Kwitowski (1982)
	Thickness	3 inches at point of maximum thickness	
	Angle	145° - 180° relative to backrest	
Backrest	Length	16 - 24 inches (adjustable)	Kramer (1971); Hartley, Cooksey, & Kwitowski (1982)
	Width (top)	20 inches	Croney (1971)
	Width (base)	18 inches (same as seat pan)	(same width as seat pan)
	Upholstery	Slight concave contouring desirable for lateral support	Kraemer (1971)
	Upholstery	Lumbar support desireable	Kraemer (1971)
	Angle	95° - 165° relative to seat pan (adjustable)	Hartley, Cooksey, & Kwitowski (1982)
Seat Pan	Width	18 inches	Woodson and Canover (1964)
	Depth (fore-aft)	16 inches	VanCott & Kinkade (1972)
	Pitch	15° rise forward from Seat Reference Point (SRP)	Le Carpentier (1969); Hartley, Cooksey & Kwitowski (1982)
	Upholstery	Max. Compression = 1 inch	Ayoub (1971)
	Upholstery	Permit sweat dissipation	
	Upholstery	Flat surface	Kroemer (1971)
	Upholstery	1 inch radius front if leg rest not used	
	Fore-Aft Adjustment	8 inches to 21 inches depending on workspace height	
	Seat Reference Point (SRP)	Within 2 inches of floor	
Leg Support (Optional)	Width	Same as seat pan	
	Length	14 inches	Hartley, Cooksey, & Kwitowski (1982)
	Angle	-12.5° relative to seat pan surface	Hartley, Cooksey, & Kwitowski (1982)

4.2.2 The backrest and seat pan should be shaped anatomically and should provide adeuqate support to the lower back. A lumbar support should be provided consisting of a pad 6" to 9" from top to bottom with the center of the forward lumbar curvature 9" to 10" above the compressed seat cushion. Seats in continuous miners should also offer adequate lateral support (in the form of a slightly concave seat back) against jerks, heavy swaying, or shocks while tramming; and the shock absorbing qualities of the seat should be suitable for accommodating operators ranging in weight from 104 lbs (5th percentile female) to 224 lbs. (95th percentile male).

4.2.3 Machine having workspaces less than 42 inches high should be equipped with seats with pans inclining backwards at an angle of at least 15° so that the operator is restrained from sliding forward as the seat is reclined. Seats used in higher workspaces may have fixed pitches of 10° to 20°. The angle between the backrest and the seat pan should be adjustable in order to accommodate the operator throughout the entire range of expected workspace heights. In the case of low-coal applications, this range should be from 95° to 165°.

4.2.4 All seat adjustment levers, knobs, or buttons should be within hand's reach by 5th percentile female and 95th percentile male operators, should not block ingress or egress, and should not pose impact hazards in the event the operator is thrown from his seat by unexpected machine motions. All adjustment operations should be quick and should not require great force or the use of tools. The adjustments should lock in all positions and should be spring loaded, where necessary, to assist the operator in moving forward to a more upright position.

4.2.5 If the seat back reclines more than 30° from vertical it should be equipped with a headrest that adjusts in both length (4 inches) and angle (145° to 180°) relative to the backrest so that operator eye height can be maintained. The headrest should be at least 12 inches wide and should conform to the dimensions and configuration shown in Figure 2.

4.3 Visibility Recommended Practice

4.3.1 The continuous miner operator should have clear and unimpeded vision of all required visibility locations. These locations are shown schematically in Figure 3, and are listed and described in Table 2. Additional recommended visibility locations are included. The cutterhead and tail boom are in a lowered horizontal profile. Priority designations correspond to criticality of feedback elements contributing to safe and efficient operation.

4.3.2 The operator should have clear and unimpeded vision of each location at the designated height. It is recommended that, at each location, the operator be able to see all heights above the lowest specified height with minimal interference from machine parts.

4.3.3 Eye reference points for 5th percentile female through 95th percentile male operators should be used in assessing visibility of the locations listed in Table 2.

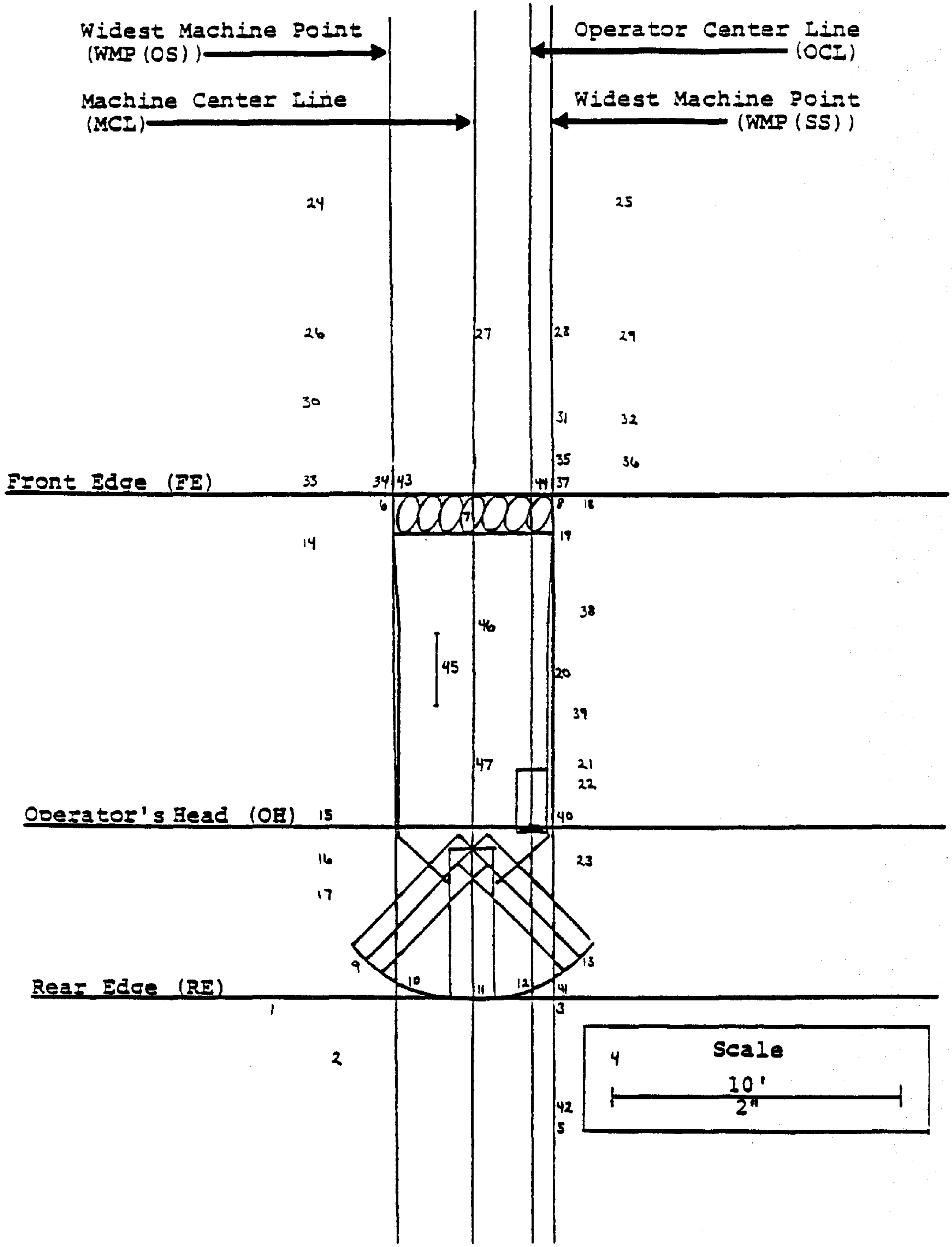


Figure 3. Recommended Visual Attention Locations for Continuous Miner Operation

Table 2. Recommended Visual Attention Locations for Continuous Miner Operation

NUMBER	AREA	PRIORITY	STATUS	HEIGHT	LOCATION
1	Rearward	Primary	Required	Median Machine	7.5' external to opposite side of machine at boom rear edge
2	Rearward	Primary	Required	Operator Eye	5' external to opposite side of machine and 5' behind boom rear edge
3	Rearward	Primary	Required	Floor	Aligned with cab side wides machine point at boom rear edge
4	Rearward	Primary	Required	Operator Eye	5' external to cab side widest machine point and 5' behind boom rear edge
5	Rearward	Primary	Required	Floor	Aligned with cab side widest machine point and 10' behind boom rear edge
6	Cutterhead	Primary	Required	Top of machine part through entire range of motion	End of opposite side of machine part
7	Cutterhead	Primary	Recommended	Top of machine part through entire range of motion.	Midpoint along machine par
8	Cutterhead	Primary	Required	Top of machine part through entire range of motion	End of cab side of machine part
9	Tail Boom	Secondary	Required	Median machine height to highest boom position	Boom extended fully outwar from center line toward opposite side of machine
10	Tail Boom	Secondary	Recommended	Median machine height to highest boom position	Boom extended halfway outward from center line towa opposite side of machine
11	Tail Boom	Secondary	Required	Median machine height to highest boom position	Boom straight with the center line

Table 2. Recommended Visual Attention Locations for Continuous Miner Operation (Continued)

NUMBER	AREA	PRIORITY	STATUS	HEIGHT	LOCATION
12	Tail Boom	Secondary	Recommended	Median machine height to highest boom position	Boom estended halfway outward from center line toward opposite side of machine
13	Tail Boom	Secondary	Required	Median machine height to highest boom position	Boom extended fully outward from center line toward operator side of machine
14	Left Side	Secondary	Required	Operator Eye	2.5' external to opposite side from the operator's head
15	Left Side	Secondary	Required	Operator Eye	2.5' external to opposite side from the operator's head
16	Left Side	Secondary	Required	Operator Eye	2.5' external to opposite side from boom pivot point
17	Left Side	Secondary	Required	Operator Eye	2.5' external to opposite side and 2.5' behind operator's head
18	Right Side	Secondary	Required	Floor	1.25' external to operator's side of machine from front edge of cutterhead
19	Right Side	Secondary	Required	Floor	1.25" external to operator's side of machine from rear edge of cutterhead
20	Right Side	Secondary	Required	Median Machine	Midpoint between operator and cutterhead on operator's side
21	Right Side	Secondary	Required	Floor	1' external to operator's side of machine and 1' forward from front of cab
22	Right Side	Secondary	Required	Floor	1' external to operator's side of machine from inside edge of front of cab
23	Right Side	Secondary	Required	Floor	1' external to operator's side of machine and 1' back from the operator's head

Table 2. Recommended Visual Attention Locations for Continuous Miner Operation (Continued)

NUMBER	AREA	PRIORITY	STATUS	HEIGHT	LOCATION
24	Forward	Secondary	Required	Operator Eye	2.5' external to opposite side of machine and 10' forward from front edge of cutterhead
25	Forward	Secondary	Required	Operator Eye	2.5' external to operator's side of machine and 10' forward from front edge of cutterhead
26	Forward	Secondary	Required	Operator Eye	2.5' external to opposite side of machine and 5' forward from front edge of cutterhead
27	Forward	Secondary	Required	Operator Eye	5' forward from front edge of cutterhead aligned on machine center line
28	Forward	Secondary	Required	Floor	5' forward from front edge of cutterhead and within 5' external to operator's side of machine
29	Forward	Secondary	Required	Floor	2.5' external to operator's side of machine and 5' forward from front edge of cutterhead
30	Forward	Secondary	Required	Operator Eye	2.5' external to opposite side of machine and 2.5' forward from front edge of cutterhead
31	Forward	Secondary	Required	Floor	2.5' forward from front edg of cutterhead and within .5 external to operator's side of machine
32	Forward	Secondary	Required	Floor	2.5' external to operator's side of machine and 2.5' forward from front edge of cutterhead
33	Forward	Secondary	Required	Operator Eye	2.5' external to opposite side of machine from the front edge of the cutterhea

Table 2. Recommended Visual Attention Locations for Continuous Miner Operation (Concluded)

NUMBER	AREA	PRIORITY	STATUS	HEIGHT	LOCATION
34	Forward	Secondary	Required	Operator Eye	Corner of front edge of cutterhead and opposite side of machine
35	Forward	Secondary	Required	Floor	.5' external to operator's side of machine and .5' forward of front edge of cutterhead
36	Forward	Secondary	Required	Floor	1' forward of front edge of cutterhead and within .5' external to operator's side of machine
37	Forward	Secondary	Required	Floor	At front edge of cutterhead and within .5' external to operator's side of machine
38	Cable	Secondary	Required	Floor	Front edge of track on operator's side of machine
39	Cable	Secondary	Recommended	Floor	Rear edge of track on operator's side of machine
40	Cable	Secondary	Required	Floor	Edge of machine at operator' cab
41	Cable	Secondary	Recommended	Floor	Rear edge of tail boom from operator's side of machine
42	Cable	Secondary	Required	Floor	10' back from cab on operator's side of macnine
43	Gathering Head	Tertiary	Required	Operator Eye	Farthest point of gathering head extension on opposite side of machine
44	Gathering Head	Tertiary	Required	Floor	Farthest point of gathering head extension on operator's side of machine
45	Roof	Tertiary	Required	Seam Height	Along center line of machine halfway between operator and rear edge of cutteredge
46	Conveyor	Tertiary	Recommended	Conveyor Height	Within 3-5' of rear edge of cutterhead
47	Conveyor	Tertiary	Required	Conveyor Height	At front edge of operator's cab

4.3.4 Evaluation procedures detailed in SAE XJ 1296 "Recommended Practice, Human Factors Guidelines for Shuttle Cars" should be used in assessing the visibility of required and recommended visibility locations. Two techniques are described either of which validly evaluate the extent to which the operator has a clear and unimpeded view of each visibility location.

4.3.5 Extreme fore-aft visibility locations shown in Figure 3 are based on a maximum tram speed of 2.5 mph which has an emergency stopping distance of 10 feet. For machines with faster tram speeds these locations must be extended outwards from the machine to provide adequate braking distances. These distances are shown in Table 3, based on SAE XJ 1329 "Minimum Performance Criteria for Braking Systems for Rubber-Tired Self-Propelled Underground Mining Machines."

4.4 Operator Protection Recommended Practice

4.4.1 Emergency Escape

4.4.1.1 At least one emergency escape route other than normal cab entry/exit should be provided so that escape from the cab is possible even if the main entry is totally blocked.

4.4.1.2 The preferred location of the emergency escape opening is toward the rear of the continuous miner.

Table 3. Necessary Stopping Distances (Based On SAE XJ 1329)

MAXIMUM TRAM SPEED (mph)	REACTION TIME DISTANCE (ft)*	+ BRAKING DISTANCE (ft)**	NECESSARY STOPPING DISTANCE (ft)***
1	3.0	0.7	10.0
2	6.0	1.4	10.0
2.5	7.0	1.8	10.0
3	9.0	2.3	11.0
4	12.0	3.4	15.0
5	15.0	4.7	20.0
6	18.0	6.1	24.0
7	21.0	7.7	29.0
8	23.0	9.5	33.0
9	26.0	11.4	37.0
10	29.0	13.5	43.0

NOTE: * Assumes 2 second reaction time.

** From SAE Subcommittee 29, Working Group 8: Brake Standards for Underground Machines.

*** Values rounded off to nearest whole number. Values less than 10 ft. are assigned a value of 10 ft.

4.4.1.3 The escape opening should have as minimum dimensions those shown in Figure 4 but these dimensions should be enlarged as required to insure emergency egress is possible by a 95th percentile male operator starting his escape from a normal seated position and assuming that the normal entry/exit is totally blocked.

4.4.1.4 The emergency opening should be provided with suitable hand and/or foot holds to facilitate escape by both 5th percentile female and 95th percentile male operators from a normal seated operating position.

4.4.1.5 When a movable door or hatch is provided for the emergency exit it should be possible to open that door or hatch with a single motion of the hand or foot. When a handle is used to open the latch, the required activation force should not exceed 30 pounds. If the operator is required to move some surface or control in order to effect his escape, it should be possible for a 5th percentile female or a 95th percentile male operator to perform that motion with the required strength given the operator's expected escape posture or body position.

4.4.2 Protective Safety Structures

4.4.2.1 An operator's compartment, which includes a deck for the operator to ride on the miner, should be provided when there are machine-mounted controls for operating the machine.

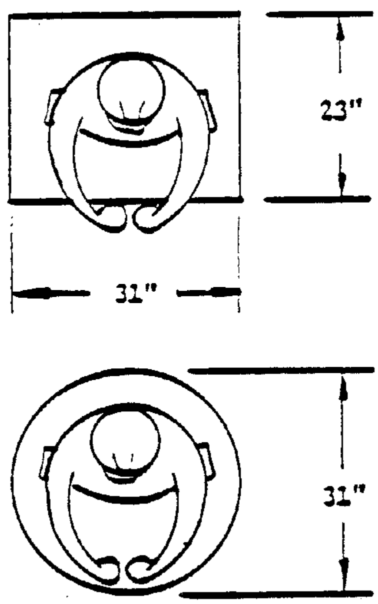


Figure 4. Minimum Dimensions for Emergency Escape Openings (From Diffrient, Tilley, and Harman, 1981)

4.4.2.2 The operator's compartment should have a canopy as required in Section 75.1710-1, Title 30 of the Code of Federal Regulations.

4.4.2.3 The operator's compartment should be designed so that no part of the operator's body is required to be exposed outside the protective dimensions of the compartment-canopy module during normal operations of the machine, such as the operator reaching for controls or repositioning to obtain vision and visual cues.

4.4.2.4 The floor of the operator's cab and the canopy must both be extended beyond the side of the machine frame a minimum of ten inches to protect the operator if he/she is required to lean out to see well enough to perform normal machine operations such as tramming, cutting, loading, or maneuvering the machine.

4.4.3 Noise

4.4.3.1 Noise levels in the operators cab of the continuous miner should be determined following precedures set forth in applicable federal regulations (CFR 30, Part 70, Subpart F - Noise Standard).

4.4.3.2 Results of the cab noise level evaluation tests along with expected exposure rates should be compared with values shown in Table 4.

Table 4. Permissible Noise Exposure Levels Over Time (dBA)*

Duration per Day (Hours)	Noise Level (dBA)
8	90
6	92
4	95
3	97
2	100
1 1/2	102
1	105
3/4	107
1/2	110
1/4 or less	115

* From Code of Federal Regulations Title 30, Section 70.510

In cases where the permissible noise exposure level is exceeded, every effort should be made to attenuate the cab noise to acceptable levels while still conforming to the other guidelines of this recommended practice, especially visibility.

4.4.3.3 If the sound level in the operator's cab cannot be reduced to less than 100 dBA (the permissible two-hour exposure level) while the continuous miner is engaged in its normal production task (cutting, loading, or cutting and loading simultaneously) a sign should be placed in the secondary visual area of the operator's cab warning the operator that noise levels in the cab exceed accepted exposure standards and hearing protection is recommended. This sign should be printed in plain, capital letters at least ½" high and should say:

WARNING! LOUD NOISE.

USE EAR PROTECTION

WHILE CUTTING AND/OR LOADING.

4.4.4 Operator Seat Restraint

4.4.4.1 The operator seat should be designed to provide adequate body support to aid the user in maintaining his position while the machine is in motion.

4.4.4.2 The operator seat should be positioned in the cab in a location that maximizes outside visibility so that the operator is not required to leave his seat in order to safely and efficiently operate the machine.

4.4.4.3 The seat should be positioned in order to reduce the likelihood that the user will impact controls, canopy, or other machine components when subjected to normal machine motions.

4.4.4.4 The seat should be provided with a lap belt that is securely attached to the cab structure. This belt should be easily adjustable and should have a quick release buckle to facilitate operator emergency egress.

4.5 Total Operator Envelope

4.5.1 Workspace Dimensioning Recommended Practice

4.5.1.1 Workspace dimensions should be selected on the basis of the minimum expected operational interior workspace height, and should be large enough to accommodate 95th percentile male operators. The graph in Figure 5 should be used to determine the interior cab length requirements for a planned interior cab height for a given anthropometric range of operators.

4.5.1.2 The assumptions used in constructing the graph in Figure 5 were seat pitch of 10 degrees; seat pan depth of 16 inches; seat reference point 1 inch above cab floor; angle between foot and lower leg of 95 degrees; operator's head

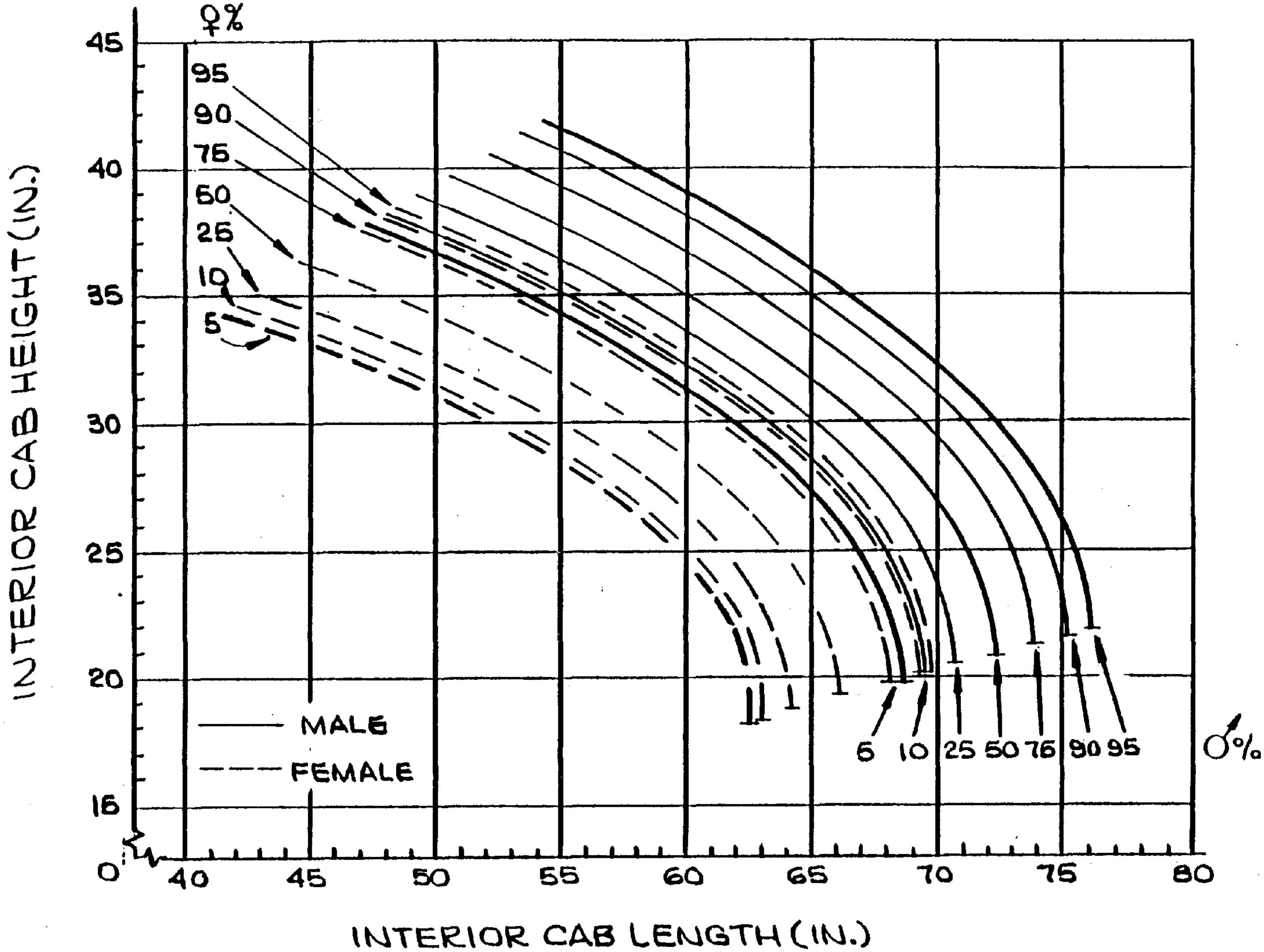


Figure 5. Predictive Equation Lines

in constant contact with rear cab wall; and, clearance of 2 inches between canopy underside and operator's mining cap (or cap lamp). These assumptions are generally applicable to most cabs, however, if they are significantly violated by design considerations the cab dimensions should be established through special anthropometric studies using 2-D manikins or mockup evaluations.

4.5.1.3 If the operator's seat is sprung or damped against vertical shocks and vibration, the height measurements of the operator's body from the upper sprung position of the seat plus at least 2 inches of cap clearance should be considered when determining the required degree of inclination of the seat and resulting cab length requirements.

4.5.1.4 Knee angle should be considered in determining interior cab length when foot controls requiring various forces are used. Figure 6 identifies these relationships for two foot angles. For foot controls requiring strong forces (over 100 lbs), a larger knee angle of at least 135 degrees should be used.

4.5.1.5 Seat pitch may be varied in accordance with interior cab length. Figure 7 may be used to determine seat pitch with planned cab length for certain interior cab heights. In general, a fixed seat pitch of 15^{o} is recommended.

4.5.1.6 Seat pitch should be varied to insure proper knee angles for given foot pedal force requirements. Figure 8 should be used to determine seat pitch for planned interior cab height and foot control force.

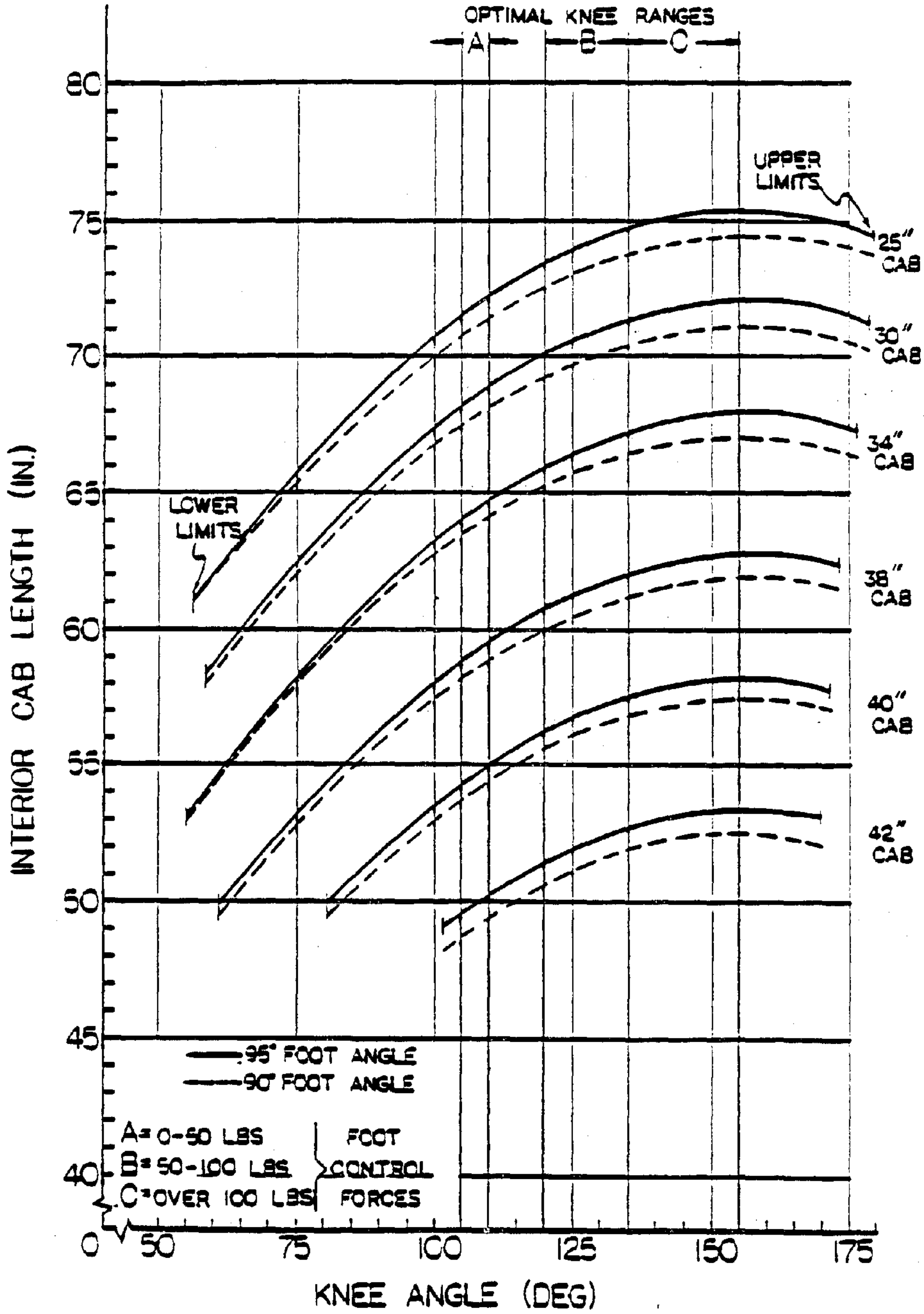


Figure 6. Prediction lines for altering interior cab length by changing knee angles and foot angles in various interior cab heights (assuming 2" cap clearance).

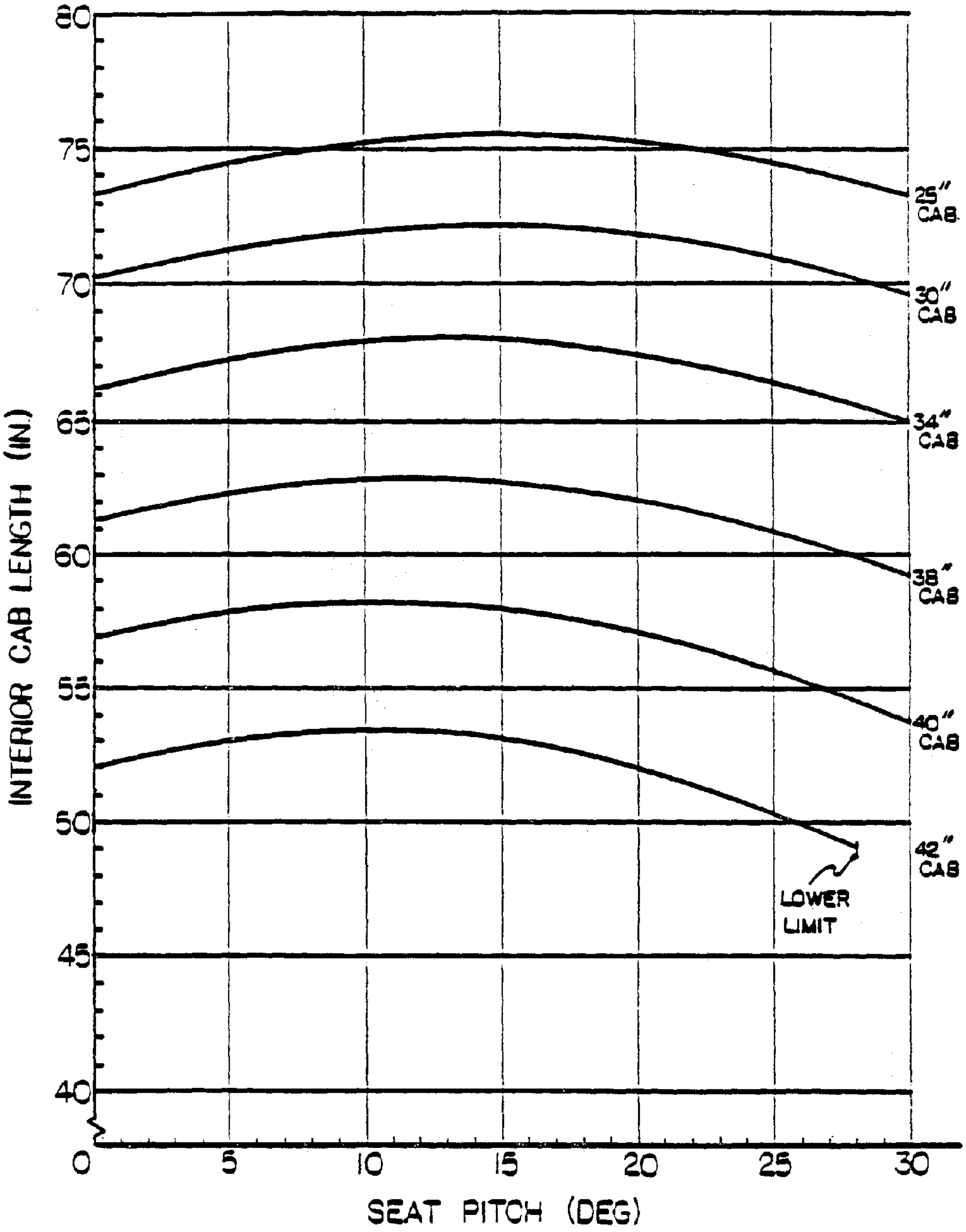


Figure 7. Prediction lines for altering interior cab length by changing the seat pitch for various interior cab heights (assuming 2" cap clearance).

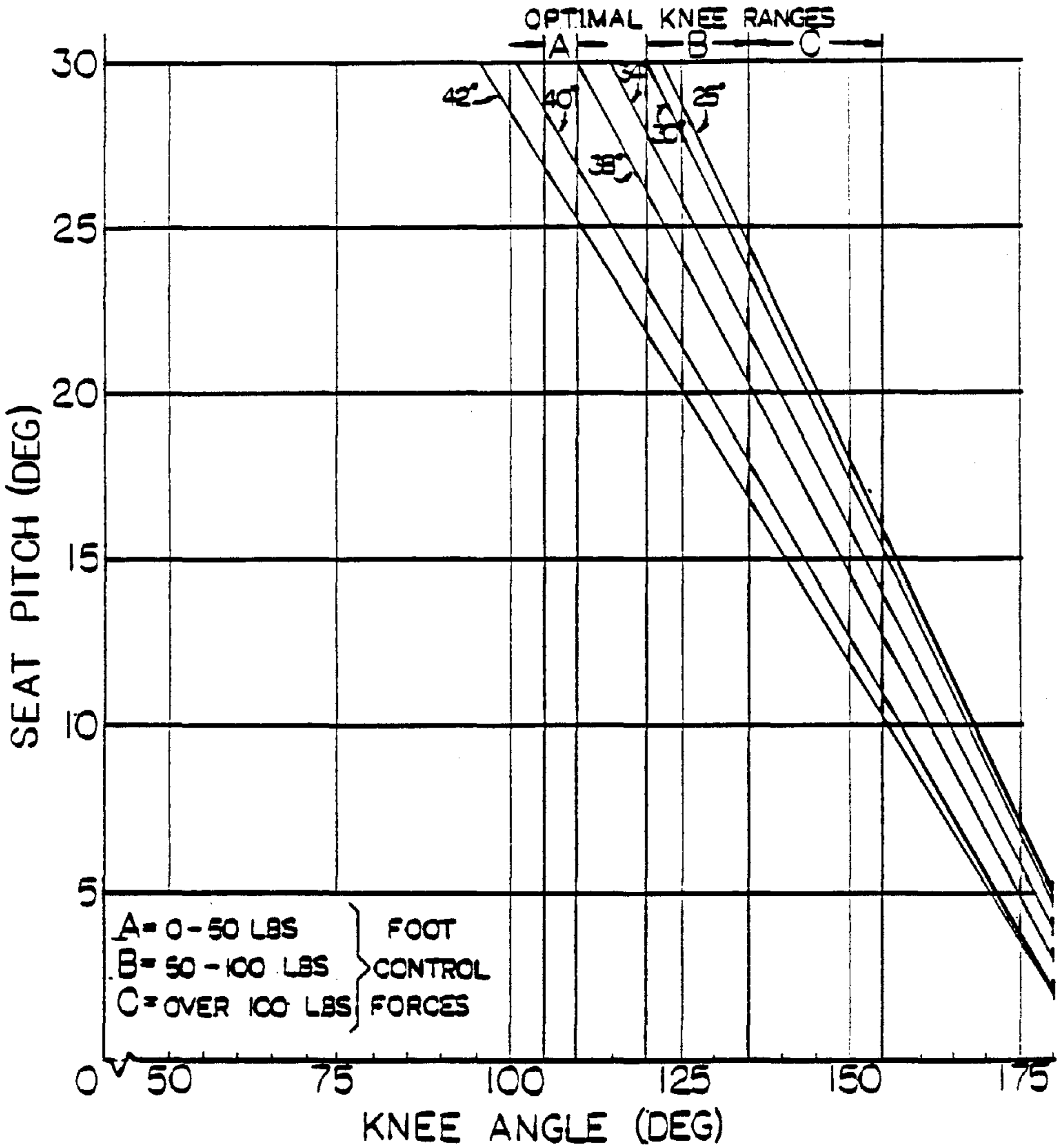


Figure 8. Relationship between seat pitch angle and knee angle for various interior cab heights (assuming 2" cap clearanc-`

4.5.1.7 The minimum width of usable cab workspace should be no less than 36 inches. There should be no sharp edges or protruding objects in the workspace that may injure the operator or interfere with ingress/egress.

4.5.2 Workspace Layout Recommended Practice

4.5.2.1 Control Layout

4.5.2.1.1 Proper placement of a control depends primarily upon its priority ranking. This ranking is based on the control's importance to system functioning and its frequency of use. Control priority locations should generally follow guidelines given in Table 5.

4.5.2.1.2 Common continuous miner controls are listed in Table 6 according to primary, secondary, and tertiary priority. Layout of these controls in the cab workspace should follow the guidelines previously described in Section 4.5.2.1.1.

4.5.2.1.3 Fore-aft control/display panel adjustment can be minimized or eliminated by providing an optimum panel location and then having the operator adjust the seat to achieve a comfortable and efficient body position relative to the panel.

4.5.2.1.4 Hand grip reach distances should be compatible with anthropometric characteristics of 95th percentile males through 5th percentile females.

Table 5. Control Priority Locations

PRIMARY CONTROLS

Given optimum locations in readily accessible positions, based on functional reach capabilities, grip postures, line of sight (LOS), etc.

Within 15 degrees laterally on either side of the operator's median plane (0 degrees) and within 30 degrees vertically above or below the operator's normal LOS (15 degrees below the horizontal plane).

Preferably right hand operation.

Longer in overall length than other controls.

SECONDARY CONTROLS

Placed within overall operational areas, but not necessarily within optimum areas.

Left or right hand operation.

Within 30 degrees laterally of operator's median plane (0 degrees).

TERTIARY CONTROLS

Placed within the limits of the operator's operational range. Because of low criticality and frequency of use, given location after placement of primary and secondary controls.

Within visual operational limits of 94 degrees laterally either side of the operator's median plane (0 degrees).

Table 6. Control Recommended Practice

CONTROL NAME	LABELING*	FUNCTION	TYPE	CHARACTERISTICS	MOTION STEREOTYPE**	RANKING	COMMENTS
Circuit Breaker	Main Breaker ON TRIPPED OFF RESET (see Figure 9)	Controls Power to Machine	Circuit Breaker Lever Switch	4 Position switch (on, tripped, off, reset). When tripped must be reset before switched to on.	Up and clockwise for on Down and counter clockwise for off and reset	Tertiary	Lever arm pointer should not cover labels that call out switch position
Canopy Elevation	Canopy UP DOWN	Raises or Lowers Canopy	Lever Switch	Momentary 3-position with spring return to center off position	Forward, Up, or away from operator to raise canopy Center OFF Backward, Down, or toward operator to lower canopy	Tertiary	Control should be guarded or located to avoid inadvertant activation
Conveyor Run	Conveyor Run FWD OFF LOAD	Switches Conveyor (and Gathering Head motion, if any) to run toward the tail for loading or toward cutterhead for clearing obstructions		Detented 3-position switch	Forward, up, or away from operator to run conveyor toward cutter head Center OFF Backward, down, or toward operator to run conveyor boom	Secondary	This switch may simultaneously control both the conveyor and the gathering head (if any) motion
Conveyor Elevation	Conveyor Height RAISE LOWER	Raises or Lowers Conveyor boom	Hydraulic Lever or "Joy" Toggle Switch	Momentary 3-position with spring return to center off position	Up, toward operator, or backward to raise conveyor tail Center OFF Down, away from operator, or forward to lower conveyor tail	Primary	
Conveyor Swing	Conveyor Swing LEFT RIGHT	Swings Conveyor tailpiece to left or right	Hydraulic Lever or "Joy" Toggle Switch	Momentary 3-position with spring return to center off position	Lever motion to left to swing conveyor toward left. Lever motion to right to swing conveyor toward right	Primary	May be combined with conveyor elevation with a single 4-position joy stick with spring return to center off position
Cutter Head Elevation	Cutter Head Height RAISE LOWER	Raises or Lowers elevation of cutter head	Hydraulic Lever or "Joy" Toggle Switch	Momentary 3-position with spring return to center off position	Up, toward operator, or backward to raise cutter head Down, away from operator, or forward to lower conveyor	Primary	

* Labels and control motions should be located in accordance with the motion stereotypes given in this table or in Table 25.

** All directions given in this column assume the observer is facing toward the cutter head.

Table 6. Control Recommended Practice (Continued)

CONTROL NAME	LABELING	FUNCTION	TYPE	CHARACTERISTICS	MOTION STEREOTYPE	RANKING	COMMENTS
Cutter Head Rotation	Cutter Head Rotate START RUN OFF	Turns motors to cutter head on or off to make it rotate or stop rotating. Provides momentary start impulse	Electrical Toggle Switch or Hydraulic Lever	3 position switch with momentary "start" position and detented " "run" and "off" positions	Up, forward, or away from operator to start cutter head rotation Detented center run position Down, backward, or toward operator to stop cutter head rotation	Primary	
Cutter Head Extension	Cutter Head Sump EXTEND RETRACT	Extends or retracts cutter head on machines that do not tram into fact to advance cut	Hydraulic Lever or "Joy" Toggle Switch	Momentary 3-position with spring return to center off position	Forward, up, or away from operator to advance cutter head toward face Center OFF Backward, down, or toward operator to retract cutter head toward tail piece	Primary	This control is optional. Some machines may be designed to advance their cut by tramming into the face
Emergency Stop	Emergency Stop and/or Red Color	Causes immediate shut down of power to machine	Switch activated by an irregularly shaped bar located within easy reach of the operator or Large Mushroom Switch	Momentary switch requiring separate restart using a distinct maximum 2-inch stroke and 15 lb force to activate control at any point along the effective length of the panic bar. All edges exposed to operator should be rounded to minimize impact hazard At least 2-inch clearance from other machine structures, or out side edge of machine	Push to shut off machine	Primary	Switch should be readily accessible but not likely to be inadvertantly activated Machine components should be designed to stop their motion as soon as possible after emergency stop of system takes place
Fire Suppression	Fire	Provides manual override to automatic fire suppression system		Red mushroom	Push to activate fire suppression	Secondary	This function may be combined with the Water Spray control
Gathering Head Elevation	Gath. Head Height RAISE HOLD FLOAT	Causes gathering head to raise, hold or "float" on ground	Hydraulic Lever or Electrical Toggle Switch	3-position with momentary "raise" and spring return to "hold", detented "float" position	Up, toward operator, or backward to raise the gathering head Center hold position Down, away from operator, or forward to lower gathering head to float position	Secondary	This control is optional. Some machines may not use gathering head mechanisms to collect coal onto the conveyor
Hydraulic Power Supply	Pump Motor START RUN STOP	Controls supply of hydraulic power to machine system by starting or stopping an electric motor connected directly to a hydraulic pump	Lever Switch or Electrical Toggle Switch	3-position switch with momentary start position and detented run and stop positions	Clockwise rotation to start position with spring back to counter clockwise stop or Up, forward, or away from operator to momentary start position Center detented run position Down, backward, or toward operator to detented stop position	Secondary	

Table 6. Control Recommended Practice (Concluded)

CONTROL NAME	LABELING	FUNCTION	TYPE	CHARACTERISTICS	MOTION STEREOTYPE	RANKING	COMMENTS
Lights	Lights ON OFF	Controls supply of electrical power to machine lighting system	Lever Switch or Electrical Toggle Switch	2 position, detented	Up, forward, or away from operator to turn lights on Down, backward, or toward operator to turn lights off	Secondary	Headlights used in tramming may be on a separate, independently controlled circuit
Stabilization Jack	Stab Jack UP DOWN	Controls hydraulic flow into stabilization jack cylinders	Hydraulic Lever	3-Position momentary with spring return to center off position	Up, backward, or toward operator to raise stab jack Center OFF Down, forward, or away from operator to lower the stab jack	Secondary	
Tram Speed Selection	Tram Speed FAST SLOW	Controls fast or slow tram speed	Lever Slide Knob or Electrical Toggle Switch	Lever slides forward and backward with detented positions at each end of 2 1/2" to 4" stroke	Forward, up, or away from operator to set speed to fast Backward, down, or toward operator to set speed to slow	Primary	Tram speed should be interlocked with cutter head powe so that fast tram is not possible when cutter head is rotating
Tram Steering	Tram Steer FWD REV (see Figure 10)	Controls tram motion and direction	Ball Grip Levers or Large "Joy" Toggle Switches	3 Positions with spring loading to center off position	Forward motion of control causes forward motion of machine Center OFF Rearward motion of control causes rearward motion of machine	Primary	Control motion direction mu match machine motion directi Tram should be interlocked with a deadman foot control switch that requires activation for tram to enga
Water Spray	Water SPRAY RECIR	Controls water spray to suppress dust and/or cool machine	Lever Switch or Electrical Toggle Switch	2-Position valve control	Clockwise, up, or forward to turn spray on Counterclockwise, down, or rearward to turn spray off to recirculate	Secondary	Water spray control may include a detented position for fire suppression

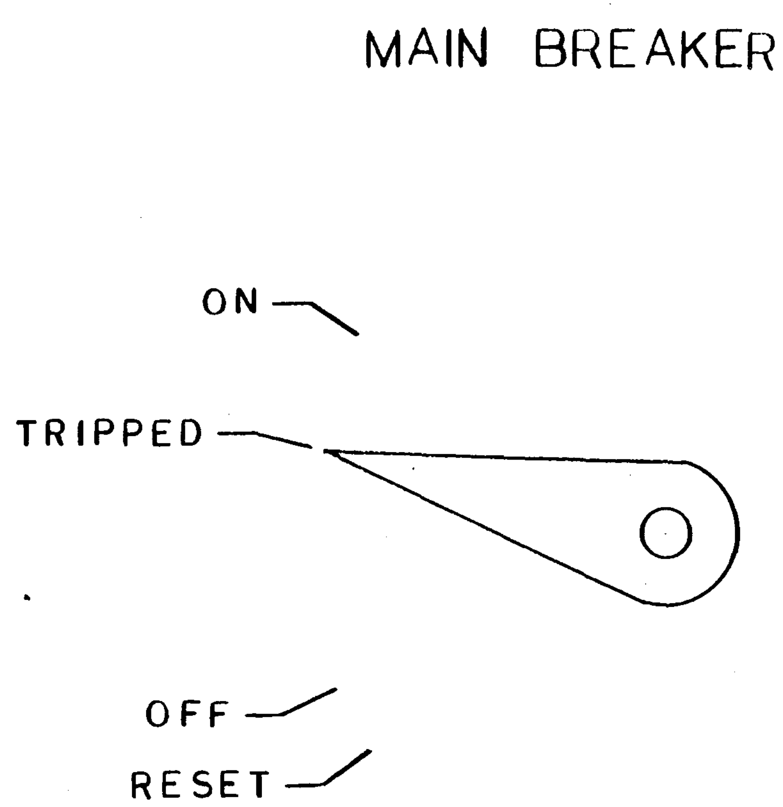


Figure 9. Preferred Labeling of Circuit Breakers

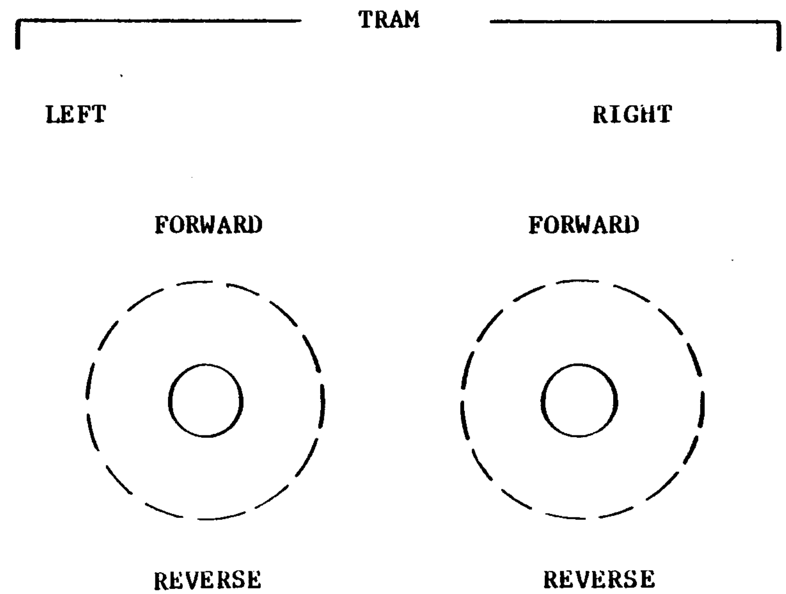


Figure 10. Preferred Labeling for Tram Controls

Grip control zones vary with interior cab workspace height. Control placement should remain within maximum and minimum zones to accommodate the population of operators. Side and plan views of these zones are shown in Figures 11 and 12 for 22 inch workspace height; Figures 13 and 14 for 32 inch workspace height; and, Figures 15 and 16 for 42 inch workspace height. A combined primary area for locating controls is shown in these figures as an area bounded by:

A. The normal grip arc for 5th percentile females

B. The minimum grip arc for 95th percentile males

C. Absolute minimum control/display distance of 13 inches from eye reference point for either size operator.

D. Upward visual angle or canopy from either eye reference point

E. Cab floor (or top of thighs of 95th percentile operator for controls over legs).

4.5.2.1.5 Coding methods such as location, shape, size, mode of operation, labeling, and color of controls should be applied to minimize operator error. Table 7 presents a summary of the relative advantages and disadvantages of various types of coding. It is generally advisable to apply as many different methods of coding as possible at one time to any given control as long as each coding method serves to clarify the identification of the control.

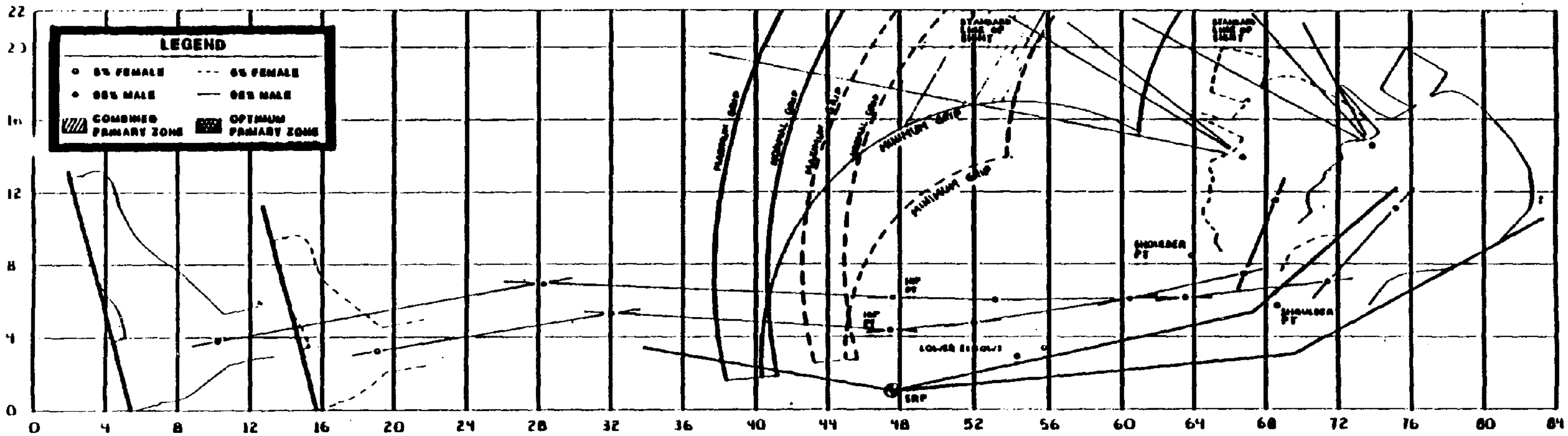


Figure 11. Side View of 22" Workspace

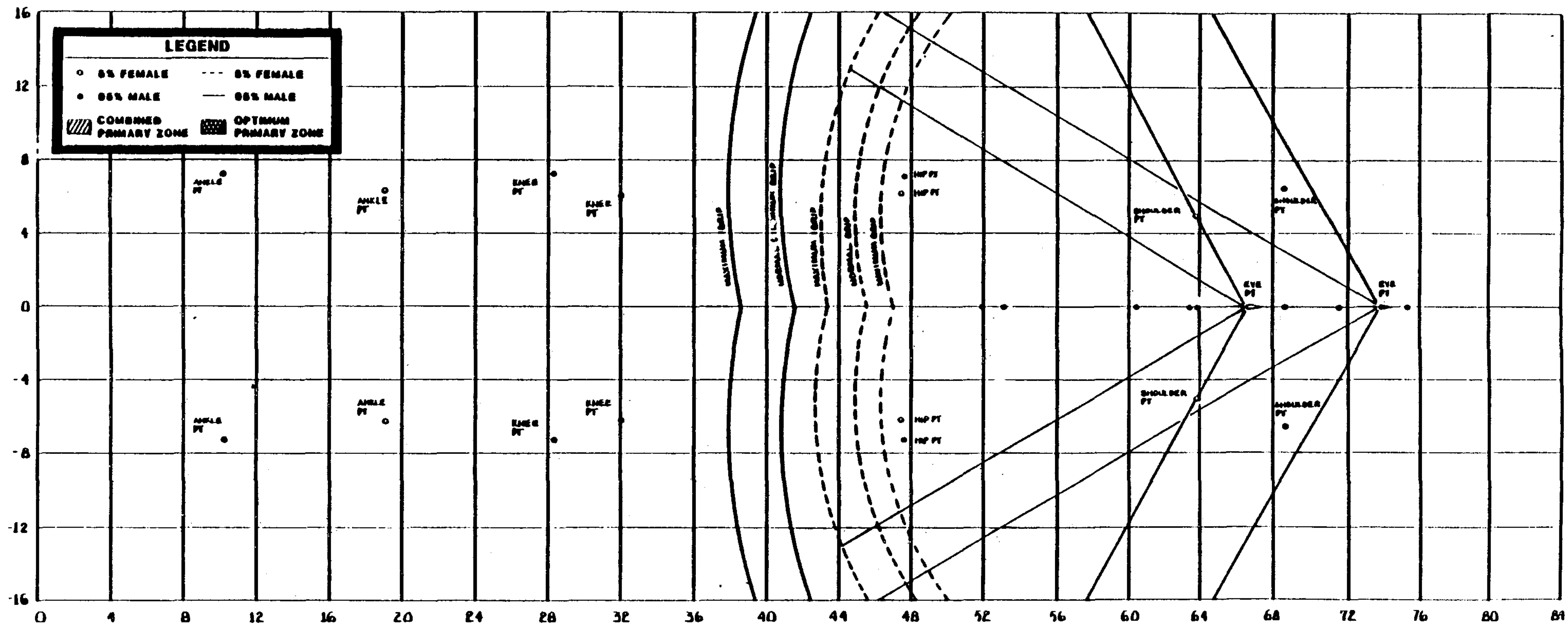


Figure 12. Plan View of 22" Workspace at Shoulder neight

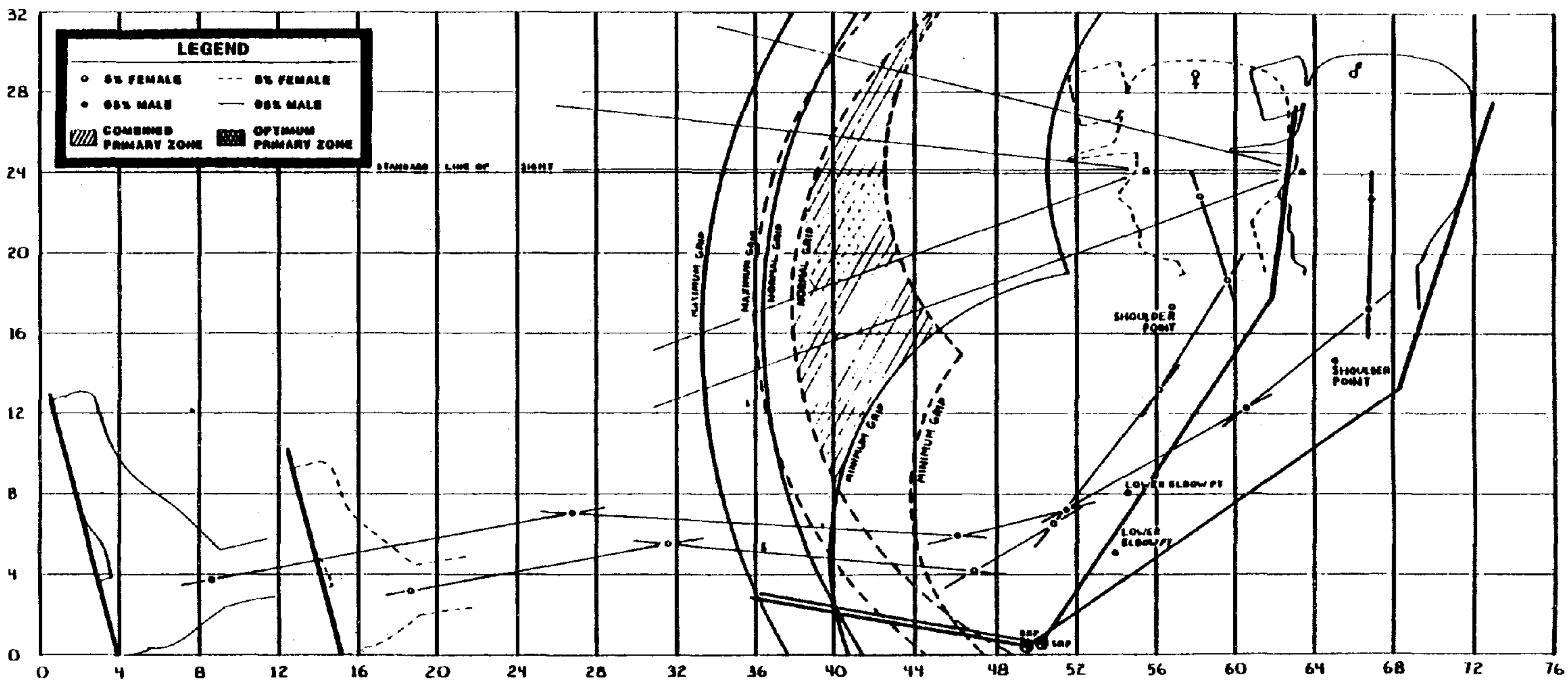


Figure 13. Side View of 32" Workspace

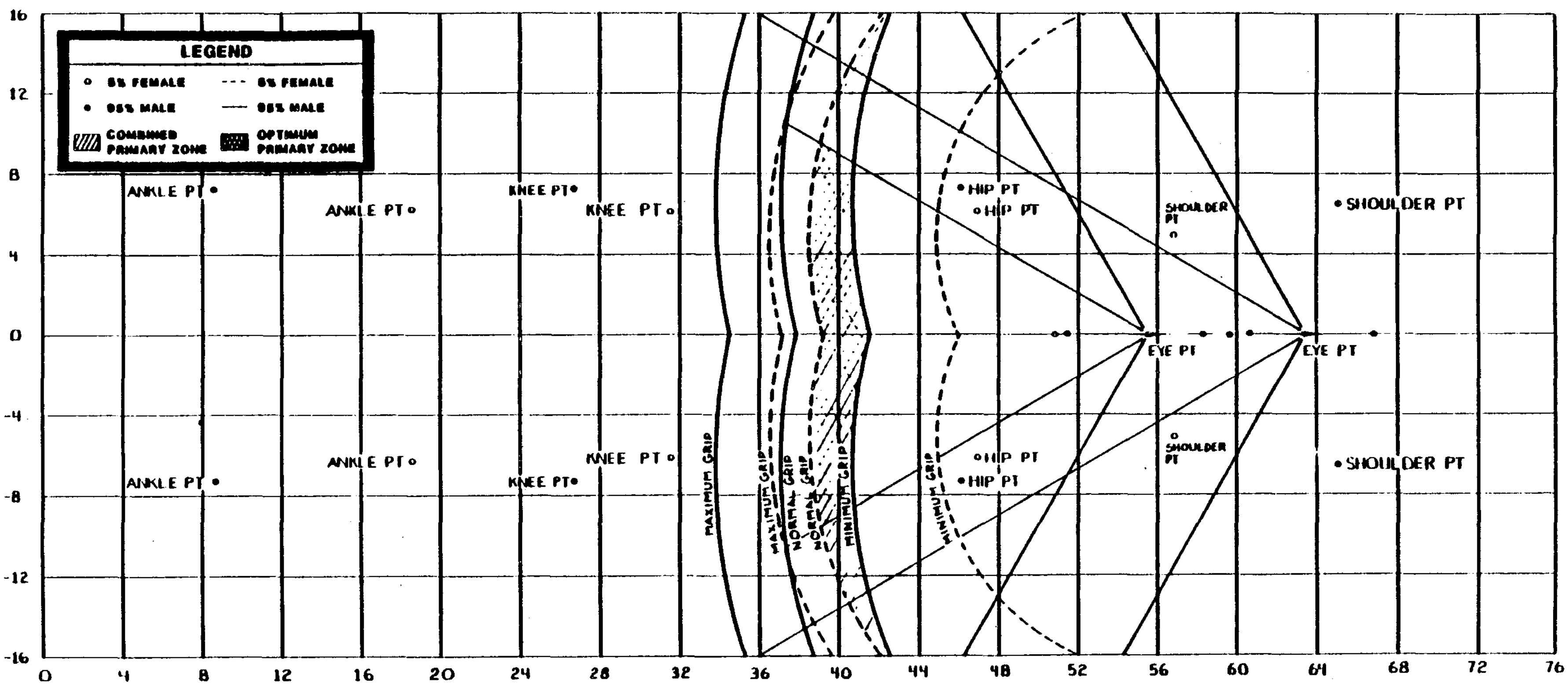


Figure 14. Plan View of 32" Workspace at Midpoint of Shoulder and Elbow

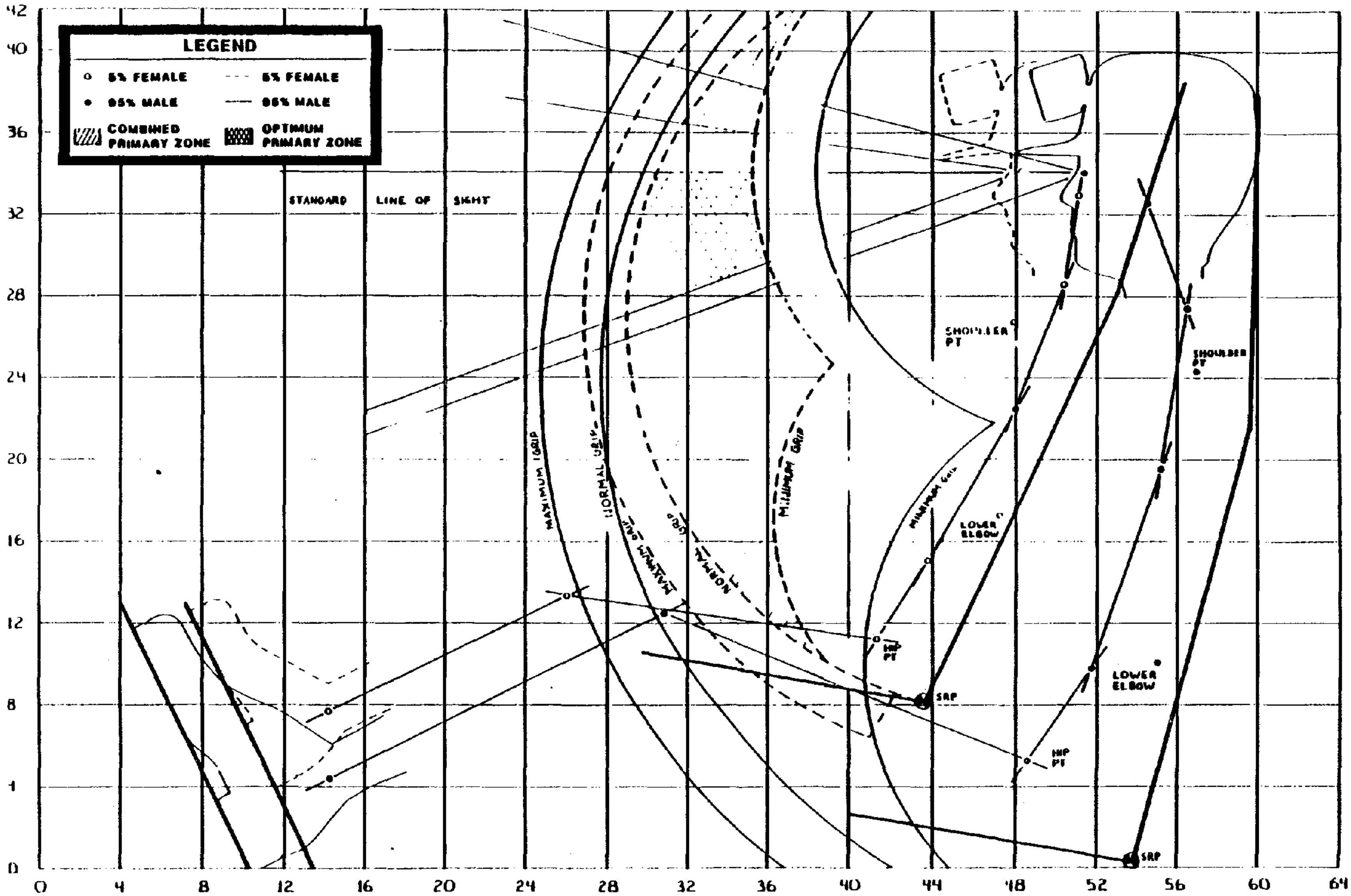


Figure 15. Side View of 42" Workspace

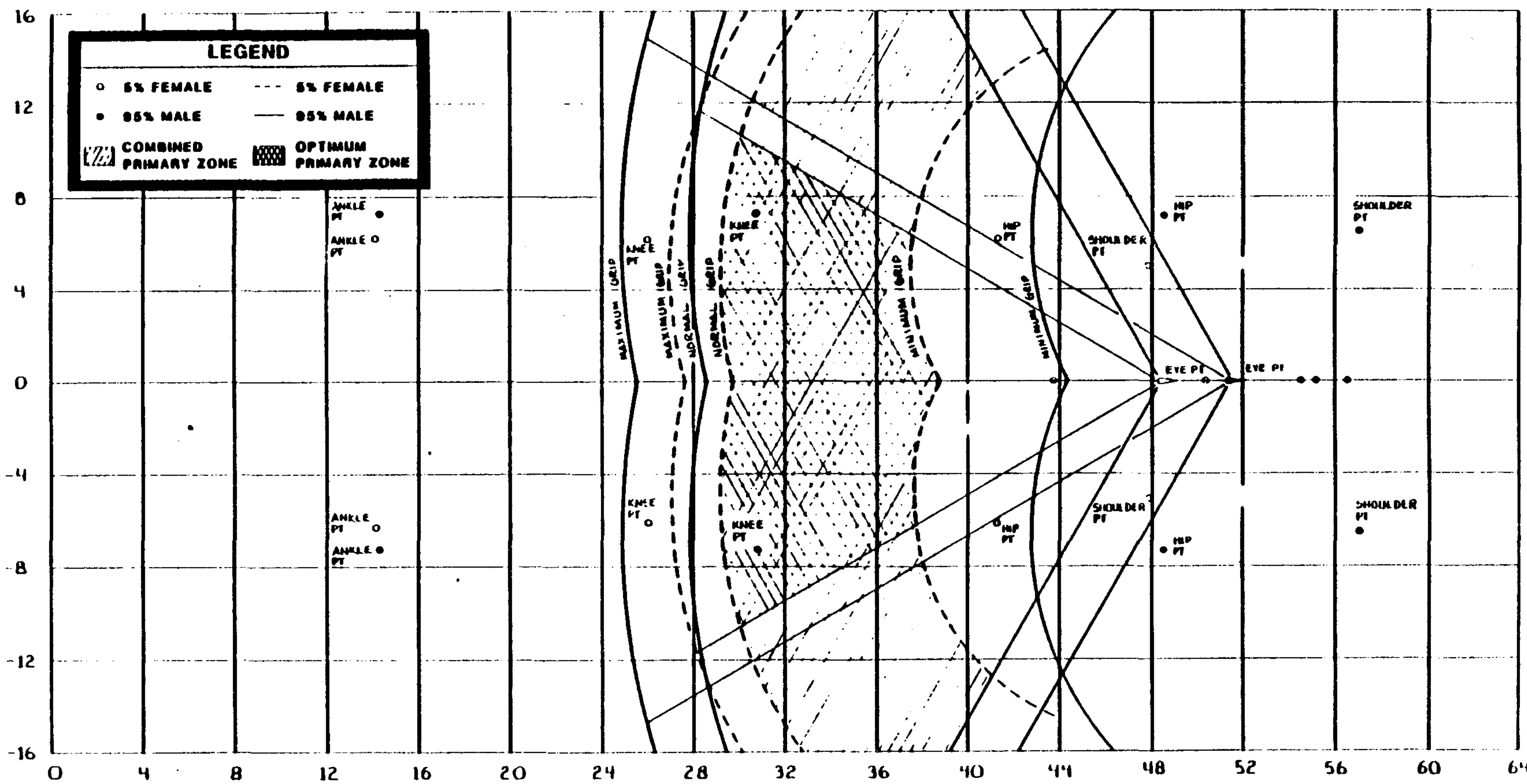


Figure 16. Plan View of 42" Workspace at Midpoint of Shoulder and Elbow

Table 7. Relative Advantages and Disadvantages of Various Methods of Control Coding

	TYPE OF CODING					
ADVANTAGES	LOCATION	SHAPE	SIZE	MODE OF OPERATION	LABELING	COLOR
IMPROVES VISUAL IDENTIFICATION.	X	X	X		X	X
IMPROVES NONVISUAL IDENTIFICATION (TACTUAL AND KINESTHETIC).	X	X	X	X		
HELPS STANDARDIZATION.	X	X	X	X	X	X
AIDS IDENTIFICATION UNDER LOW LEVELS OF ILLUMINATION AND COLORED LIGHTING.	X	X	X	X	(When trans-illuminated)	(When trans-illuminated)
MAY AID IN IDENTIFYING CONTROL POSITION (SETTINGS).		X		X	X	
REQUIRES LITTLE (IF ANY TRAINING: IS NOT SUBJECT TO FORGETTING.					X	
DISADVANTAGES						
MAY REQUIRE EXTRA SPACE	X	X	X	X	X	
AFFECTS MANIPULATION OF THE CONTROL (EASE OF USE)	X	X	X	X		
LIMITED IN NUMBER OF AVAILABLE CODING CATEGORIES.	X	X	X	X		X
MAY BE LESS EFFECTIVE IF OPERATOR WEARS GLOVES.		X	X	X		
CONTROLS MUST BE VIEWED (I.E., MUST BE WITHIN VISUAL AREAS AND WITH ADEQUATE ILLIMINATION PRESENT).					X	X

4.5.2.1.6 The direction of movement for controls should follow population sterotypes. Table 8 gives the recommended control movements for various machine functions.

4.5.2.1.7 Use of foot controls of known resistance requires certain knee angles to enable the operator to apply the appropriate force. Seat pitch and interior cab length, in turn, affect knee angles. Given interior cab length, foot angle and pedal resistance, Figure 6 may be used to determine knee angle. Then with the calculated knee angle, enter Figure 8 to determine recommended seat pitch.

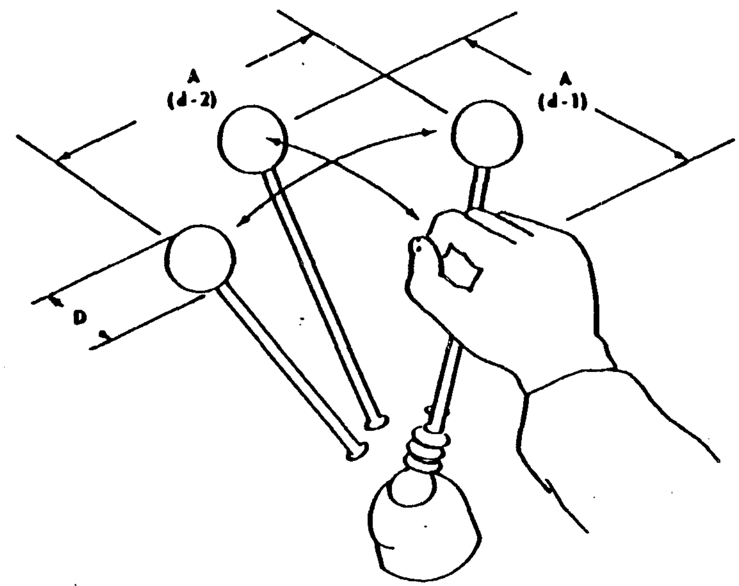
4.5.2.1.8 Controls and other cab structures should be spaced far enough apart to eliminate accidental movement or interference. Figures 17, 18, 19, 20 and 21 provide design guidelines for typical types of controls. For "blind" reaching (controls not visible to the operator), controls located forward of the operator should be spaced at least 6 inches apart; controls located above or behind the operator's shoulder should be at least 12 inches apart.

4.5.2.1.9 The extent of control movement should be in relation to display motion. This control/display ratio varies with the types of controls being used and should at a minimum be optimized for primary controls.

4.5.2.1.10 Controls for the Continuous Miner should be arranged according to the plan presented in Figure 22. Controls within each block should be arranged by function and each block should be clearly labeled and separated from

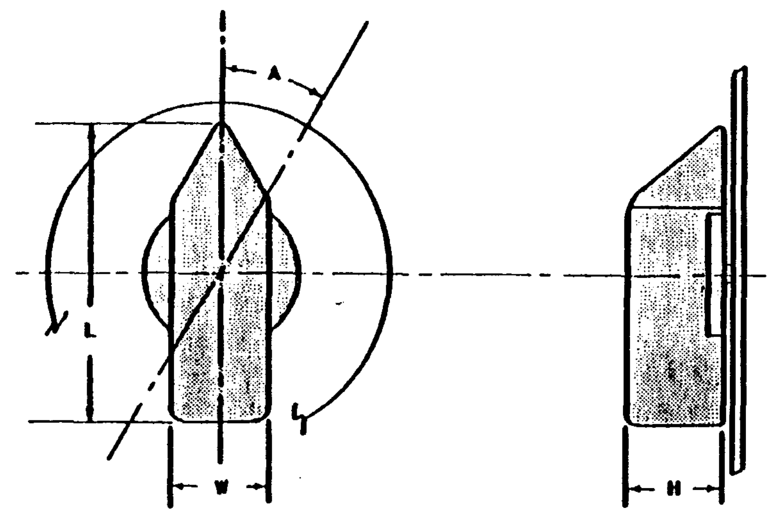
Table 8. Recommended Control Movements

FUNCTION	CONTROL ACTION
On	Up, right, forward, pull (switch knobs).
Off	Down, left, rearward, push (switch knobs).
Right	Clockwise, right.
Left	Counterclockwise, left.
Up	Up, rearward.
Down	Down, forward.
Retract	Rearward, pull, counterclockwise, up.
Extend	Forward, push, clockwise, down.
Increase	Right, up, forward, clockwise.
Decrease	Left, down, rearward, counterclockwise.



	DIAMETER D		RESISTANCE (d-1)		RESISTANCE (d-2)		DISPLACEMENT A		SEPARATION	
	Finger Grasp	Hand Grasp	One Hand	Two Hands	One Hand	Two Hands	Forward (d-1)	Lateral (d-2)	One Hand Random	Two Hands Simultaneously
Maximum	3.2"	3.5"	30 lb	50 lb	20 lb	30 lb	14.0"	38.0"	—	—
Minimum	0.7"	2.0"	2 lb	2 lb	2 lb	2 lb	—	—	2.5"	4.0"
Preferred	—	—	—	—	—	—	—	—	4.5"	6.0"

Figure 17. Control Design Criteria for Levers

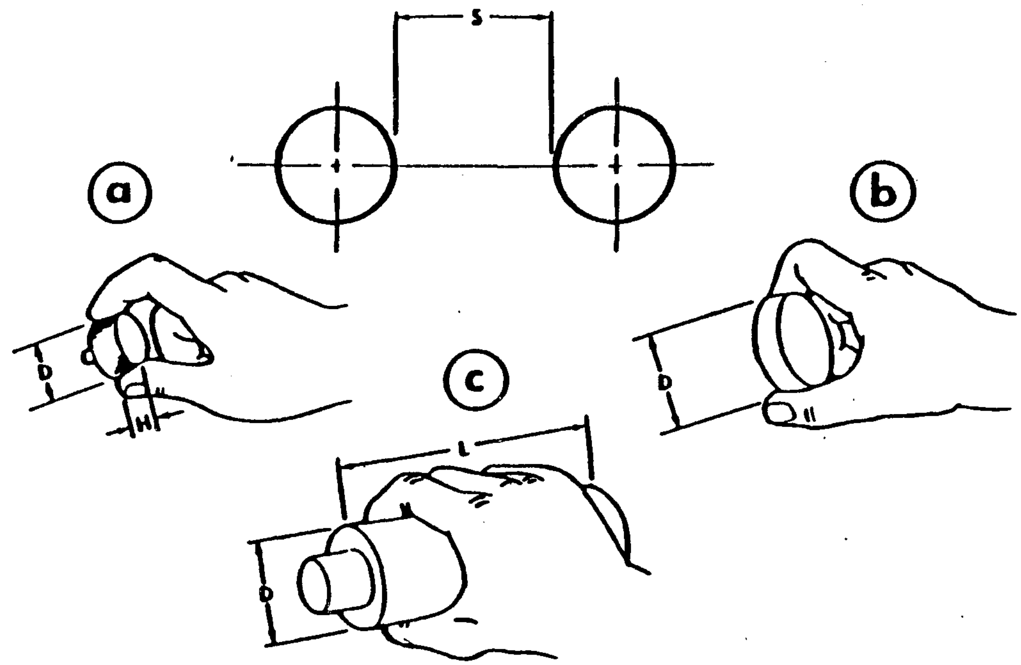


	DIMENSIONS			RESISTANCE	DISPLACEMENT		SEPARATION	
	L Length	W Width	H Depth		*	**	One-Hand Random	Two-Hand Operation
Maximum	4.0"	1.0"	3.0"	6.0 in.-lb	40 deg	90 deg	-	-
Minimum	1.0"	-	0.625"	1.0 in.-lb	15 deg	30 deg	1.3"	3.6"
Preferred	-	-	-	-	-	-	2.3"	5.6"

* For Facilitating Performance

** When Special Engineering Requirements Demand Large Separation.

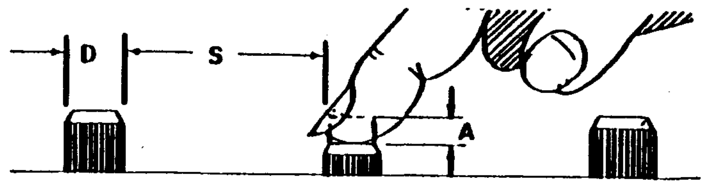
Figure 18. Control Design Criteria for Rotary Selector Switches



	DIMENSIONS					TORQUE		SEPARATION	
	Fingertip Grasp		Thumb and Finger Encircled	Palm Grasp					
	H Height	D Diameter	D Diameter	D Diameter	L Length	*	**	S One Hand Individually	S Two Hands Simultaneously
Maximum	1.0"	4.0"	3.0"	3.0"		4.5 in.-oz	6.0 in.-oz	-	-
Minimum	0.5"	0.375"	1.0"	1.5"	3.0"	-	-	1.3"	2.6"
Preferred	-	-	-	-	-	-	-	2.3"	5.6"

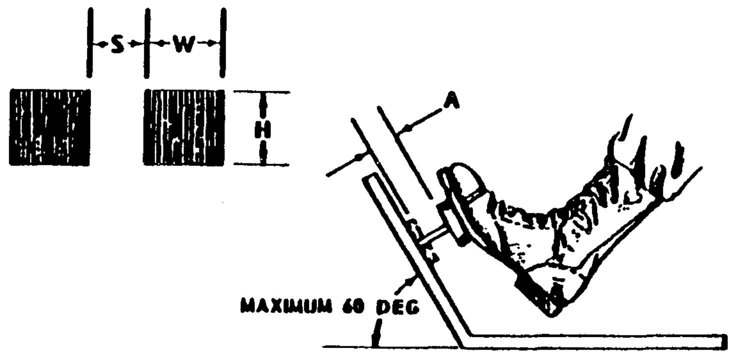
* To and Including 1.0-in. (25mm) Diameter Knobs
** Greater Than 1.0-in. (25mm) Diameter Knobs

Figure 19. Control Design Criteria for Continuous Adjustment Rotary Knobs



	DIMENSIONS		RESISTANCE		DISPLACEMENT	SEPARATION		
	Diameter D Fingertip Operation	Thumb or Heel of Hand Operation	Fingertip Operation	Little Finger Operation	A Thumb or Finger Operation	Single Finger Operation	S Single Finger Sequential Operation	Operation by Several Fingers
Maximum	0.75"	—	40 oz	20 oz	1.7"	—	—	—
Minimum	0.385"	0.75"	10 oz	5 oz	0.325"	0.6"	0.35"	0.6"
Preferred	—	—	—	—	—	2.1"	1.10"	0.6"

Figure 20. Control Design Criteria for Pushbuttons (Finger or Hand Operated)



	DIMENSIONS		DISPLACEMENT				RESISTANCE				SEPARATION	
	H Height	W Width	A Normal Operation	Heavy Boots	Ankle Flexion	Total Leg Movement	Foot Not Resting On Pedal	Foot Resting On Pedal	Ankle Flexion Only	Total Leg Movement	S One Foot Random	One Foot Sequential
Maximum	-	-	2.5"	2.5"	2.5"	7.0"	20 lb	20 lb	10 lb	180 lb	-	-
Minimum	1.0"	3.0"	0.5"	1.0"	1.0"	1.0"	4 lb	10 lb	-	10 lb	4.8"	2.8"
Preferred	-	-	-	-	-	-	-	-	-	-	6.8"	4.8"

Figure 21. Pedal Control Design Criteria

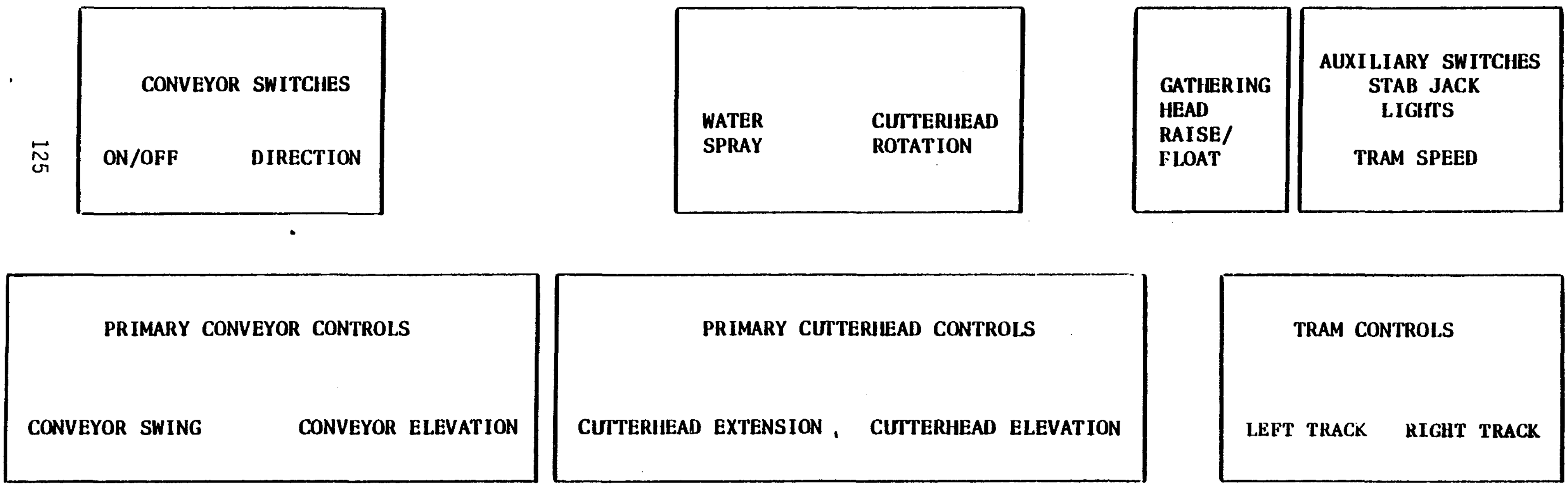


Figure 22. Recommended Control Arrangement for Continuous Miners

adjacent blocks or cab structures. The three major blocks representing Conveyor, cutter head, and tram controls should be placed in the primary control area. Slight variations in the general layout may be required to accommodate different machine configurations or features. This layout should also be followed for remote control units used with continuous miners equipped with cabs designed to conform to this recommended practice. The choice of control type is left to the workspace designer, but such controls should meet the requirements set forth in all other paragraphs in this subsection (Section 4.5.2.1) and should otherwise be compatible with the other major sections of this recommended practice.

4.5.2.2 Display Layout

4.5.2.2.1 Display placement depends upon the relative importance and type of information being presented. An Optimal Display Area within which primary displays should be located is bounded by:

A. Functional Reach (FR) arc.

B. 20 inch preferred distance from eye reference point for displays with associated controls.

C. Upward visual angle (+5 degrees to + 20 degrees as limited by the cap brim, with no upward head motion; or as limited by the canopy)

D. Downward visual angle (-30 degrees with no downward head motion).

4.5.2.2.2 Layout of visual display panels should follow recommendations discussed in the Van Cott and Kinkade Human Engineering Guide for Equipment Design (1972). Warning displays indicating a present or potential malfunction or hazard should be within 30 degrees of normal line of sight. Displays should be labeled according to machine component or function. Scale ranges and interval values should correspond with all possible readings that may occur.

4.5.2.2.3 Displays should be organized by machine function and laid out in conjunction with related controls to insure a clear relationship between each control and its associated display (if any).

4.5.2.2.4 Displays should be made of materials sufficiently reflective to be legible from all operator seat positions. Colors of displays and annunciator lights should be selected according to the population stereotypes of red for "stop" or "danger", yellow for "caution", and green for "go" or "normal". Other colors may be chosen from stereotypes presented in the references cited above. Caution should be used in relying on color coding in situations where lighting conditions vary.

4.5.2.2.5 Mechanisms for generating auditory displays and alarms should be located near the operator's head. Multiple alarms should have distinct tones and be sufficiently loud to overcome background noise. Volume should be preset to avoid being tuned low by personnel.

4.5.2.2.6 There should be no sources of glare within the operator's primary and secondary viewing areas.

4.5.2.2.7 Table 9 should be used as an aid to selecting the proper type of display for presenting a given type of information. Generally, an analog, moving pointer display is recommended for qualitative and check reading functions like hydraulic pressures, temperatures, and voltages as may be found on continuous miners.

Table 9. Relative Evaluation of Digital vs. Analog Displays

For—	Digital is—	Analog	
		Moving pointer is—	Moving scale is—
Quantitative reading.	Good (requires minimum reading time with minimum reading error).	Fair	Fair.
Qualitative and check reading.	Poor (position changes not easily detected).	Good (location of pointer and change in position is easily detected).	Poor (difficult to judge direction and magnitude of pointer deviation).
Setting	Good (most accurate method of monitoring numerical settings, but relations between pointer motion and motion of setting knob is less direct).	Good (has simple and direct relation between pointer motion and motion of setting knob, and pointer-position change aids monitoring).	Fair (has somewhat ambiguous relation between pointer motion and motion of setting knob).
Tracking	Poor (not readily monitored, and has ambiguous relationship to manual-control motion).	Good (pointer position is readily monitored and controlled, provides simple relationship to manual-control motion, and provides some information about rate).	Fair (not readily monitored and has somewhat ambiguous relationship to manual-control motion).
Orientation	Poor	Good (generally moving pointer should represent vehicle, or moving component of system).	Good (generally moving scale should represent outside world, or other stable frame of reference).
General	Fair (most economical in use of space and illuminated area, scale length limited only by number of counter drums, but is difficult to illuminate properly).	Good (but requires greatest exposed and illuminated area on panel, and scale length is limited).	Fair (offers saving in panel space because only small section of scale need be exposed and illuminated, and long scale is possible).

OPERATOR'S COMPARTMENTS FOR UNDERGROUND

CONTINUOUS MINERS

SAE Recommended Practice

Development of SAE Guidelines for Underground Operator Compartments
(USBM Contract No. H0308110)

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DRAFT

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APPENDIX 5

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SAE --- HUMAN FACTOR GUIDELINES - SHUTTLE CARS

1. Purpose

This recommended practice is intended as a guide for developing an operator's envelope with good human factors criteria for layouts of underground shuttle cars.

2. Scope

2.1 These guidelines are intended to be primarily applied to products to be designed and produced in the future.

2.2 The limitations to these guidelines are that it is probably not possible to apply them in any retrofit or rework program to equipment already in use.

3. Definitions

3.1 Operator's envelope - same as operating station and means a cubic area of space which is allocated for an operator to work controls for operating a machine.

3.2 Service Brake Pedal - to be positioned on the left relative to the operator's view.

3.3 Throttle Pedal - To be positioned on the right relative to the operator's view.
Note: Regardless of the direction of travel, the placement of the above pedals should be positioned relative to the operator as stated above.

3.4 Steering -

3.4.1 If a wheel or two wheels are used, clockwise rotation of the wheel must turn the vehicle to the right relative to the operator facing the wheel.

3.4.2 If stick steering is used, the direction of motion of the stick to the left or right must create travel in the same direction relative to the operator facing the control. In a 180° opposed position, the same condition should exist.

3.5 Parking Brake - Must hold car stationary when applied same as emergency brake but system is not deenergized when applied.

3.6 Emergency Brake - Is operated by a panic bar only and released by some distinctively separate action.

3.7 Canopy Elevation Power Assist - Does not have to be in operator's envelope -- it can be within the operator's compartment but must be out of the way of the vehicle motion controls.

3.8 Fire Suppression - This control element must be conveniently located to the operator but must be out of the way of the vehicle motion controls.

3.9 Conveyor Discharge Boom Elevate - Must be within easy arm reach.

3.10 Bell or Gong - Actuator must be convenient to the operator.

3.11 Main Power and Pump Motor - One switch will be within reach of the operator's envelope and will activate both. Some type of auditory or visual signal indicating power is on and machine is activated is desirable.

3.12 Tram Direction - One control will be within the operator's reach within the envelope. The tram direction control will be incorporated with the throttle when the compartment is a two direction/two position design. In the traverse cab, a separate control will be used for reverse direction.

3.13 Lights - Control must be within operator's envelope.

3.14 Conveyor Stop/Start - Must be within operator's envelope.

3.15 Main Breaker - Not required to be in operator's area.

4. General Criteria

Three different sizes of operator's envelopes are defined.

They are:

	Drwg #	Internal Compartment Height	View	Internal Width	Compartment Length
	1a	20"	side		80" long
4.1	1b	20"	plan	30" wide	80" long
	1c	20"	front	30" wide	80" long
	2a	30"	side		80" long
4.2	2b	30"	plan	30" wide	80" long
	2c	30"	front	30" wide	80" long
	3a	40"	side		60" long
4.3	3b	40"	plan	30" wide	60" long
	3c	40"	front	30" wide	60" long

4.4 With reference to the above controls, they are grouped below by use. That is primary or easily reached and most used; secondary which are frequently used and tertiary, infrequently used. Unless noted, all controls are hand operated controls. When considering a control layout, the recommendation would be to place primary controls in the primary zone on the drawings and so on.

4.4.1	Service brake pedal	Foot control
4.4.2	Throttle pedal	Foot control
4.4.3	Steering	Primary
4.4.4	Parking brake	Secondary

4.4.5	Emergency brake	Primary
4.4.6	Canopy Elevation Power Assist	Tertiary
4.4.7	Fire suppression	Tertiary
4.4.8	Conveyor discharge boom elevate	Secondary
4.4.9	Bell or gong	Primary
4.4.10	Main power and pump motor	Tertiary
4.4.11	Tram direction	Foot pedal or primary
4.4.12	Lights	Secondary
4.4.13	Conveyor stop/start	Primary
4.4.14	Main breaker	Tertiary

4.5 The operator's envelopes defined in the above list of drawings are respectively for 24", 36", and 48" high machines. The dimensions of 24", 36", and 48" are the machine height. The seam height will be considered to be 12" above the vehicle height. The canopy thickness is not considered in these figures. The enclosures shown are drawn to reflect recommended internal measurements. For example top of cab floor to the underside of the canopy.

4.6 The purpose of these drawings and the accompanying text is to furnish general optimized human factors guidelines for underground mining equipment and specifically shuttle cars. These guidelines would be applied primarily to products to be designed and produced in the future.

These human factors recommendations don't take into consideration:

4.7 Any limiting machine design factors

4.8 Specific recommendations can and will be made from the supporting drawings. However, it is necessary to first list those elements of importance pertaining to controls and recommended guidelines for them.

Explanation of Drawings

4.9 Three views of each chosen operator's compartment are shown. There is a grid overlayed on the space. The grid is used for locating areas for controls and for positioning of the operator.

4.10 In each of the views, the link points for the extreme size operators have been plotted. The large male is plotted with black dots and his head is outlined. The small female is plotted with red dots with boxes around the dots, and her head is outlined.

4.11 The common area of easy reach is crosshatched and the area of natural reach and movement is shaded.

4.12 Foot positions are shown as a line which represents the bottom of the foot. These lines are keyed according to the size of person they relate to.

4.13 A dotted line in the appropriate color and weight shows the approximate seat or shoulder and head rest positions.

4.14 By using a list of required controls and grading them by importance and amount of use, we can find which controls should fit into what areas of reach for the operator.

4.15 It must be remembered that the entire area shown in the drawings cannot be used for controls. Room must be left for entry and exit of the operator.

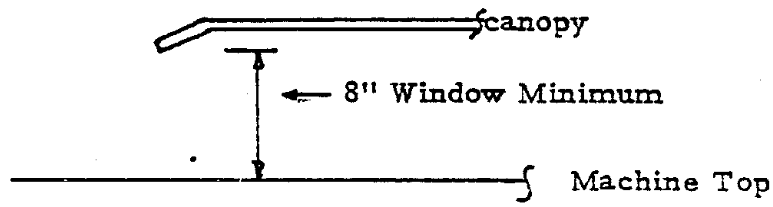
4.16 This will eliminate about half of the primary reach area and one third of the easy reach areas.

4.17 Overall compartment size, especially width, may be smaller or larger than is shown in the drawings. Compartment height must not be lower than the one specified, but it may be higher.

5. Specific Recommended Design Guidelines

5.1 Canopies, their structures and visibility through them as well as safety requirements. It is a must that the canopy must cover all of a man's body - it must be wide enough to prevent <u>any</u> part of his body, such as his head, from being caught between a canopy support post and a roof support rib. This indicates that if canopy posts are used, they should be brought in a reasonable distance from the outside perimeter of the canopy.

5.2 We must optimize visibility vertically or horizontally. We have to apply human factors requirements which will enhance safe operation from a viewing point of view. Good visibility requirements for non extended cabs as opposed to extended cabs will be different. In non extended cabs, we recommend a minimum of an 8" vertical and 20" horizontal window for all four viewing directions.



In extended decks, in the forward and reverse directions of travel, we recommend an 8" horizontal and 20" vertical window. We will only have available over the machine a small viewing capability.

5.3. Spacing of the brake and throttle should be kept far enough apart so that one pedal would not be inadvertently depressed when the other is being used.

5.4 The conveyor and boom lift controls should have different tactile devices from each other.

5.5 Steering should be with the use of a round steering wheel or joy stick.

5.6 In shuttle cars, it is recommended that only seated to semi-prone positions be designed for the operator in order to try and minimize physiological fatiguing while in the overational attitude.

5.7 Door hinges, if any, must be on loading end or face side.

5.8 Unused seat should not be a hindrance to getting in or out of the operator's envelope.

5.9 There should be no obstructions for safe exit and inadvertent energizing of the machine.

5.10 If it is required within the operator's envelope to illuminate some machine feedback data, it must be visible but not so much as to be a distraction to the operator.

5.11 Some method to prevent the accumulation of debris around the foot pedals is necessary.

6. Specific Comments Referenced to the drawings are as follows:

6.1 Drawing 1a

6.1.1 Shoulder, back and head support must be adjustable in order to accommodate the two extremes of the population we have used.

6.1.2 The hip points for the two population extremes will be kept at about the same L axis position and the primary controls will be fixed in position.

6.1.3 Pedal controls should be adjustable to accommodate population extremes. Dotted line shows fully extended position and solid line shows a non-depressed pedal position.

6.1.4 The heads of the two population extremes should be kept as indicated with the neck pivot point (No. 1) held at 10 on the H axis.

6.2 Drawing 2a

6.2.1 Head, shoulder and back support must be adjustable in order to accommodate the two extremes of the population we have drawn. The heavy line areas indicate where lumbar support must be placed.

6.2.2 The heads of the two population extremes which are drawn as well as any person between these two must be kept in a position so that the neck pivot point is at about 20 on the H axis.

6.2.3 Pedal controls should be adjustable to accommodate population extremes. Dotted line shows fully extended position and solid line shows normal non-depressed pedal position.

6.2.4 The hip points for the two population samples illustrated will be at the same position on the L axis and thus the buttock support will be fixed. Also the primary controls will be fixed in position.

6.3 Drawing 3a

6.3.1 Since the height of this operator's envelope permits a seat in the normal sense of the word, the (SRP) Seat Reference Plane is illustrated. The SRP is established by drawing a line which goes through the contact areas of the back and another line through the contact area of the legs. Where these two lines intersect, we have the SRP. The SRP should be adjustable fore and aft and up and down 4" in both direction.

6.3.2 Pedals and hand controls can remain constant in this layout.

6.3.3 It is also necessary to incline the two intersecting seat reference lines in order not to fatigue an operator in long durations of work.

APPENDIX 6

SAE XJ-2138 - HUMAN FACTORS - ROOF DRILLS

Submitted May 28, 1982

1. PURPOSE

This recommended practice is a guideline for the design of operator stations on rubber-tired, self-propelled electric powered roof drills (or roof bolting machines) used in underground mines.

2. SCOPE

2.1 These guidelines shall be applied to the design of new roof drilling machines.

2.2 These guidelines shall not be used to supplant the legal requirements established by, among other, Title 30, Code of Federal Regulations and Mine Safety and Health Administration (MSHA). Note that MSHA Technical Support, Bruceton, PA has authority for establishing control station design and location on roof drills. This guideline reflects current practices only.

2.3 The nature of roof bolting tasks require the operator to stand, kneel, squat, or sit adjacent to the machine control stations. Only while tramming between working places is the operator expected to be seated inside a compartment. Some machines provide compartments for all tasks.

Therefore, these guidelines stress the location and design of controls, the most common being lever actuated hydraulic valves. Operator workstation design features are included as Section 5.

3. DEFINITIONS

3.1 Roof Bolting Tasks

Roof drilling machines are used to drill holes in mine roofs and install roof bolts. Controls are generally arranged to accomplish these four tasks:

a. Moving the machine between working places, known as tramming.
b. Installing roof supports with Automated Temporary Roof Support (ATRS) systems if the machine is so equipped. Workstations may also be protected by moveable canopies and/or roof jacks (safety posts).
c. Repositioning the drill head between bolt locations in a lateral row of bolts or between rows.
d. Drilling holes and installing roof bolts.

3.2 Workstations

3.2.1 General

An operator's workstation is a location where control functions are performed. There are between one and six workstations on common coal mine roof drills as shown in Figure 1. An enclosed operator's compartment will usually be provided at the tram station.

3.2.2 Workstation Compartment

A substantially constructed cab or canopy shall be provided at the tram station as specified in Title 30 CFR. Canopies are required at all other workstation except when the machine is equipped with an Automated Temporary Roof Support (ATRS) system approved by MSHA.

Drilling, repositioning, and ATRS stations consist of controls mounted on the side of the machine frame. A

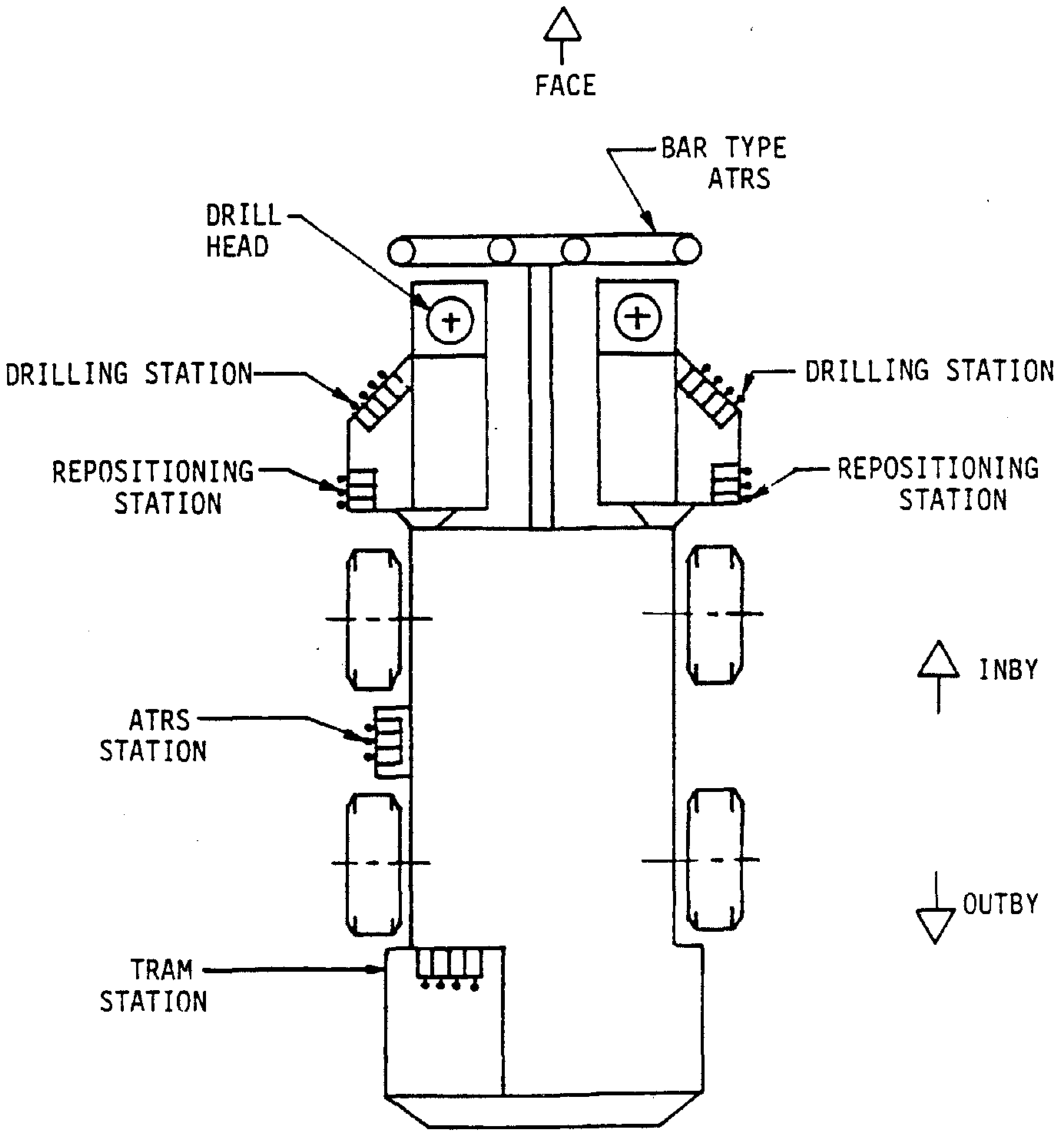


Figure 1. Generic Workstation Orientation

well-defined operator compartment is usually not provided; the operator stands or squats next to the machine on the mine floor.

Two different styles of ATRS systems are in common use. The bar-type supports the full width of the entry, permitting one or more complete rows of bolts to be installed without repositioning the machine or lowering the ATRS. The safety arm-type supports the roof around the drilling head but must be lowered to reposition for each bolt hole.

3.2.3 Workstation Controls

3.2.3.1 Several workstations may be grouped or co-located at certain locations depending on machine configuration.

3.2.3.2 Tram station

Except for low coal roof drills, a separate tram compartment shall contain all controls for moving the machine. Skid steer machines have two tram levers, left and right side, along with a brake lever. Steerable axle machines have automotive style steering wheel and foot pedal(s). Common controls include motor start/stop, gong, lighting, and cable reel.

3.2.3.3 ATRS station

If an ATRS is mounted on the roof drill a special workstation shall be provided. It shall be located so the operator is under supported roof (bolted) when the ATRS is lowered or raised. Additionally, controls for tramming the machine at limited speed (inch tram) between bolt rows may be located at this station.

3.2.3.4 Repositioning station

Repositioning controls move the drilling head laterally between bolt locations in a row. These are typically boom swing or mast slide functions. Small, single boom roof drills with fixed heads do not have repositioning controls. The location of the repositioning station depends on the ATRS confirguration as follows:

a. No ATRS - repositioning controls located at a convenient position close to the drill head.
b. Bar-type ATRS (not lowered while a row is bolted) - repositioning controls located at a convenient position close to the drill head.
c. Safety arm-type ATRS (lowered to relocate the drill head) - repositioning controls located under supported roof (bolted), usually about five feet behind the drill head.

3.2.3.5 Drilling station

Controls for drilling the hole and installing the roof bolt are located within reach of the drill head. Although it is desireable to keep the controls as far from the drill head as possible, the operator shall be capable of installing drilling tools and roof bolts into the chuck while manipulating the controls.

3.3 Common Control Terminology

Control names and definitions are given by workstation. A list of common descriptors used by roof drill manufacturers and suggested abbreviations appear in Table 1.

Table 1. Control Names and Labels

Typical Manufacturer Control Name	Control Suggested Name	Suggested Label
ATRS	ATRS Set	ATRS
ATRS Extend	ATRS Sump	ATRS SUMP
ATRS Fold	ATRS Fold	ATRS FOLD
ATRS Set	ATRS Set	ATRS
ATRS Sump	ATRS Sump	ATRS SUMP
ATRS Tilt	ATRS Fold	ATRS FOLD
Auger Clamp	Drill Guide	GUIDE
Auto Drill	Auto Drill	AUTO DRILL
Blower	Dust Collector	DUST
Bolt Torque	Bolt	BOLT
Boom	Feed	FEED
Boom Feed	Feed	FEED
Boom Extended	Sump	SUMP
Boom Lift	Boom Lift	LIFT
Boom Raise	Feed	FEED
Boom Roll	Boom Tilt	TILT
Boom Sump/Head Sump	Sump	SUMP
Boom Swing	Boom Swing	SWING
Boom Tilt	Boom Tilt	TILT
Boost	Fast Feed	F.FEED
Brake Lock	Parking Brake	PARK
Brake Pedal	Service Brake	BRAKE
Cable Reel	Reel	REEL
Canopy	Canopy	CANOPY
Centralizer	Drill Guide	GUIDE
Circuit Breaker	Circuit Breaker	CB
Cradle	Cradle	CRADLE
Cradle Lift	Cradle	CRADLE
Cradle Swing	Boom Swing	SWING
Diverter Valve	Diverter	DIVERT
Drill Guide	Drill Guide	GUIDE
Drill Head	Drill Rotate	DRILL
Drill Pot	Drill Rotate	DRILL
Drill Speed	Drill Speed	SPEED
Drill Thrust	Feed	FEED
Drilling Water	Drill Water	WATER
Drop Foot	Stab Jack	STAB
Drop Head	Drop Head	DROP HEAD
Dust Bin	Dust Bin	DUMP
Dust Collector	Dust Collector	DUST
Fast Feed	Fast Feed	F.FEED

Table 1. Control Names and Labels (Continued)

Typical Manufactuere Control Name	Control Suggested Name	Suggested Label
Feed	Feed	FEED
Fire Control	Fire Supression	FIRE
Floor Jack	Frame Jack (for machine)	JACK
Foot	Stab Jack	STAB
Frame Jack	Frame Jack	JACK
Front End Lift	Front End Lift	FRONT LIFT
Impactor	Impact	IMPACT
Inch Tram	Inch Tram	INCH
Left Tram	Left Tram	L.TRAM
Light Switch	Lights	LIGHTS
Main Power	Main Power	POWER
Mast Feed	Feed	FEED
Mast Lift	Mast Lift (not feed)	LIFT
Mast Rollover	Mast Roll	ROLL
Mast Slide	Slide	SLIDE
Operator's Deck	Deck Lift,Deck Slide	DECK
Oscillation	Impact	IMPACT
Panic Bar	Panic Bar	STOP
Parking Brake	Parking Brake	PARK
Percussion	Impactor	IMPACT
Positioning	Inch Tram	INCH
Power Take Off	Power Take Off	PTO
Pump Motor	Pump Motor	PUMP
Rear End Lift	Rear End Lift	REAR LIFT
Reel	Reel	REEL
Reel Speed	Reel Speed	REEL SP
Remote Tram	Inch Tram	TRAM
Resin Bolt	Resin Bolt	BOLT
Right Tram	Right Tram	R.TRAM
Rock Duster	Rock Duster	ROCK DUST
Rotation	Drill Rotate	DRILL
Safety Jack	Safety Post	POST
Safety Post	Safety Post	POST
Service Brake	Service Brake	BRAKE
Split/Combine Tram	Tram Speed	TRAM SPEED
Stab Jack	Stab Jack (for drill-arm)	STAB
Stab Jack	Frame Jack (for machine)	JACK
Stab Jack	Safety Post (roof jack)	POST
Start/Stop	Pump Motor	PUMP
Steering	Steer	STEER
Thrust	Feed	FEED
Tightener	Bolt Torque	BOLT
Tram Pedal	Tram	TRAM
Vacuum Pump	Dust Collector	DUST
Vibration	Impact	IMPACT

3.3.1 Drilling Station

- Drill rotate control is used to rotate drill head in forward (normal drilling) and reverse direction (optional).
- Feed control is used to raise or lower the drill head and to vary drill thrust rate.
- Torque control is used to select either drill or bolt torque pressure relief setting.
- Drill guide control is used to activate a device to collar the drill steel near the roof.
- Drill clamp control is used to activate a mechanism to secure the drill steel in the drill head.
- Fast feed control is used to increase the feed rate of the drill head.
- Drill speed control is used to change the drill rotation speed.
- Impactor control is used to activate impactor (or percussion) function.

3.3.2 Repositioning Station

- Boom swing (or mast slide) control is used to change the lateral position of the drill head.
- Sump control is used to move the drill head longitudinally along the machine or boom centerline.
- Canopy (or safety post) control is used to raise and lower a canopy (or safety post).
- Cradle (or drop mast) control is used to raise and lower a support under the drill head that transfers drill thrust loads into the floor.
- Boom tilt (or mast roll) control is used to roll the boom (or mast) for angle bolting.

3.3.3 ATRS Station

- Inch tram controls are used to tram the roof bolter at reduced speed, usually between 50 and 80 fpm, between rows of bolts.
- Stab jack control is used to raise and lower the frame jack, typically positioned under the machine frame or drilling boom to transmit thrust loads into the floor.
- ATRS set control is used to raise and lower the automated temporary roof support (ATRS).
- ATRS sump control is used to extend and retract the ATRS along the machine centerline.
- ATRS fold control is used to fold and unfold the ATRS for reduced tram height.
- Parking brake control is used to engage or release the parking brake.

3.3.4 Tramming Station

- Tram levers (left and right) are used for tramming and steering a squirm-steer roof bolter.
- Steering wheel is used to control the direction of travel of a roof bolter with a steerable axle.
- Tram pedal is used on steerable axle machines to regulate the tram speed.
- Tram canopy control is used to raise and lower the canopy over the tram station.
- Cable reel control is used to pick up and pay out the trailing cable.
- Diverter control is used to switch the flow of hydraulic oil from the tram function to the drill function or vice versa.
- Parking brake control is used to engage or release the parking brake.
- Service brake is used to slow machine tram motion.
- Tram direction control is used on steerable axle machines to select forward, reverse, or neutral.

3.3.5 Other Controls

- Main power control is a lever or switch for activating all electrical power to the machine.
- Pump motor start/stop switches are provided at tram stations.
- Machine lighting and head light switches are located where convenient.
- Fire suppression device actuators are located by appropriate codes.
- Panic bars are defined and located by Title 30 CFR.
- There may be other controls not specified by these lists.

3.4 <u>Control Arrangements</u>

3.4.1 Sequencing

Dual head roof drills have identical sets of controls located on the outside of booms or masts. They can be sequenced in the same left-to-right pattern, known as place arrangement, or in the same pattern relative to forward (or inby), known as mirror-image arrangement. Figure 2 illustrates these configurations.

3.4.2 Control Priorities

3.4.2.1 Primary controls are those most frequently used and shall be located within the operator's primary reach envelope. See Section 5 for these reach envelopes.

3.4.2.2 Secondrary controls are less frequently used and may be located within primary or secondary reach envelopes.

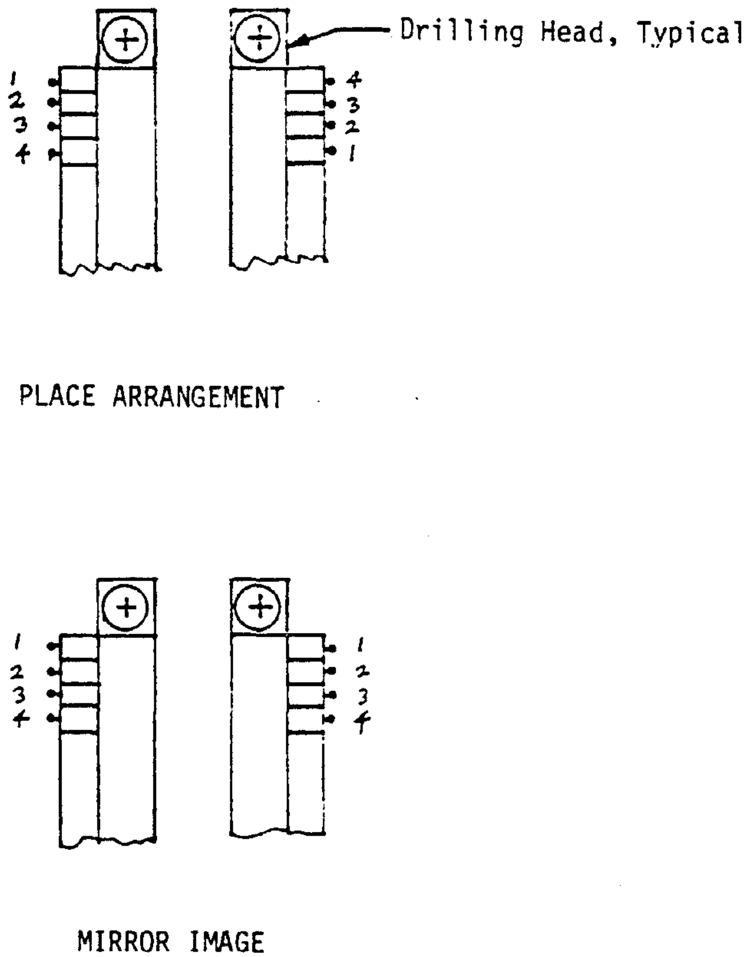


Figure 2. Control Sequencing Relative to Drill Head

3.4.2.3 Critical controls are infrequently used but must be easily distinguished from all other controls and easily actuated. They shall be located within the primary reach envelope but separated from normal control actuation patterns.

4. OPERATOR WORKSTATION GUIDELINES

4.1 Controls

4.1.1 Priorities

4.1.1.1 Primary controls shall be located within the operator's primary reach envelope. Primary controls include:

- Drill Rotate
- Feed
- Drill Guide/Clamp
- Canopy (Safety Post)
- Sump (Boom, Head)
- Cradle (Drop Mast, Stab Jack)
- Boom Swing (Mast Slide)
- ATRS Set
- Frame Jack
- Inch Tram
- Tram Levers

4.1.1.2 Secondary controls shall be located within either the primary or secondary reach envelope but shall not interfere with primary control activation patterns. Secondary controls include:

Bolt Torque	Tram Canopy
Drill Speed	Cable Reel
Impactor	Diverter
Tilt (Boom, Mast)	Steering Wheel
Fast Feed	Tram Pedal

ATRS Sump	Brake Pedal
ATRS Fold	Main Power
Parking Brake	Pump Motor
	Lighting

4.1.1.3 Critical controls shall be located in prominent positions within the primary reach envelope which facilitate identification and ease of actuation. Critical controls include:

Panic Bar
Brake Lever (Skid Steer)
Fire Suppression

4.1.2 Coding Technique

4.1.2.1 Coding by grouping and sequencing

Primary controls shall be coded by grouping and sequencing within the group. Sequencing within the groups shall be mirror-image where duplicate stations are provided and shall be sequenced with respect to the drill head. Groupings and sequencing are shown in Table 2.

4.1.2.2 Coding by tactile feel

Where practicable, primary control groups shall extend slightly above and beyond other controls to establish their significance. Each control group shall be identified by a shape-coded knob according to Table 2 and Figure 3.

4.1.2.3 Coding by sight

All controls, except those readily identifiable by their nature (such as the steering wheel), shall

Table 2. Control Grouping and Sequencing

Control Group	Sequence from Drill Head[1]	Control Name	Shape Code[2]
Drilling	1	Drill Guide/Clamp	—
	2	Drill Rotate	Yes
	3	Feed	—
Repositioning	1	Boom Swing/Mast Slide	Yes
	2	Cradle/Stab Jack/Drop Head	—
	3	Sump (Boom, Head)	—
	4	Canopy/Safety Post	—
ATRS	See Chart Below	Inch Tram (May be 2 Levers)	—
		Fram Jack/Stab Jack	—
		ATRS Set	Yes
Tram	—	See Section 4.1.6	—

[1]Drill head is forward, or inby, on the machine. For a vertical arrangement of levers, the sequence shall be from top (#1) to bottom.

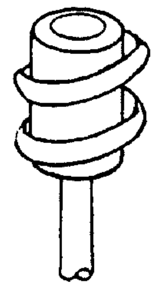
[2]See Figure 3 for shape code recommendations.

ATRS Station Sequence Chart

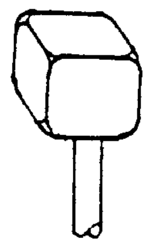
Lever Group Orientation	Sequenced From*	Sequence
Parallel to Machine Centerline	Drill Head	1. ATRS Set 2. Frame Jack/Stab 3. Inch Tram
Perpendicular to Machine Centerline	Machine Center	1. ATRS Set 2. Frame Jack/Stab 3. Inch Tram
Vertical	Bottom to Top	1. ATRS Set 2. Frame Jack/Stab 3. Inch Tram

*This orientation places the inch tram control(s) in the most convenient location for the operator (i.e., outward or on top) as he walks next to the machine.

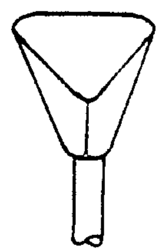
DRILL ROTATE



BOOM SWING



ATRS SET



Notes:

1. Knobs shall be the same relative size as adjacent primary control knobs.
2. Horizontal levers may take the form of square, triangular, or round bar (with wire wrap) that have tactile feel to a gloved operator for distinguishing from adjacent levers.
3. Round off all corners.

Figure 3. Shape Coded Knobs for Specific Controls

be labeled with the control name and direction of actuator motion. All control labels shall be clearly visible to the operator from his normal work posture and shall be of a permanent nature legible in the mining environment. Labels mounted on detachable levers are not recommended.

4.1.3 Direction of Motion

4.1.3.1 Lever motions for controls and the resulting machine or actuator direction of motion shall be as shown in Table 3.

4.1.3.2 Control direction of motion shall correspond with the resulting machine direction of motion as follows:

a. Where practicable, regardless of Table 3
b. Where the control station moves in response to control inputs, as with tram levers, boom swing/mast slide, boom sump, etc.

4.1.3.3 In general, the lever should be pushed to actuate the principle feature of the actuator. Therefore, horizontal levers should be pushed down or away from the operator to initiate principle functions. Angled levers falling between vertical and horizontal orientation shall be categorized as vertical or horizontal according to the push-to-actuate principle based on the normal operator position for that station.

4.1.4 Detented Handles

Unless required by machine function, all controls shall spring-return to neutral when released by the operator. Detented levers shall not be used for drill rotatiion, boom swing/mast slide, feed, tram, or resin bolt.

Table 3. Direction for Control Motion

Control Name	Lever Orientation[1]			
	Vertical		Horizontal	
Drill Rotate	In=Drill	Out=Rev	Up=Rev	Down=Drill
Feed[3]	In=Raise	Out=Lower	Up=Lower	Down=Raise
Torque	In=Drill	Out=Bolt	Up=Drill	Down=Bolt
Drill Guide/Clamp	In=On	Out=Off	Up=Off	Down=On
Fast Feed[3]	In=On	Out=Off	Up=Off	Down=On
Drill Speed[2]	CW=Slow	CCW=Fast	CW=Fast	CCW=Slow
Impactor	In=On	Out=Off	Up=Off	Down=On
Boom Swing/Mast Slide[3,4]	In=Away	Out=Toward	Up=Away	Down=Toward
Sump[4] (Boom/Head)	In=Out	Out=Back	Up=Out	Down=Back
Canopy/Safety Post[3]	In=Raise	Out=Lower	Up=Lower	Down=Raise
Cradle/Stab Jack	In=Raise	Out=Lower	Up=Raise	Down=Lower
Boom Tilt	In=CW	Out=CCW	Up=CW	Down=CCW
Inch Tram[3]	[4]	[4]	[4]	[4]
Stab Jack	In=Set	Out=Raise	Up=Raise	Down=Set
ATRS Set[3]	In=Set	Out=Lower	Up=Lower	Down=Set[3]
ATRS Sump[4]	In=Out	Out=Back	Up=Out	Down=Back
ATRS Fold	In=Unfold	Out=Fold	Up=Unfold	Down=Fold

[1]"In" means push away from the operator, "out" means pull toward the operator.

[2]CW=Clockwise, CCW=Counter Clockwise.

[3]These controls shall require a guard or interlock to prevent inadvertent activation by roof fall or by operator leaning against or climbing on the control station.

[4]See Section 4.1.3.2

4.1.5 Hands-Off Drilling

A reliable means of securing the rotating drill steel and bolt tightening wrench in the drilling head shall be provided to permit the operator to drill holes and install bolts without stabilizing the tools with his hand.

Additionally, a means of pulling stuck drill steels from the roof shall be provided.

4.1.6 Tram Controls

4.1.6.1 Tram control levers for skid-steer machines shall move in the same direction as machine movement. Lever location shall correspond with the machine side actuated, i.e., left lever actuates the left tram.

4.1.6.2 Steerable-axle machines shall be equipped with automotive style steering wheel and tram pedal(s). If two pedals are provided for tram speed and service brake functions, they shall both be actuated by the right foot and the brake pedal will be on the left side. Steering shall be consistent with the direction of travel if the operator reverses seat position.

4.1.7 Guarding

Unless protected by a canopy, all controls shall be guarded to prevent hand injuries from falling roof rock. Additionally, these controls shall be guarded to prevent inadvertent actuation from the operator leaning against or climbing on the controls:

Feed	Boom Swing/Mast Slide
Fast Feed	Tram Levers

4.1.8 Levers and Pedals

Recommended design limitations for pedals and levers are shown in Table 4.

4.2 Control Height vs. Posture

For lever actuation when the operator is standing, kneeling, or squatting on the floor, the optimum control height places the forearm level with the floor. This dimension can be determined experimentally using average-sized subjects. Operator posture depends on the mining height and is best determined empirically.

4.3 Visibility Assessment

The following points should be considered when the manufacturer assesses the visibility from various control stations:

Drilling Station and Repositioning Station

- Drill head for its full vertical travel
- Hole location at the roof line
- At least 10 feet (3 m) of the roof area inby the operator
- Rib area within a radius of 10 feet (3 m)
- Floor area adjacent to machine at drilling and ATRS station.

ATRS Station

- Roof area above ATRS, full entry width
- Floor area ahead of machine where practical
- Rib area on operator's side of machine
- Floor area adjacent to machine between drill and tram stations.

Table 4. Recommended Design Features for Levers and Pedals

Feature	Minimum	Maximum
<u>LEVERS</u>		
Knob Diameter, inches (mm)		
Finger Grasp	0.5 (13)	3.0 (76)
Hand Grasp	1.5 (38)	3.0 (76)
Separation, Centerline to Centerline, inches (mm)		
One Hand, Random Order	1.7 (44)	4.0 (102)
Two Hands, Simultaneously	3.0 (76)	6.0 (152)
Actuation Force, pounds (N)		
Hand Operatoed	—	10 (44)
Hand and Arm Operated	—	15 (67)
<u>PEDALS</u>		
Size, inches (mm)		
Length	3.5 (89)	—
Width	1.0 (25)	—
Displacement, inches (mm)		
Ankle Flexion	—	2.5 (64)
Leg Movement	1.0 (25)	7.0 (178)
Control Separation, Centerline to Centerline, inches (mm)		
One Foot, Randomly	4.0 (102)	6.0 (152)
One Foot, Sequentially	2.0 (51)	4.0 (102)
Actuation Force, pounds (N)		
Ankle Flexion	10 (44)	20 (89)
Leg Movement	10 (44)	50 (222)

Tram Station

- Cable handler (helper)
- Roof and rib areas at least 10 feet (3 m) ahead of machine
- Both ribs from above eye height
- Behind machine

4.4 Operator Protection

Valve banks and control levers shall be positioned so that the operator is located under supported roof or a canopy at all times. When the machine is positioned for the bolt closest to the rib, an escapeway clearance of 18 inches (457 mm) minimum shall be provided between the mine rib and the boom side.

4.5 Operator Envelopes

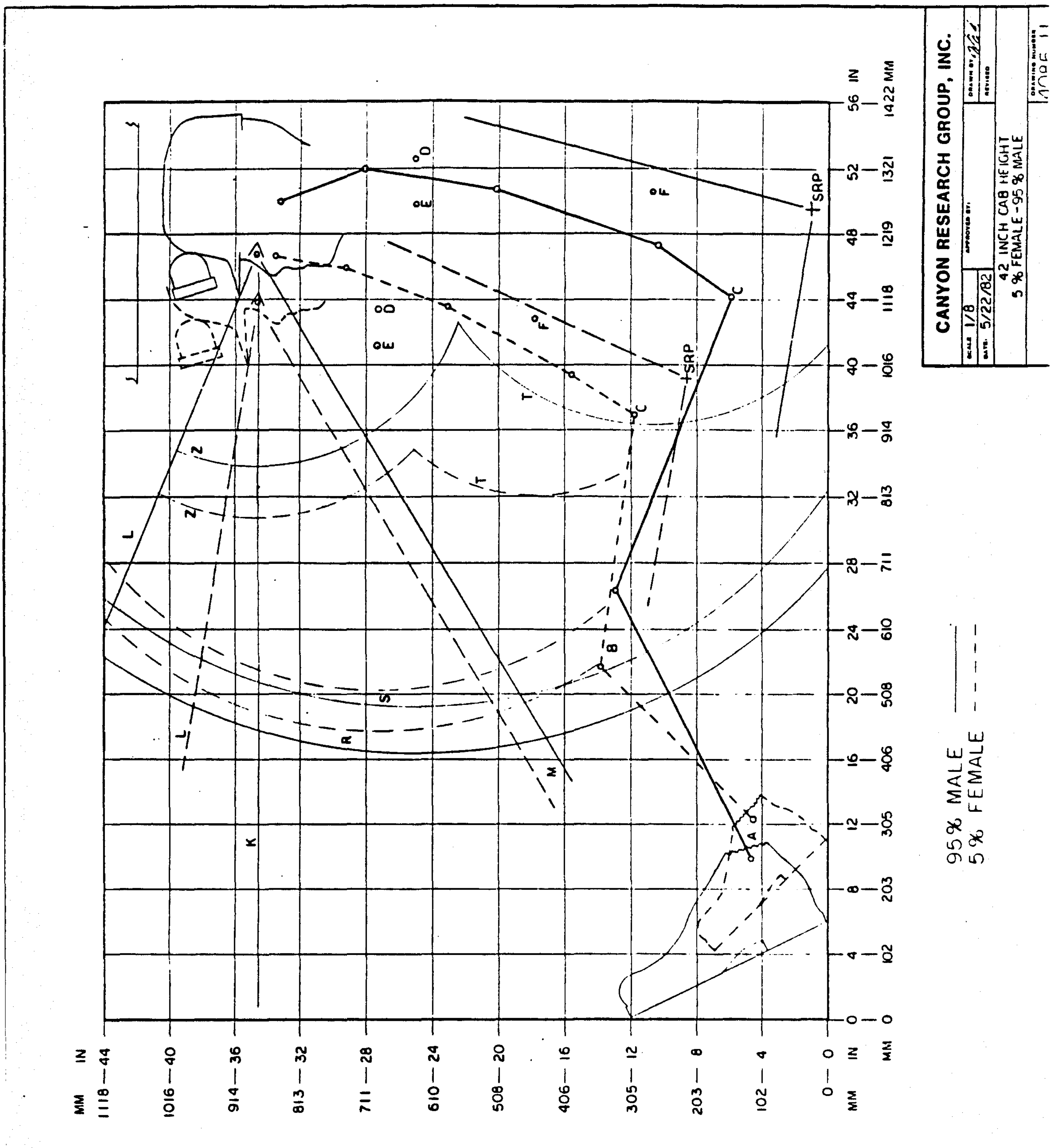
Operator enclosures shall be designed to accommodate a population ranging from 5th percentile female through 95th percentile male.

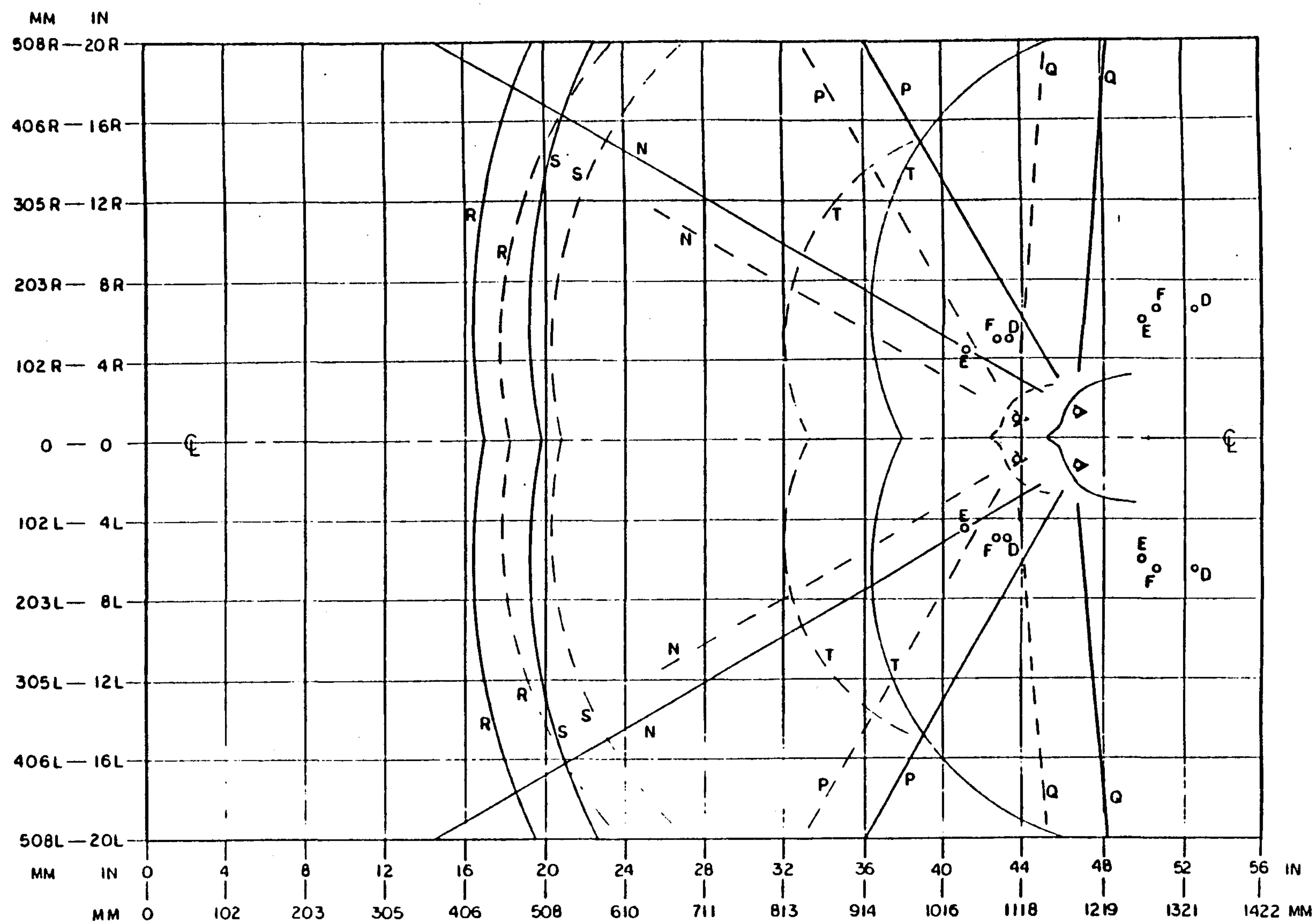
The attached drawings illustrate operator size accommodation requirements for three compartment heights. The grid provides a means of scaling information.

Compartment heights less than 26 inches (660 mm) are not recommended because the 95 percentile male operator cannot maintain the normal line of sight in a horizontal plane.

The following code letters are used on the operator enclosure drawings:

A. Ankle Point
B. Knee Point
C. Hip Point
D. Shoulder Point
E. Shoulder Extended
F. Elbow Point
K. Standard Line of Sight
L. Upper Line of Sight
M. Lower Line of Sight
N. Warning Display Vision
P. Controls and Display Vision
Q. Peripheral Vision
R. Maximum Control Reach
S. Maximum Control Grip
T. Minimum Control Grip
Z. Minimum Display Distance


CANYON RESEARCH GROUP, INC.
SCALE 1/8
DATE 5/22/82
42 INCH CAB HEIGHT
5 % FEMALE - 95 % MALE
95% MALE
5% FEMALE
SRP
MM IN
IN MM



95% MALE ———————

5% FEMALE — — — — —

CANYON RESEARCH GROUP, INC.

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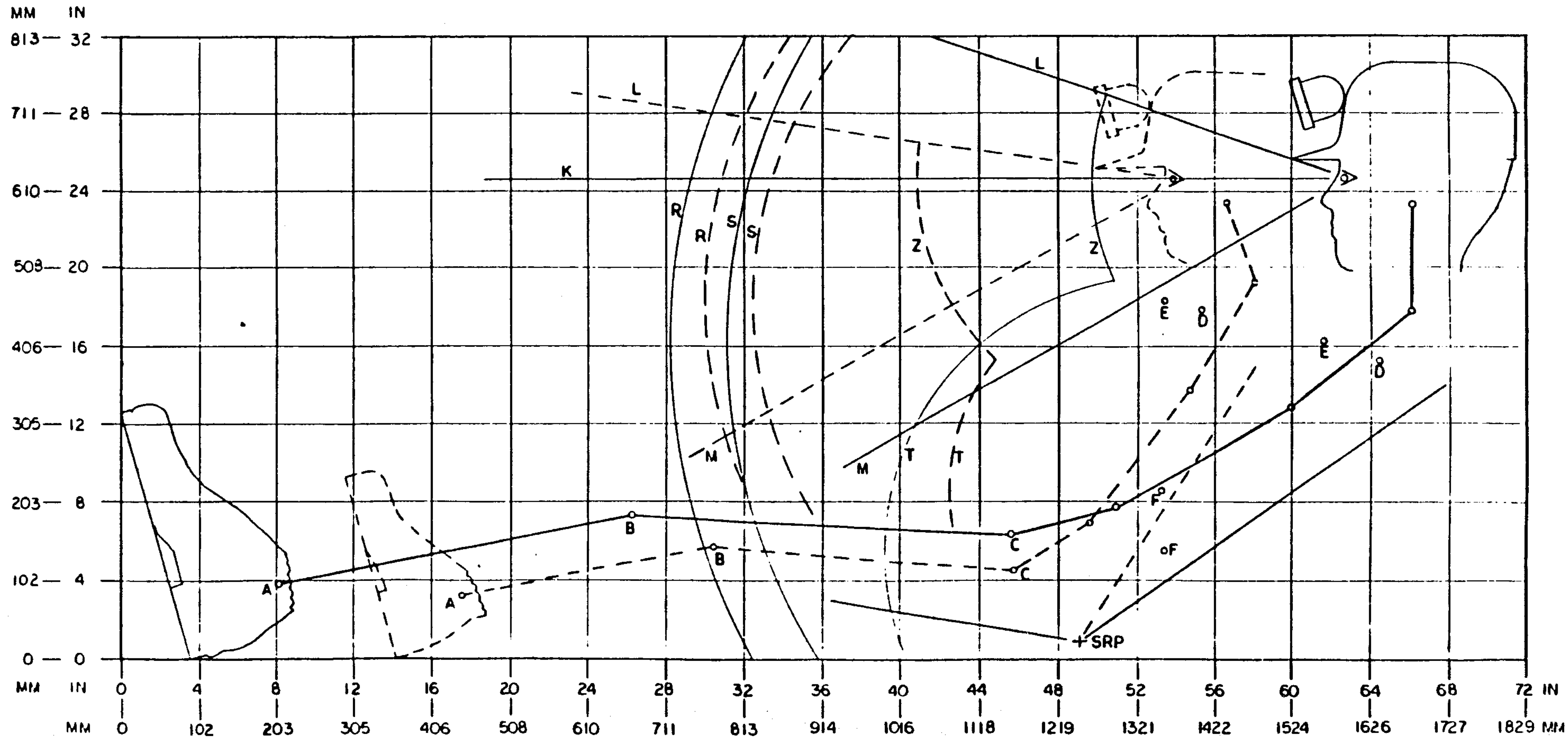
42 INCH CAB HEIGHT
5% FEMALE - 95% MALE
DRAWING NUMBER 4085-12



95 % MALE ——————
5 % FEMALE - - - - -

CANYON RESEARCH GROUP, INC.

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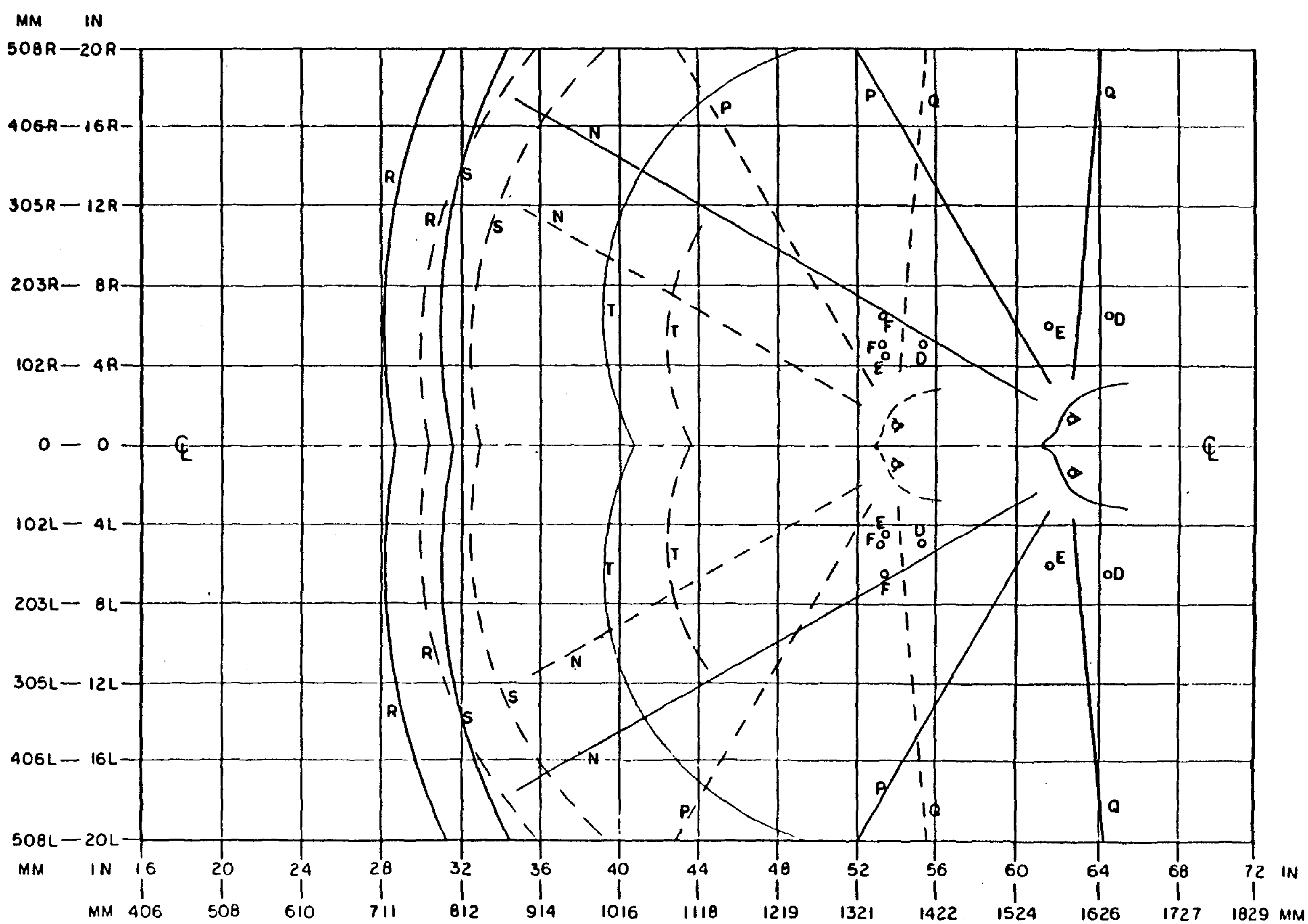

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5 % FEMALE — — — — —

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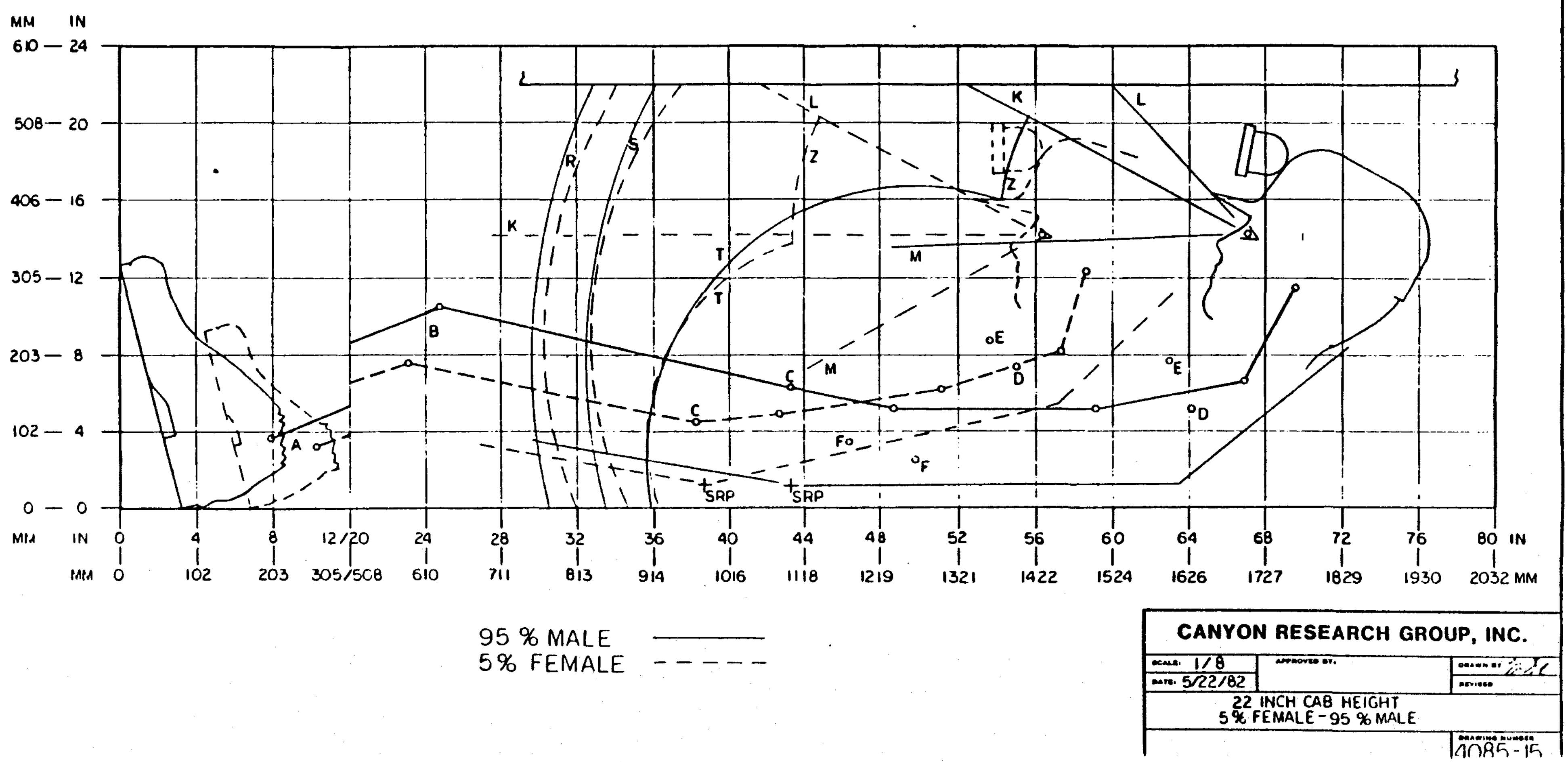
95 % MALE
5% FEMALE
CANYON RESEARCH GROUP, INC.
SCALE: 1/8
DATE: 5/22/82
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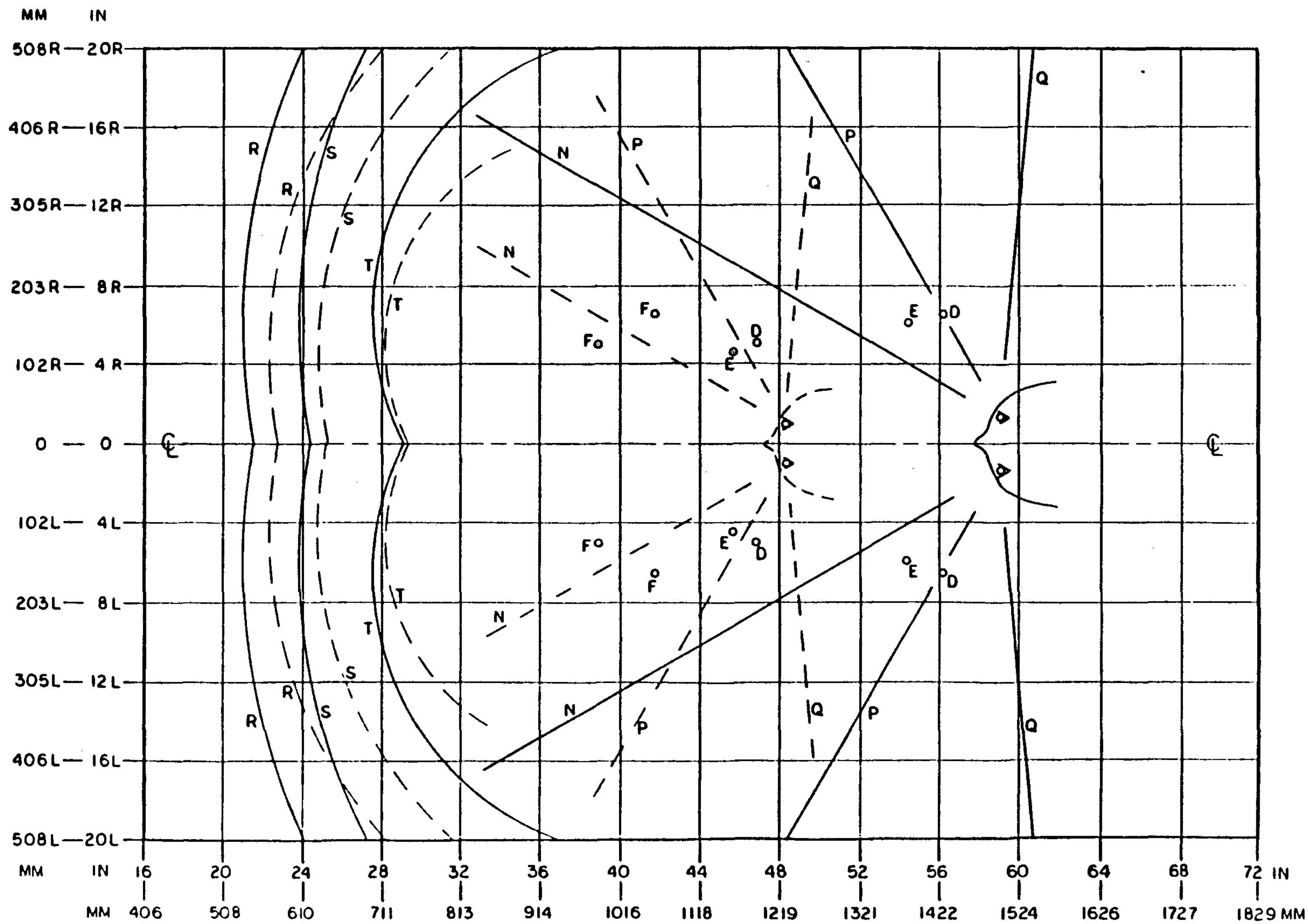
5% FEMALE - 95 % MALE
4085-15



95 % MALE ————

5 % FEMALE — — — —

CANYON RESEARCH GROUP, INC.

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DATE: 5/22/82		REVISED
22 INCH CAB HEIGHT 5 % FEMALE - 95 % MALE		DRAWING NUMBER: 4085-16

Development of SAE Guidelines
for
Roof Drills

HUMAN FACTORS DESIGN GUIDELINES
FOR ROOF DRILLS
MAY 1982
USBM CONTRACT NO. H0308110
XJ 1314

Prepared For:

Society of Automotive Engineers, Inc.
400 Commonwealth Drive
Warrendale, Pennsylvania 15096

Prepared By:

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APPENDIX 7

HUMAN FACTORS DESIGN GUIDELINES FOR MOBILE UNDERGROUND MINING EQUIPMENT
(Proposed SAE XJ1314)

Prepared For:

Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, Pennsylvania 15096

Prepared Under:

U.S. Bureau of Mines Contract
Number H0308110

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Essex Corporation
333 North Fairfax Street
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October 30, 1984

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PRELIMINARY DRAFT

1. PURPOSE

This recommended practice summarizes human engineering principles and standards applicable to the design of mobile mining equipment used in underground coal mines. It includes design recommendations to enhance operator efficiency, safety, and comfort. General recommendations applicable to all machines covered by this document are presented followed by recommendations unique to each category of equipment.

This recommended practice is intended for use in the design of new mining equipment. It may also be used for the redesign of existing machines. The guidance contained herein, however, does not supplant the requirements of civil authority such as Title 30, Code of Federal Regulations, Part 75.

2. SCOPE

The design recommendations presented here address workstation and operator compartment design, control design, visibility requirements, and other productivity and safety related equipment design for the following categories of mining machines:

- o Continuous Miners
- o Cutters
- o Face Drills
- o Loaders
- o Personnel Carriers
- o Roof Drills
- o Scoops and Ramcars
- o Shuttle Cars
- o Utility Vehicles

3. DEFINITIONS

The definitions and interpretations listed below have been used throughout this Recommended Practice. Where appropriate, reference has been made to relevant Society of Automotive Engineer (SAE) or other industry group definitions. Similiarly, relevant Federal Regulations have been referenced as appropriate.

ATRS — Automatic Temporary Roof Support System designed to provide bolter operators with temporary roof support while installing roof bolts.

Back Angle — Angle created by the seat pan and the backrest.

Backrest — Portion of the seat providing support for the operator's back from the hip to the shoulder.

Compartment Height — Height of the operator's compartment measured from the top of the floor pan to the bottom of the roof structure.

Control Force — Amount of muscle force required to activate a control.

Canopy — Overhead protective structure covering the mining machine workstation.

Control — Input device used to initiate, alter or terminate a machine function.

Display — Device or design feature designated to provide status, position, or condition information to the operator through visual or auditory feedback.

Drill Station — The primary workstation for the operator of a roof drill or face drill.

Eye Reference Point — A point located on the bridge of the nose and centered between the operator's eyes.

Foot Control — Control input device activated by left or right foot.

Foot - Lower Leg Angle — The angle between the lower leg and bottom plane of the foot.

Functional Grip — The distance from the shoulder pivot point to the center of the palm of the hand.

Functional Reach — The distance between the relaxed shoulder pivot point and the tip of the outstretched fingers.

Functional Reach Extended — Functional reach as measured with the shoulder pivot point extended as far forward as possible.

Hardhat — Hard protective helmet worn as protection against falling materials or impact.

Hardhat Minimum Clearance — The minimum two inch space between the miner's hardhat and the lower surface of the Canopy recommended by SAE J833 (Jan '80).

Knee Angle — The angle formed by the upper and the lower leg.

Maximum Grip — The maximum distance at which an operator can grip and operate a control with the shoulder fixed and arm extended to its forward most position.

Maximum Control Space — The acceptable space for infrequently used hand and foot controls as defined by SAE J898 (April 1980).

Maximum Rated Capacity — Maximum design load a vehicle is rated to handle.

Minimum Grip — The closest distance at which an operator can grip and operate a hand or foot control.

Necessary Stopping Distance — Distance required to bring a vehicle with maximum rated load traveling at maximum tramming speed to a stop, plus the distance the vehicle travels during the operator's two-second reaction time.

Normal Grip — Distance at which an operator can grip and operate a control without extending the shoulder.

Operator Compartment — Fully or partially enclosed operator workstation.

Operator Work-Station — Any location on a mining machine at which personnel routinely operate, tram or otherwise control machine functions.

Optimal Control Space — The space encompassed by the normal reach and normal grip range of an operator with shoulder pivot point held fixed.

Panic Bar — Emergency de-activate or de-energize device actuated by gross body movements or when brought into contact with a structure, a wall or the operator's body.

Percentile — Percentage of the population equal to or smaller than the dimension given.

Primary Controls — Most frequently used or most critical controls.

Primary Displays — Most frequently used or most critical displays.

Repositioning Station — A position other than a tram station at which a machine can be maneuvered in the work area.

Seat Pan — Bottom of a seat providing support to the buttocks and thighs.

Seat Pitch Angle — Angle between plane of the seat pan and plane of the compartment floor.

Seat Reference Point — The undeflected point at which the seat pan and backrest meet, located approximately 102mm to rear and 56mm below the hip point.

Secondary Controls — Less frequently used or less critical controls.

4. Workstation Design

An operator's workstation is defined as any location on a mining machine at which personnel routinely operate, tram or otherwise control machine functions. Table 1 identifies representative type of workstations for the eight categories of machines included here. This table will aid the reader in relating comments about specific workstations to applicable machine categories.

A number of human engineering design points should be addressed when designing workstations for underground coal mining equipment. The first is the physical size of the worksation itself and the operator's position within it. Since lower seam mines have insufficient seam height to permit an erect seated operator position, the operator must assume various reclined positions. This posture becomes more supine as seam height decreases. More fully reclined positions demand careful placement of hand and foot controls for operators in this biomechanically disadvantaged position. If the workstation does not have a seat, the operator may be required to stoop, kneel, or crouch in order to operate the machine. Again, attention must be paid to the design and placement of controls to ensure safe, efficient machine operation. If the workstation has a canopy over it, additional design allowances must be made for canopy support structures, operator visibility and operator head clearance while wearing a hardhat. Finally, the dimensions of the workstation must be sufficient to permit relatively free arm-to-control movements and operator ingress-egress.

A second factor involves the design and placement of the controls within the workstation. This is critical in confined areas where space for controls is limited and operator mobility restricted. Control activation force interacts with body posture, thus necessitating design forces that can be competently handled in a supine, semi-supine, or crouched position.

Table 1

Representative Workstations By Machine Type

	Operator Stations		Tram Stations		Drill Stations		Ancillary Stations	
Equipment Category	Reposition Station	Dual Position	Single Direction	Dual Direction	Single Position	Dual Position	Reposition Station	ATRS Station
LOADERS	X							
CUTTERS	X							
FACE DRILLS	X							
ROOF DRILLS			X		X	X	X	X
CONTINUOUS MINERS	X							
PERSONNEL CARRIERS	X	X	X	X				
SCOOPS & RAMCARS	X							
SHUTTLE CARS	X	X						
UTILITY VEHICLES	X							

A third factor is the operator's posture and body support within confined or supine workspaces. If the operator is reclined, additional support under the buttocks, back, and head should be provided to reduce control input errors, machine motion induced injuries, and operator fatigue. Design parameters such as seat pan angle, backrest angle, headrest angle, and seat position within the compartment must be considered in order to optimize control of the machine and ensure the protection of the operator.

A fourth factor is operator visibility. Workstations must be designed to permit operators minimally obstructed visual contact with critical work areas, machine components, workstation controls, displays, and other personnel.

Other factors to be addressed include operator isolation from vibration and noise, acceptable ingress-egress opening size, provisions for emergency escape routes, operator and passenger restraint systems on moving vehicles, protection of passengers on transport and utility vehicles, and accommodations for personnel safety equipment.

The following sections provide guidelines and "tools" for addressing the above issues. Supporting documents listed in the References section of this report contain additional information.

ANTHROPOMETRIC MEASUREMENTS

Of the hundreds of anthropometric measurements possible from the human body, 25 measures are required to design most operator workstations. Figure 1 summarizes relevant anthropometric measures for the design of mining equipment. The data presented are for the 5th percentile female and the 95th percentile male. Since the measures are for the lightly clothed individual with no miner's hardhat, battery pack, self-rescue unit or hand tools hanging from the belt, the values represent minimum dimensions for each size category.

Table 2 lists additional space requirements for various items of personal protective equipment typically found in the underground work environment.

Table 2

Supplemental Space Required For Personal Protective Equipment

Item Description	Add To	Height	Width	Length
Miner's Hard Hat	head	50mm (2")	50mm (2")	50mm (2")
Miner's Boots (leather)	foot	25-50mm (1 - 2")	25mm (1")	25mm (1")
Miner's Boots (rubber)	foot	12mm (¼")	12mm (¼")	12mm (¼")
Gloves (light)	hand	—	—	8-12mm (¼")
Gloves (heavy)	hand	12mm (¼")	12mm (½")	12mm (½")
Battery Pack	waist	—	50mm (2")	—
Self Rescuer	waist	—	87mm (3½")	—
Flame Safety Lamp	waist	—	50-65mm (2")	—
Breathing App. (self-contained)	waist	—	75-125mm (3 - 5")	—

Units in mm/(inches)

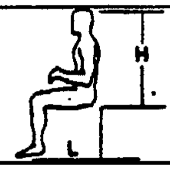
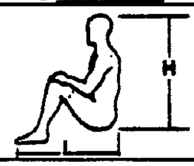
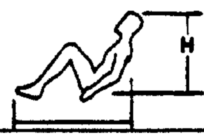
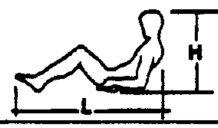
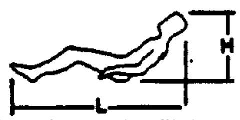
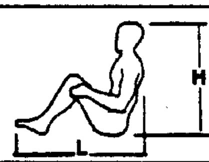
SEATED POSITION	BODY LENGTH (L)		HEIGHT (H)**	
	Minimun	Preferred	Minimum	Preferred
	940 mm (37 in.)	1000 mm (39.4 in.)	1025 mm (40.4 in.)	1100 mm (43.3 in)
	940 mm (37 in.)	1010 mm (39.8 in.)	980 mm (38.6 in.)	1100 mm (43.3 in.)
	1250 mm (49.2 in.)	1400 mm (55.1 in.)	640 mm (25.2 in.)	650 mm (25.6 in.)
	1500 mm (59.1 in.)	1600 mm (63 in.)	600 mm (23.6 in.)	620 mm (24.4 in.)
	1700 mm (66.9 in.)	1800 mm (70.9 in.)	500 mm (19.7 in.)	540 mm (21.3 in.)
	1875 mm (73.8 in.)	1950 mm (76.8 in.)	480 mm (18.9 in.)	520 mm (24.5 in.)
	2000 mm (78.7 in.)	2100 mm (82.7 in.)	360 mm (14.2 in.)	460 mm (18.1 in.)
	875 mm (34.4 in.)	900 mm (35.4 in.)	980 mm (38.6 in.)	1100 mm (43.3 in.)

TABLE 3

Body Lengths as a Function of Seated Postures

OPERATOR COMPARTMENT DIMENSIONS

The minimum interior height and length for a fully or partially enclosed operator's compartment (cab) is a function of the operator's size, seated posture, seat design, and control inputs required. The width of the compartment is impacted by seated posture, cab length, control placement, and control actions required.

Cab Height and Cab Length — Table 3 summarizes body length and seated heights for a number of work postures typically found on lower seam coal equipment. The minimum length shown is for the 50th percentile male with light clothes and boots. The heights shown includes the miner's hardhat and the recommended two-inch minimum clearance between the hat and the underside of the compartment roof.

Seated Operator Body Width — Shoulder breadth is the relevant anthropometric dimension needed for establishing seated width requirements for normally seated or supine personnel. For most individuals, shoulder width provides sufficient space for the accommodation of battery packs and small handtools hung from the belt. If personnel, however, sit cross-legged or with their knees to the chest, additional width is required.

Table 4 summarizes minimum and preferred compartment width for the 5th percentile female and the 95th percentile male miner. The values reflected in this table are for individuals with light clothing and carrying battery packs.

Table 4

Minimum And Recommended Compartment Width

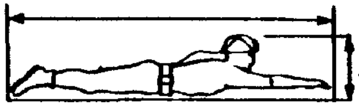
SEATED POSITION	MINIMUM 5th Percentile	RECOMMENDED 95th Percentile
Normal Seated	432mm (17.0 in.)	526mm (20.7 in.)
Cross Legged	650mm (25.6 in.)	750mm (29.5 in.)
Knees to Chest	600mm (23.6 in.)	625mm (24.6 in.)
Supine	450mm (18.0 in.)	560mm (22.0 in.)

(Ref 2 and 7)

Figure 1. Anthropometric Data For Representative Work Positions (Ref 1 and 2).

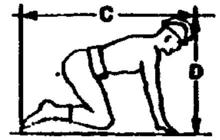
Prone

Prone height A	480 mm
Prone length B	2740 mm



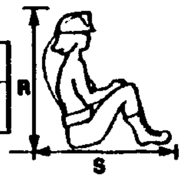
Kneeling

Dimension	
Kneeling length C	1415mm
Kneeling height D	1000mm



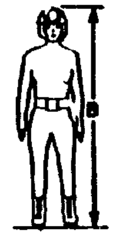
Seated (Confined)

Dimension		Men	Women
Seated height	R	973mm	854mm
Seated length	S	900mm	875mm



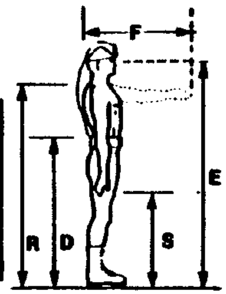
Standing

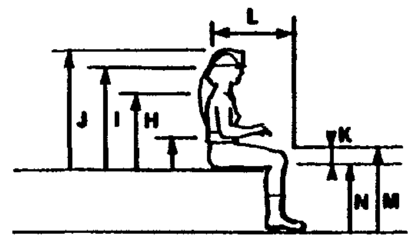
Dimension	Men			Women		
	5th	50th	95th	5th	50th	95th
Stature B	1640mm	1751mm	1861mm	1510mm	1625mm	1731mm



Reaching

Dimension		Men			Women		
		5th	50th	95th	5th	50th	95th
Shoulder height	D	1323mm	1427mm	1530mm	1219mm	1324mm	1429mm
Eye height	E	1526mm	1639mm	1751mm	1400mm	1508mm	1616mm
	F						
Elbow height	R	1006mm	1088mm	1171mm	912mm	993mm	1073mm
Fingertip height	S	601mm	660mm	718mm	542mm	599mm	657mm





Seated (Side View)

Dimension		Men			Women		
		5th	50th	95th	5th	50th	95th
Elbow rest height	G	196mm	230mm	284mm	188mm	229mm	270mm
Shoulder height	H	549mm	604mm	658mm	518mm	570mm	624mm
Eye height	I	745mm	805mm	865mm	661mm	744mm	800mm
Sitting height	J	857mm	915mm	973mm	798mm	854mm	913mm
Thigh clearance	K	127mm	152mm	177mm	104mm	139mm	174mm
Buttock-knee length	L	548mm	597mm	645mm	525mm	577mm	628mm
Knee height	M	500mm	546mm	591mm	480mm	502mm	543mm
Stool height	N	371mm	415mm	458mm	341mm	382mm	423mm

Seated (Front view)

Dimension		Men			Women		
		5th	50th	95th	5th	50th	95th
Shoulder breadth	P	420mm	462mm	504mm	374mm	419mm	464mm
Hip breadth	Q	321mm	360mm	400mm	319mm	377mm	434mm

Operator Reach and Visual Envelopes — Figures 2, 3, and 4 summarize seated operator arm reach and visual envelopes for representative 42", 32", and 22" high operator compartments, respectively. These values define the primary visual and reach envelope for the 5th percentile female and the 95th percentile male. It should be noted that as the cab height is decreased, the individual's primary visual envelope is reduced. This is the result of decreased head mobility resulting from the chin contacting the collar bone and the shoulder when moving from side to side and from restricted up and down head mobility.

OPERATOR COMPARTMENT INGRESS-EGRESS

For machines equipped with fully or partially enclosed operator compartments or tram stations, the ingress-egress opening should permit rapid unobstructed entry and exit. Table 5 summarizes recommended entry widths and heights for various common seam heights. In addition to the physical dimensions, the following entry design practices should be incorporated:

- o Operating controls should be designed and or located so that they cannot be kicked, bumped, or inadvertantly activated during operator ingress-egress.
- o Hand grips and foot holds should be provided to facilitate entry and exit, where possible, especially on lower-seam machines. Hand grips and footholds should not interfere with emergency egress.
- o Ingress-egress openings should be protected from potential fires, shocks, or mechanical hazards.
- o Entries should be designed to be free of blockage or obstruction created by other machine parts in the event of collision.
- o For 42" and lower-seam height machines, ingress-egress opening widths should be increased by 50 percent over the value listed in Table 5, if possible, to permit the operator to swing legs and feet into the compartment rather than having to entering feet first.

Table 5

Recommended Ingress-Egress Opening Dimensions

COMPARTMENT HEIGHT	ENTRY WIDTH		ENTRY HEIGHT	
	Minimum	Preferred	Minimum	Preferred
1219mm (48.0 in.) and Over	580mm (22.8 in.)	1200mm (47.2 in.)	1180mm (46.5 in.)	1500mm (59.1 in.)
914mm (36.0 in.) to 1219mm (48.0 in.)	660mm (26.0 in.)	1200mm (47.2 in.)	860mm (33.9 in.)	1050mm (41.3 in.)
914mm (36.0 in.) and Under	660mm (26.0 in.)	1500mm (59.1 in.)	580mm (22.8 in.)	860mm (33.8 in.)

(Adapted from Ref. 7 and Ref. 8)

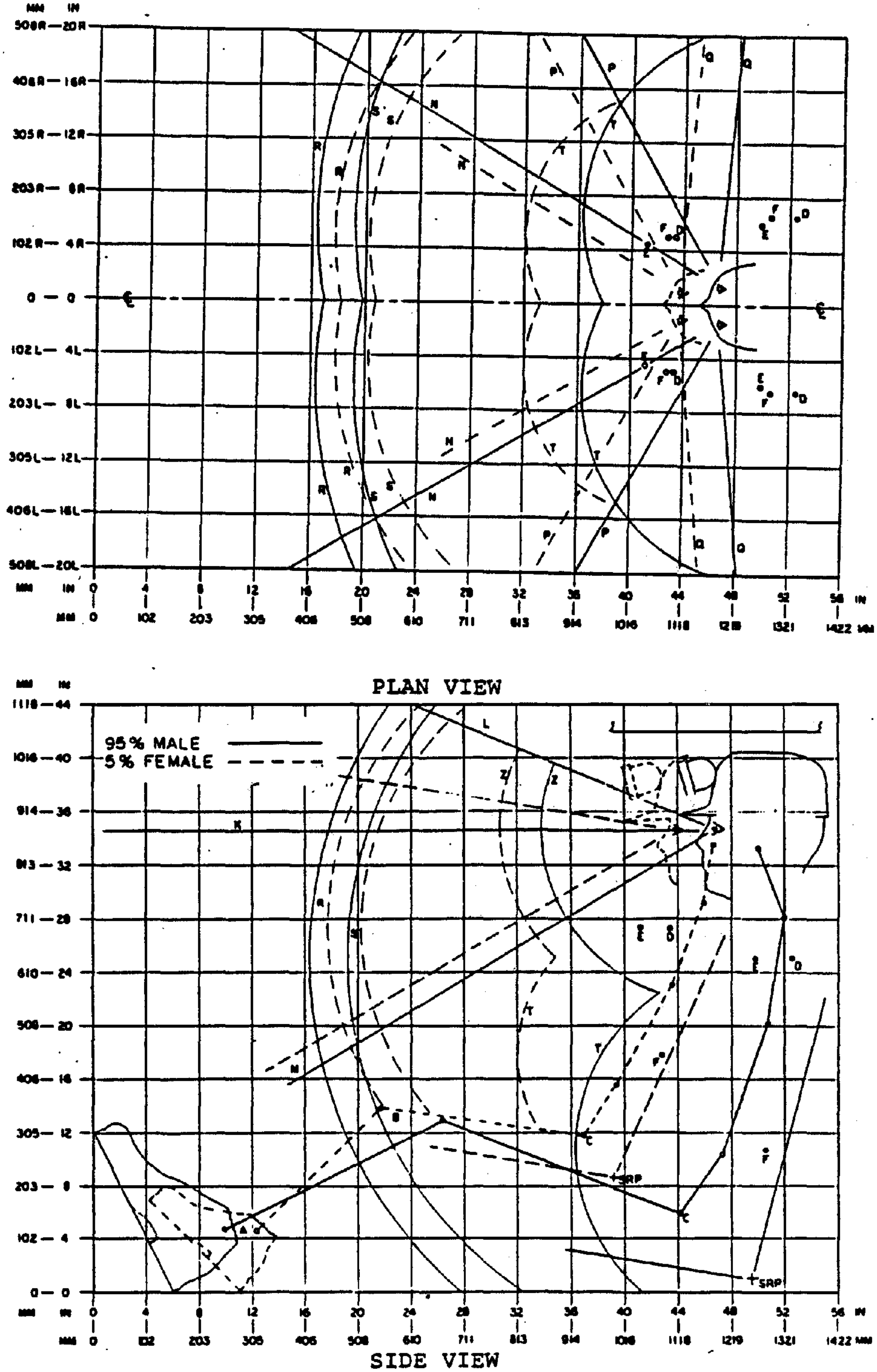
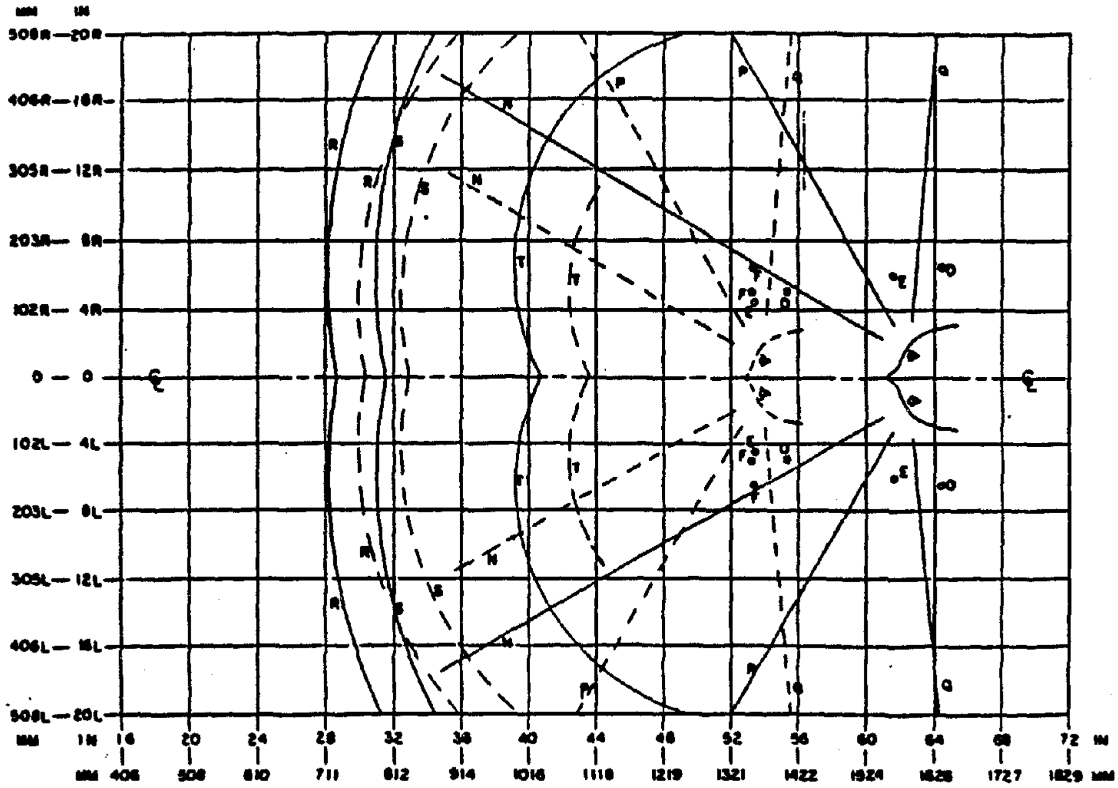
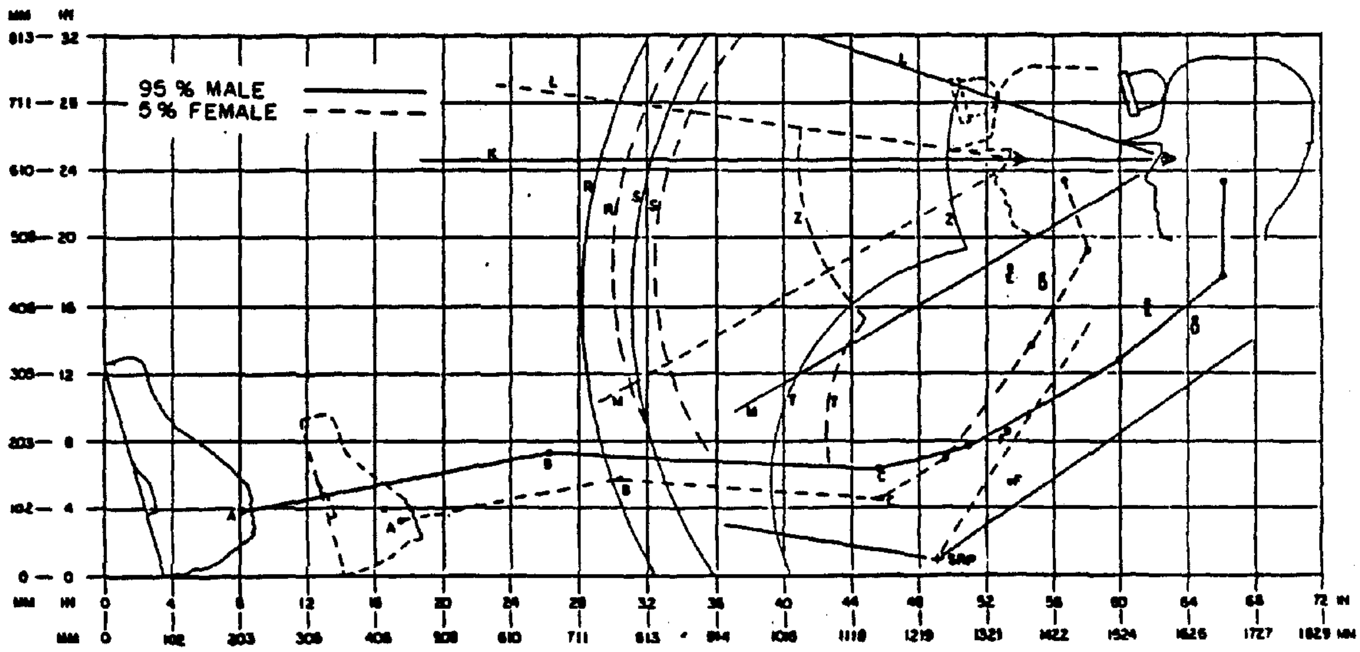


Figure 2: Visual & Reach Envelope For A 42" Cab.

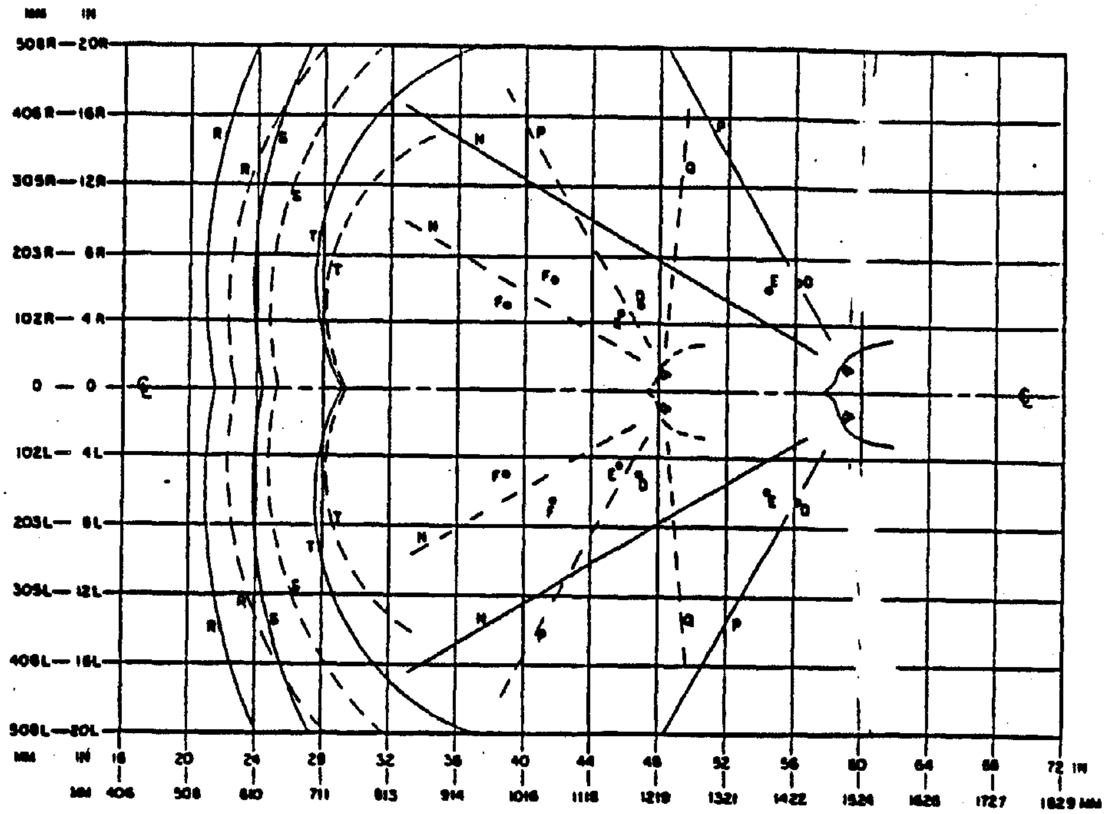


PLAN VIEW

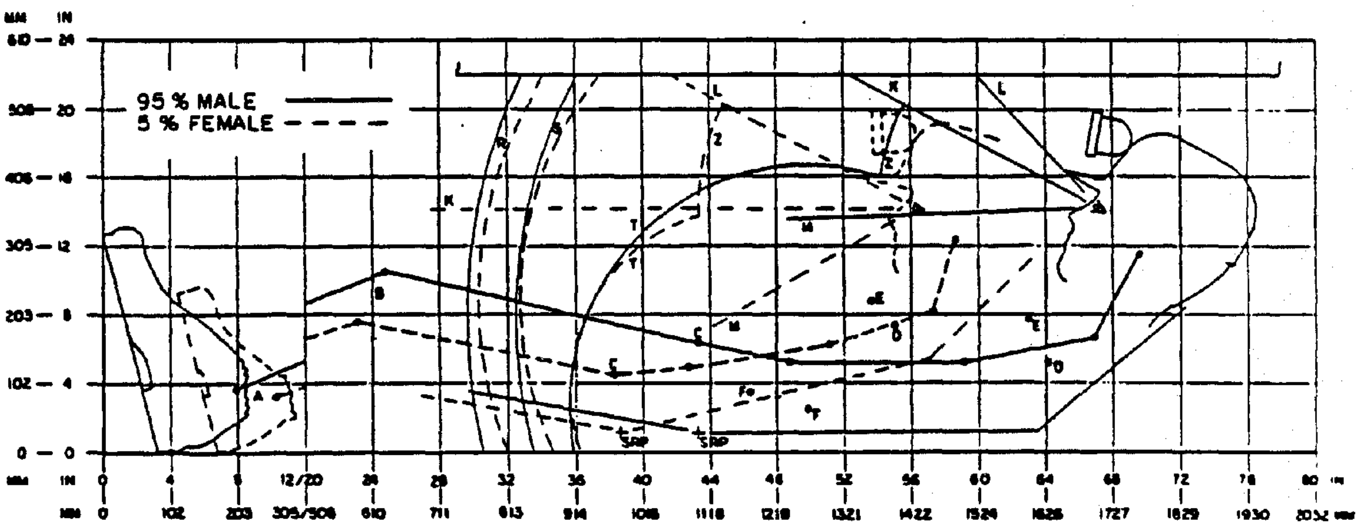


SIDE VIEW

Figure 3: Visual & Reach Envelopes For A 32" Cab.



PLAN VIEW



SIDE VIEW

Figure 4: Visual And Reach Envelopes For A 22" Cab.

EMERGENCY EGRESS

An emergency escape hatch, opening or route should be provided for enclosed operator or personnel compartments should the primary exit be blocked or otherwise rendered unusable. The emergency escape route should exit towards the rear of the vehicle or towards protected roof. Minimum emergency exit openings are summarized in Figure 5.

PASSENGER SPACE REQUIREMENTS

Table 6 summarizes recommended design space requirements for passengers riding on mobile mining equipment (exclusive of the machine operator). The values shown are for lightly clothed personnel with boots and miner's hardhats. Height requirements include the minimum two inch clearance between the hat and the underside of the compartment roof. The seated width requirements for the 38" compartment assumes the person's knees are next to the chest and the arms are wrapped around the legs.

OPERATOR PROTECTION

The folowing human engineering design recommendations focus on improving protection and efficiency. They should be incorporated, where possible, in the design of operator workstations.

Protective Canopy — The operator's compartment should be provided with a protective canopy as required in Section 75.2720-1, Title 30 of the Code of Federal regulations. The protective canopy should cover the minimum defined area as shown in Table 2 or as much of the operator's body as possible consistent with visual requirements of machine operation. Support structures for the protective canopy should not protrude into the operator's compartment.

Exposure of Operator's Body — The operator's compartment should be designed to insure that no part of the operator's body is exposed outside the canopy or the operator's compartment during normal machine operation.

Extension of Canopy and Floor — The side of the canopy and the operator's compartment floor should be extended a minimum of 10 inches beyond the side of the machine if the operator is required to look down the side of the vehicle or to reach out from under protection to perform job related tasks.

Operator Head Clearance — A minimum of two inches (2") clearance should be provided between the top of the miner's hardhat and the underside of the operator's compartment or the tram station roof.

Figure 5: Minimum Dimensions for Emergency Escape Openings (Ref 9).

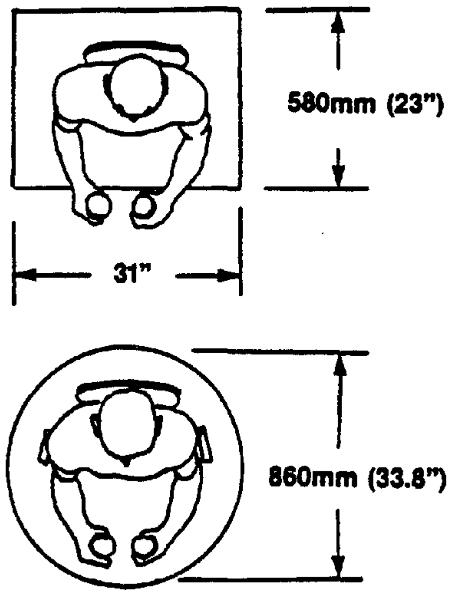


Table 6
Passenger Length, Width, and Height Space Requirements

Compart-ment height	Length		Width		Height	
	min.	pref.	min.	pref.	min.	pref.
48"	875 (34.4)	900 (35.4)	432 (17.0)	526 (20.7)	980 (38.6)	1100 (43.3)
38"	1500 (59.1)	1800 (70.9)	600 (23.6)	625 (24.6)	875 34.4)	900 (35.4)
28"	2000 (78.7)	2100 (82.7)	450 (18)	560 (22)	480 (18.9)	520 (24.5)

(Ref. 2)

Rib Roll Protection — Where possible, safety panels, heavy mesh screens, or other protective devices should be provided for side mounted compartments to protect the operator from rib rolls or from collisions with pillars while turning.

Panic Bars — Each operator work station should be equipped with a panic bar, emergency cut-off switch, or button that can be readily activated using gross hand or foot movements. If the moving machine or a machine component could entrap the operator against the face, the rib or the side of the machine itself, a panic bar should be installed so that entrapment cannot occur.

Operator Restraint Device — Seatbelts, access opening safety chains, doors, or other appropriate restraint devices should be installed on mobile equipment to prevent the operator from falling out or being thrown out of a machine while it is moving, maneuvering or in the event of a collision.

Protection from Spillage — Guards should be provided to protect the operator from spillage of materials from conveyor belts, scoop buckets, or other parts of the machine while loading, transporting, or discharging material.

Noise Protection — Table 7 summarizes permissible decibel levels and exposure durations as specified in CFR 30, Part 70, Subpart F (noise). The following recommendations are to assist in protecting the operator from excessive noise.

- Determine Potential noise Level — Potential noise in the operator's compartment or workstation area should be determined in compliance with the above cited regulation. Sources of excessive noise should also be identified.
- Isolate Operators Compartment — The operator's compartment should be isolated, where possible, from direct exposure to high noise sources by isolation, deflector shields, or other components.
- Improve Cab Design — The operator's compartment should be designed so as not to entrap noise, or to reflect secondary sources of noise into the compartment. Sound absorption and control materials should be installed where appropriate.
- Warnings — If the interior sound levels cannot be reduced to permissible levels during certain machine operations, signs should be conspicuously posted within the seated operator's primary field of view indicating that noise levels exceed permissible levels during these operations and cautioning the operators to wear hearing protection.

Table 7

Permissible Noise Exposure Levels Over Time

Duration Per Day (hours)	Noise Level (dBA)	Duration Per Day (hours)	Noise Level (dBA)
8	90	1-1¼	102
6	92	1	105
4	95	¾	107
3	97	½	110
2	100	¼ - less	115

(Ref. CFR 30, Part 70, Subpart F)

SEAT DESIGN

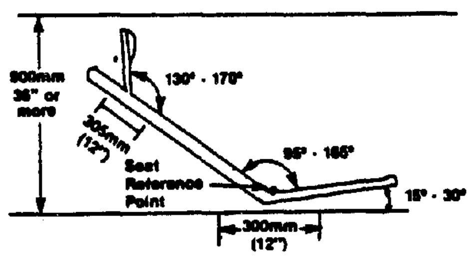
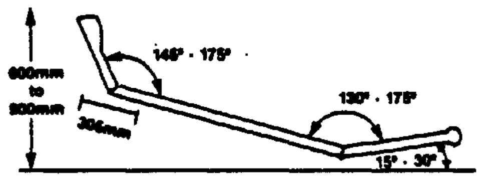
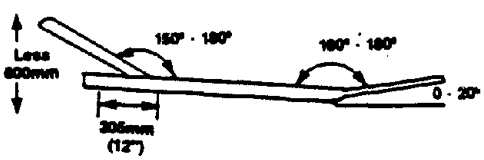
To accommodate the 5th percentile female through the 95th percentile male user, four seat design parameters are critical. These include:

- Pan to Seatback Angle — This angle will approach 90° as the seat back approaches the vertical position and will approach 180° in cabs designed for low seam mines.
- Pan Angle — The angle of the seat pan relative to the cab floor is important for comfort and for body support during rapid decelerations or collisions.
- Seat Back to Headrest Angle — In partially or fully reclined seats a headrest is needed to allow operators to effectively view their primary visual areas over extended periods of time.
- Length of Backrest — The length of the human back varies greatly. In order to accommodate a range of potential users, the length of the backrest should be adjustable, if possible.

Table 8 summarizes recommended seat design specifications for three compartment heights (over 36", 24"-36" and under 24"). These design values may be adapted to individual cab configurations as necessary. For those applications where it is not practical to include adjustable headrest-back-seat pan configuration, a curved transition from the headrest to back support with a radius of 24"-32" may be used. Care should be taken, however, to ensure that the operator's head is never locked into a position of more than 45° relative to the back.

Where possible, vibration isolation should be designed into the seat-cab installation to reduce operator exposure to machine vibration, bumps, jolts and other mechanical shock. An occupant restraint system or belt should also be incorporated to prevent the

TABLE 8
SEAT DESIGN AS A FUCNTION OF OPERATOR CAB HEIGHT

SEAT CONFIGURATION BY SEAM HEIGHT	PAN ANGLE FROM FLOOR	BACK TO PAN ANGLE	HEAD REST TO BACK ANGLE	HEAD REST TRAVEL ALONG BACK	SEAT WIDTH/ HEAD REST WIDTH	PAN LENGTH	HEIGHT OF BACK
	15 - 30°	100°- 165°	130° - 170°	177.8 mm (7")	456 - 510 mm (18"- 20") 306 mm (12")	375 - 400 mm (12" - 14")	400-600mm (16" - 24") Adjustable
	15° - 30°	130° - 175°	145° - 175°	177 - 8 (7")	456 - 510 (18" - 20") 306 (12")	375 - 400 (Adjustable)	400-600mm (16 - 24")
	0° - 20°	160° - 180°	150° - 180°	177 - 8 (7") 306 mm (12")	510 - 530 mm (20" - 22")	375 - 400mm (12" - 14")	400-600mm (16 - 24") (Adjustable)

operator from being thrown out of the cab during a turn or hard bump and to prevent the operator from being thrown into one end of the cab in the event of a collision.

Knee angle should be considered in designing reclined or supine seats when foot controls requiring large forces are used. For foot controls requiring 75 pounds or more of activation force, a knee angle of 135° or larger should be used.

VISIBILITY REQUIREMENTS

Visibility requirements define what the machine operator needs to see in order to safely and efficiently operate a mining machine. Visibility defines what the operator in a normal seated position can see. Several methods are available for determining visibility requirements (e.g., Sanders and Kelly, 1981) and for assessing visibility (e.g., SAE XJ1296, Sanders and Kelly, 1981).

Table 9 presents a summary of the minimum operator information requirements for the categories of mobile machines covered by this document. It is, however, important that operator visibility requirements be determined for each specific machine design. Unique machine design features may require that additional critical visual information be available to the operator.

MINIMUM TRAMMING VISIBILITY

When tramming, it is imperative that the operator be able to visually inspect the pathway in front of the moving vehicle for at least the necessary stopping distance (NSD). The NSD is defined as the distance needed to bring a vehicle travelling at maximum tram speed to a full stop using the service break plus the distance the vehicle travels at a maximum speed during the 2.0 second operator reaction time. Table 10 summarizes necessary stopping distances for various machine tram speeds. This represents the minimum forward visibility from the normally seated tram position.

TABLE 9
MINIMUM OPERATOR INFORMATION REQUIREMENTS

OPERATOR INFORMATION REQUIREMENTS	CONTINUOUS MINERS	CUTTERS	FACE DRILLS	LOADERS	PERSONNEL CARRIERS	ROOF DRILLS	SCOOPS/ RAM CARS	UTILITY VEHICLES
TRAMMING								
• POSITION RELATIVE TO RIB, ROOF, CORNER	X	X	X	X	X	X	X	X
• LOCATION OF OBSTACLE WITHIN NECESSARY STOPPING DISTANCE	X	X	X	X	X	X	X	X
• SPEED OF MOVEMENT	X	X	X	X	X	X	X	X
• LOCATION OF MACHINE WITHIN MINE	X	X	X	X	X	X	X	X
• CONDITION OF TRACK/ROADWAY	X	X	X	X	X	X	X	X
LOADING								
• POSITION OF TAIL BOOM RELATIVE TO HAULAGE CONVEYANCE	X							
• AVAILABLE HEAD SPACE REMAINING	X			X				
• RATE OF MATERIAL OFF TAIL BOOM	X			X				
• POSITION OF VEHICLE RELATIVE TO MINER				X				
• POSTION OF BLADE RELATIVE TO COAL PILE							X	
• LOCATION OF OBSTACLES & HAZARDS	X			X			X	
• POSITION & HEIGHT OF LOAD ON VEHICLE	X			X			X	
• POSITION OF VEHICLE RELATIVE TO ROOF SUPPORT	X			X			X	
• CONDITION OF ROOF, RIB AND FACE	X			X			X	
DUMPING								
• POSITON RELATIVE TO DUMP SITE				X			X	
• POSITION OF LOAD ON VEHICLE				X			X	X
• LOCATION OF OBSTACLE & HAZARDS				X			X	X
• STATUS OF DUMP SITE				X			X	X
EXCAVATION								
• POSITION OF CUTTING HEAD/BAR	X	X	X					
• ALIGNMENT OF HEAD TO WORKING FACE	X	X	X					
• LOCATION RELATIVE TO ROOF SUPPORT	X	X	X					
• RATE OF CUTTING COAL FROM FACE	X	X						
• CONDITION OF WORK FACE	X						X	
DRILLING								
• POSITION OF SPOT TO BE DRILLED			X			X		
• PROGRESS OF DRILL INTO ROOF OR FACE			X			X		
• LOCATION/ACTIONS OF 2ND OPERATOR			X			X		
• POSITION RELATIVE TO ROOF			X			X		
• OBSTACLES AND HAZARDS IN WORK PLACE:			X			X		
• OBSERVING TEMPORARY SUPPORT SYSTEM FROM CONTROL POSITION						X		

Table 10

Necessary Stopping Distance Based On SAE XJ1329

MAXIMUM TRAM SPEED (mph)	REACTION TIME DISTANCE (ft)*	+	BRAKING DISTANCE (ft)**	=	NECESSARY STOPPING DISTANCE (ft)***
1	3.0		0.7		10.0
2	6.0		1.4		10.0
2.5	7.0		1.8		10.0
3	9.0		2.3		11.0
4	12.0		3.4		15.0
5	15.0		4.7		20.0
6	18.0		6.1		24.0
7	21.0		7.7		29.0
8	23.0		9.5		33.0
9	26.0		11.4		37.0
10	29.0		13.5		43.0

(Adopted From Ref. 11)

NOTE: * Assumes 2 second reaction time.

** From SAE Subcommittee 29, Working Group 8: Brake Standards for Underground Machines.

*** Values rounded off to nearest whole number. Value less than 10 ft. are assigned a value of 10 ft.

DESIGN OF CONTROLS

The principal human engineering considerations in the design of controls include; direction of control input motion, physical size and separation of control input devices, control lever displacement distances, control activation forces and control mounting angle. This section presents a summary of design recommendations for hand and foot activated controls.

DIRECTION OF MOTION

Table 11 summarizes recommended control input actions or direction of motion to elicit specific machine responses. These control inputs correspond to existing cultural sterotypes and assist in reducing control activation errors.

HAND OPERATED CONTROLS

Table 12 summarizes human engineering recommendations for the design of hand operated controls. In general, knobs, rotary switches, and small panel mounted levers should be used for mode/rate selection functions. Hand operated levers such as hydraulic valve controls should be used to initiate system functions, increase speed and to raise/lower equipment components. Floor mounted hand levers should be used where large activation forces or large displacements are needed.

FOOT ACTIVATED CONTROLS

Table 13 summarizes activation forces, dimensions, separation and displacement recommendations for foot activated controls. Foot controls should be used when high activation force or prolonged activation (e.g., in excess of 5.0 seconds) is required. Foot controls may also be used to distribute operator functions to avoid too many hand control functions. Foot activated controls should not be used when the operator is standing on a moving vehicle, when the control location causes the user to hold his/her leg in an awkward or raised position or when rapid vehicle deceleration could impare the control function.

Except for controls which generate continuous outputs, all foot pedals should return to the original null position when the operator's foot is removed. If a control is located where the operator may rest his/her foot on it between uses, sufficient spring tension to prevent the weight of the foot from inadvertently activating the control (i.e., 44N or 10 pounds) shall be provided.

Foot pedals should not be used for vehicle accelerators or brakes when the operator is seated in a sharply reclined (60^{o} or more) or in a supine position. Likewise, foot controls should not be used for a sharply reclined or supine operator when activation forces greater than 500N (112 pounds) are required.

Foot activated switches should be located for activation by the toe and ball of the foot rather than the heel. A pad/pedal may be used atop the switch to aid in locating it. A positive indication of activation should be provided, such as an audible click or snapping feel. Only one foot activated switch should be used for each foot.

Table 11

Recommended Control Motions

Control Device	Direction of Input/Response	
Foot Pedals	PUSH to:	Activate Accelerate (forward) Apply brakes Activate retarders Turn on/off Engage a function
	RELEASE to:	Deactivate Decelerate Release Disengage
Levers	PUSH to: (forward)	Move forward Increase Lower Activate
	PULL to: (backwards)	Stop Move backwards Engage brakes Raise
Pushbuttons	PUSH to:	Engage/disengage
Rotary Switches	TURN to: (clockwise)	Increase speed/volume
Toggle Switches	PUSH UP to:	Select a Function Activate
	Push DOWN:	DEACTIVATE
Emergency Cutoff Button/Switches	PUSH to:	Deactivate
Cranks/Wheels	TURN RIGHT:	Start Increase Speed Turn to right

TABLE 12
HAND CONTROL DESIGN SPECIFICATIONS

HAND CRANKS						
RPM	Handle Length	Handle Diameter	Max. Radius	Min. Radius	Max. Resistance	Min. Resistance
0 - 175	95 mm (3.75")	25 mm (1.0")	410 mm (16")	230 mm (9")	9 N (2 lbs.)	220 N (50 lbs.)
175 - 275	95 mm (3.75")	25 mm (1.0 ")	200 mm (8")	125 mm (5")	27 N (60 lbs.)	67 N (15 lbs.)
275 up	38 mm (1.5")	13 mm (0.5")	145 mm (4.5")	13 mm (.5")	9 N (2 lbs.)	22 N (5 lbs.)

KNOB DIAMETER		
	Finger Grasp	Hand Grasp
Minimum	13 mm (0.5 inches)	38 mm (1.5 inches)
Maximum	75 mm (3.0 inches)	75 mm (3.0 inches)

HANDWHEEL				
	Wheel Diameter		Resistance	
	1 Hand	2 Hand	1 Hand	2 Hand
Minimum	50 mm (2")	180 (7")	22 N (5 lbs.)	22 N (5 lbs.)
Maximum	110 mm (4.25")	530 (21")	133 N (30 lbs.)	220 N (50 lbs.)

HAND-OPERATED LEVER DISPLACEMENT				
	Seat Back 90° - 60°		Seat Back 60° - 0°	
	Lateral	Fore-Aft	Lateral	Fore-Aft
Maximum	970 mm (38 in.)	360 mm (14 in.)	360 mm (14 in.)	180 mm (7 in.)

HAND GRIP FOR HAND/ARM LEVERS	
Minimum Diameter	19 mm (.75 inches)
Maximum Diameter	38 mm (1.5 inches)
Minimum Length	95 mm (3.7 inches)

HAND-AND-ARM OPERATED LEVER DISPLACEMENT		
	Seat Back 90° - 45°	Seat Back 45° - 0°
Maximum	90° or 914 mm (36 inches)	45° or 457 mm (18 inches)
Preferred	60° or 610 mm (24 inches)	30° or 305 mm (12 inches)

HAND-OPERATED LEVER RESISTANCE	
Hydraulic Valve	
Minimum	9 N (2 lbs.)
Maximum	135 N (30 lbs.)

HAND-AND-ARM OPERATED LEVER RESISTANCE		
	Seat Back 90° - 45°	Seat Back 45°
Minimum	22 N (5 lbs.)	11 N (2.5 lbs.)
Maximum	222 N (50 lbs.)	111 N (25 lbs.)
Preferred	111 N (25 lbs.)	44 N (10 lbs.)

PUSH BUTTONS				
	Dia. Finger Operated	Dia. Hand Operated	Resistance	Diameter
Min.	10 mm (.25")	19 mm (.75")	2.8 N (10 oz)	9 mm (.325")
Max.	19 mm (.75")	—	11 N (40 oz)	43 mm (1.7")

CONTROL SEPARATION		
	One-Hand	Two-Hand
Minimum	50 mm (2 inches)	75 mm (3 inches)
Preferred	100 mm (4 inches)	125 mm (5 inches)

(Adopted From Ref. 2 and Ref. 8)

TABLE 13
FOOT ACTUATED CONTROL DESIGN FEATURES

FOOT CONTROL ACTIVATION FORCE				
	Normally Seated Operator 90° - 45°		Reclined or Supine Operator 45° - 0°	
	Minimum	Maximum	Minimum	Maximum
Foot Not Resting on Pedal	18 N (4 lbs.)	90 N (20 lbs.)	18 N (4 lbs.)	90 N (20 lbs.)
Foot Resting on Pedal	45 N (10 lbs.)	90 N (20 lbs.)	18 N (4 lbs.)	90 N (20 lbs.)
Ankle Flexion only to Activate	—	45 N (10 lbs.)	18 N (4 lbs.)	45 N (10 lbs.)
Total Leg Movement Required to Activate	45 N (10 lbs.)	800 N (180 lbs.)	45 N (10 lbs.)	400 N(90 lbs.)

CONTROL DISPLACEMENT AND SEPARATION				
	Normally Seated Operator 90° - 45°		Reclined or Supine Operator 45° - 0°	
	Minimum	Maximum	Minimum	Maximum
With Heavy Boots	25 mm (1.0 inch)	65 mm (2.5 inches)	25 mm (1.0 inch)	65 mm (2.5 inches)
Ankle Flexion	25 mm (1.0 inch)	65 mm (2.5 inches)	25 mm (1.0 inch)	65 mm (2.5 inches)
Total Leg Movement	25 mm (1.0 inch)	180 mm (7 inches)	25 mm (1.0 inch)	100 mm (4 inches)

PEDAL SEPARATION		
Type of Use	Minimum	Maximum
One-Foot Random	100 mm (4 inches)	150 mm (6 inches)
One-Foot Sequential	50 mm (2 inches)	100 mm (4 inches)

PEDAL ANGLE	
Seat Back	Pedal Angle*
Normal	75° to 90°
Reclined	45° to 60°
Supine	30° to 45°

(Adopted From Ref. 2 and Ref. 8)

*From Vertical

Table 14

Relative Advantages And Disadvantages of Various Methods of Control Coding

ADVANTAGES	TYPE OF CODING: LOCATION	SHAPE	SIZE	MODE OF OPERATION	LABELING	COLOR
IMPROVES VISUAL IDENTIFICATION.	X	X	X		X	X
IMPROVES NONVISUAL IDENTIFICATION (TACTUAL AND KINESTHETIC).	X	X	X	X		
HELPS STANDARDIZATION.	X	X	X	X	X	X
AIDS IDENTIFICATION UNDER LOW LEVELS OF ILLUMINATION AND AND COLORED LIGHTING.	X	X	X	X	(When trans-illuminated)	(When trans-illuminated)
MAY AID IN IDENTIFYING CONTROL POSITION (SETTINGS).		X		X	X	
REQUIRES LITTLE IF ANY TRAINING: IS NOT SUBJECT TO FORGETTING.					X	
DISADVANTAGES						
MAY REQUIRE EXTRA SPACE.	X	X	X	X	X	
AFFECTS MANIPULATION OF THE CONTROL (EASE OF USE).	X	X	X	X		
LIMITED IN NUMBER OF AVAIL. CODING CATEGORIES.	X	X	X	X		X
MAY BE LESS EFFECTIVE IF OPERATOR WEARS GLOVES.		X	X	X		
CONTROLS MUST BE VIEWED (I.E., MUST BE WITHIN VISUAL AREAS AND WITH ADEQUATE ILLUMINATION PRESENT).					X	X

CONTROL CODING

Coding methods such as location, shape, size, mode of operation, labeling and color should be applied to minimize operator error. Two or more coding techniques may be used simultaneously to enhance discrimination of controls. Table 14 summarizes the advantages and disadvantages of each type of coding.

LIMB SUPPORT

Appropriate limb support should be provided for panel, sidewall, roof, or floor mounted controls as summarized in Table 15. If limb support can be provided by the control input device itself, and if prolonged periods of control activation are not required, additional limb support may not be required.

If the operator is in a supine or reclined position, foot action other than ball-toe movement should not be required. Similiarly, foot activated controls should not be used to control machine tram functions unless provisions are made so that one foot is fixed to provide operator body support during rapid deceleration.

Table 15

Recommended Support for Hands and Feet

Type of Control Input	Location of Support
Large Hand Movement	Elbow
Small Hand Movement	Forearm
Finger Movement	Wrist Area
Foot Movement	Heel of Foot
Knee (side motion)	Heel of Foot

CONTROL LAYOUT

Several methods are available for optimally locating controls in a workstation (ref 14). In brief, these methodologies include the following steps:

- Conduct Task Analysis — Walk-through operation of the machine with the proposed control configuration and determine the frequency and criticality of each control action, control input patterns, and identify potential safety related problems.

- o Prioritize Controls — Prioritize controls on the basis of frequency of use and criticality in completing task.
- o Group Controls Based on Priority — Group controls as either primary, secondary, or tertiary with respect to task completion and operator safety. Primary controls are frequency used controls and/or controls critical to the completion of the task. Secondary controls are less frequently used controls not used in completing primary task. Tertiary controls are controls not frequently used and not task related.
- o Layout of Primary Controls — Configure primary controls in the operator's primary reach and visual envelope as defined by Figures 6, 7, and 8. Primary displays should be configured within 15 degrees laterally of the operator's median plane and within 30 degrees vertically from the normal line of sight from the seated or designated work position. Task related controls should be grouped together and sequenced to correspond to actual sequence needed to complete the task cycle. Safety related or emergency controls should be located proximal to most frequently used controls or to the controls they counteract.
- o Layout of Secondary Controls — The less frequently used controls and displays should be located in the operator's secondary reach and visual envelopes. The secondary visual envelope is defined as 30 degrees laterlly on either side of the operator's median and within 30 degrees vertically of the normal line of sight.
- o Tertiary Controls — Tertiary controls and displays are noncritical or infrequently used, or maintenance related units and may be located outside the operator's primary envelopes. If located within the workstation, they may be located within 94 degrees of the operator's median plane.

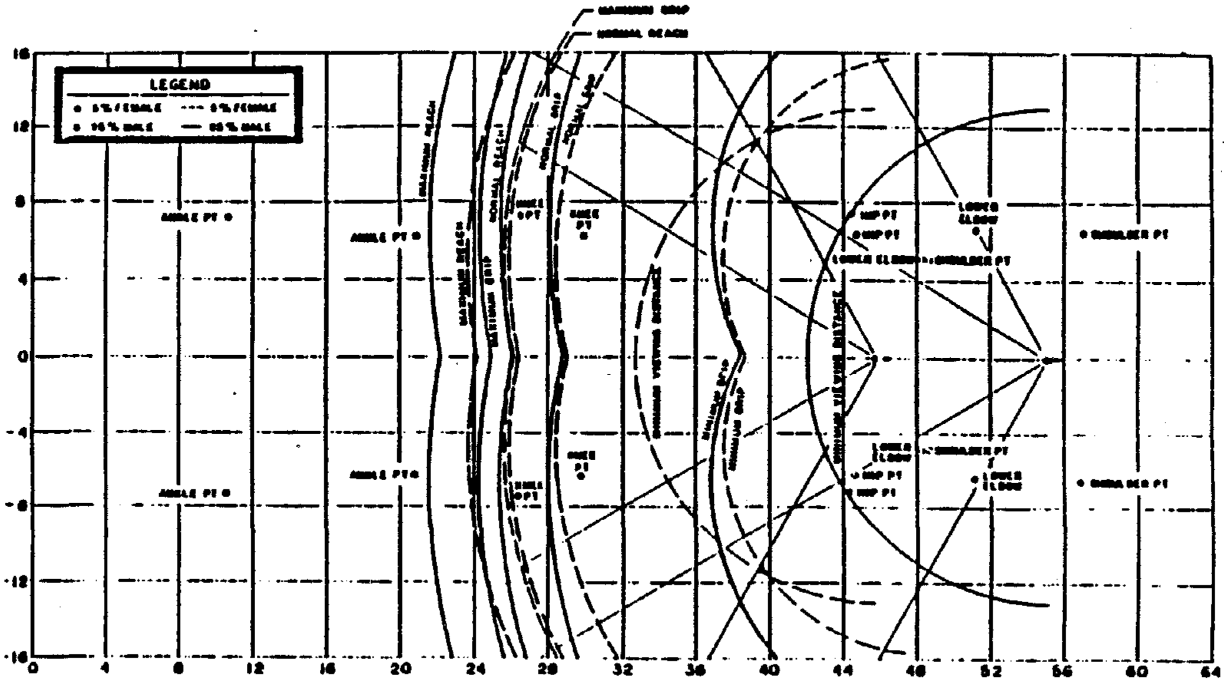
Table 16 prioritizes major controls for the various categories of machines. All controls should be reprioritized based on the specific application and the machine they are used on.

Figures 6, 7, and 8 identify the primary and secondary control location zones for a 42", 32", and a 22" high work place. These values are for both the 5th percentile female and the 95th percentile male operator.

As a general rule, designers of workstations should begin with the seat reference point (SRF) and the seat design should then be completed. The operator's shoulder point and eye reference point should then be established. Primary controls and displays should then be located relative to the normally seated position (e.g., shoulders against the backrest) or the normal operating position (e.g., centered in the workplace). Displays should be laid out relative to the normally seated eye reference point. Routine use of primary controls or reading of primary displays should not require the operator to move

Table 16
Prioritization of Controls Across Machine Categories

	P — PRIMARY CONTROLS S — SECONDARY CONTROLS T — TERTIARY CONTROLS CONTROL OR CONTROL FUNCTIONS	UTILITY VEHICLES	LOADERS	CUTTERS	FACE DRILLS	SHUTTLE DRILLS	CONTINUOUS MINERS	PERSONNEL CARRIERS	SCOOP/ DRILL CARS	FEEDER BELTERS
	DIRECTION OF MOTION	.	S	.	.	.	S	S	S	S
	SPEED CONTROL	P	P	P	P	P	S	P	P	P
	STEERING CONTROL	P	P	P	P	P	S	P	P	P
TRAMING	SERVICE BRAKE	P	P	P	P	P	P	P	P	P
	EMERGENCY BRAKE	S	.	.	.	.	.	P	.	S
	PARKING BRAKE	S	T	S	.	S	S	S	S	.
	SANDER CONTROL	.	.	.	.	.	.	P	.	.
	POWER ON/OFF	T	T	T	T	T	T	T	T	T
	PANIC BAR/EMERGENCY CONTROL	P	P	P	P	P	P	P	P	P
	PUMP START/STOP	S	S	S	S	S	S	S	S	S
	STAB JACK CONTROL	.	S	S	S	.	S	.	.	S
	CABLE REEL	.	S	S	S	S	S	.	.	S
GENERAL	LIGHTS CONTROL	S	S	S	S	S	S	S	S	S
	CIRCUIT BREAKERS	T	T	T	T	T	T	T	T	T
	WARNING DEVICES	S	S	S	S	S	S	S	S	S
	TROLLY POLE RESET	.	.	.	.	.	.	S	.	.
	POWER SOURCE SELECT	T	.	.	.	.	.	T	.	.
	FIRE SUPPRESSION SYSTEM	.	.	.	P	P	P	P	P	P
	CONVEYOR DIRECTION	.	P	.	.P	.	.	.	.	
EXTRACTION DUMPING	CONVEYOR ON/OFF	.	S	.	.	S	S	.	.	.
	CONVEYOR ELEVATION	.	P	.	.	S	P	.	.	.
	CONVEYOR SWING	.	S	.	.	S	S	.	.	.
	CUTTER HEAD ELEVATION	.	.	.	.	.	P	.	.	.
	CUTTER HEAD EXTENSION	.	.	.	.	.	P	.	.	.
	CUTTER HEAD ROTATION	.	.	.	.	.	S	.	.	.
	WATER SPRAY	.	.	.	.	.	S	.	.	.
	CANOPY HEIGHT READJUSTMENT	.	.	S	S	S	.	.	S	
	BOOM ELEVATE/LOWER	.	.	P	P	.	.	.	.	P
	DRILL ROTATE	.	.	.	P	.	.	.	.	P
	BOOM ROLL	.	.	P	P-	.	.	.	.	
CUTTING/DRILLING	BOOM SWING AND STOP	.	.	P	P	.	.	.	.	P
	BAR OR DRILL TILT	.	.	P	P	.	.	.	.	P
	BAR SWING	.	.	P	.	.	.	.	.	.
	CUTTER CHAIN START/STOP	.	.	S	.	.	.	.	.	.
	BUG DUST AND START/STOP	.	.	S	.	.	S	.	.	.
	DRILL FEED	.	.	.	S	.	.	.	.	P
	ATRS CONTROL	.	.	.	.	.	.	.	.	P
	GATHERING HEAD ELEVATE	.	P	.	.	.	S	.	.	.
	BOOM SWING	.	S	.	.	.	P	.	.	.
LOADING	GATHERING ARM START/STOP	.	S	.	.	.	S	.	.	.
	BOOM LIFT/LOWER	.	S	.	.	.	.	.	.	.
	BUCKET ELEVATION	.	.	.	.	.	.	.	S	.
	BUCKET EJECTOR	.	.	.	.	.	.	.	S	.



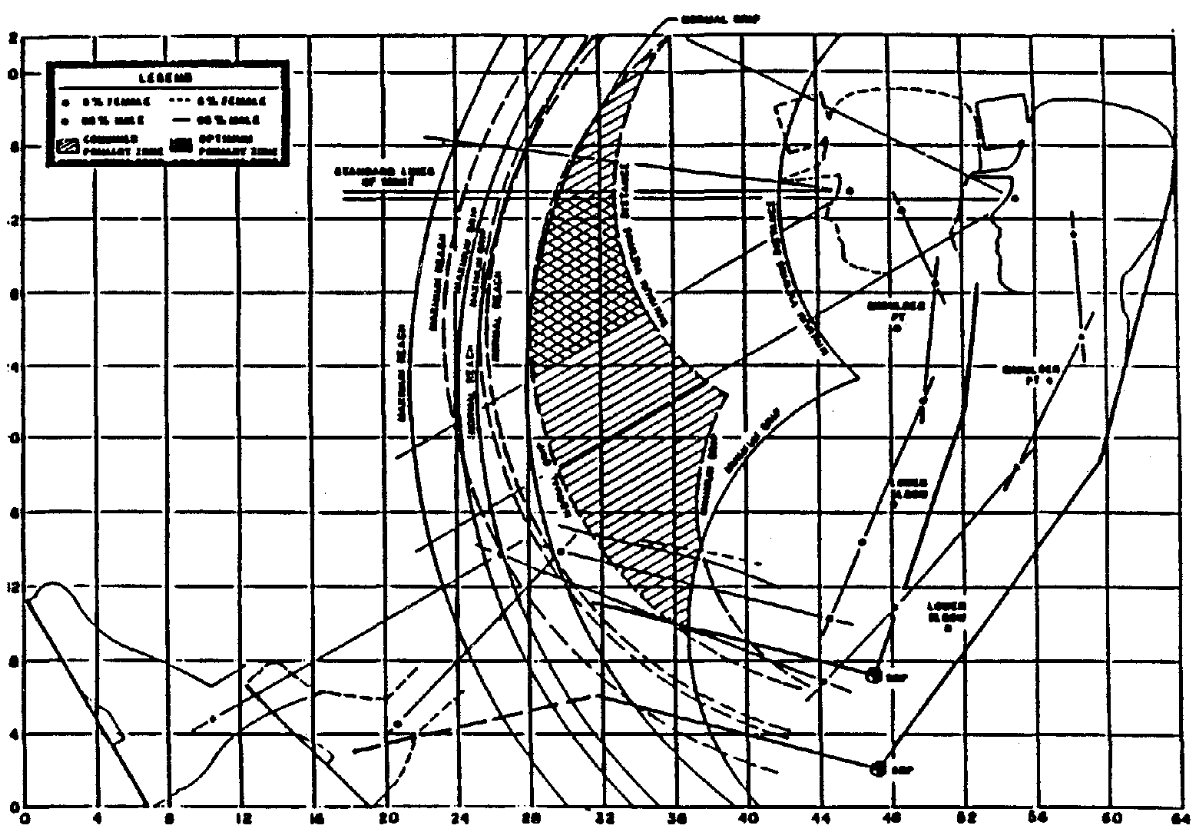


Figure 6: Primary and Secondary Control Location Zones For 42"
Workstation.

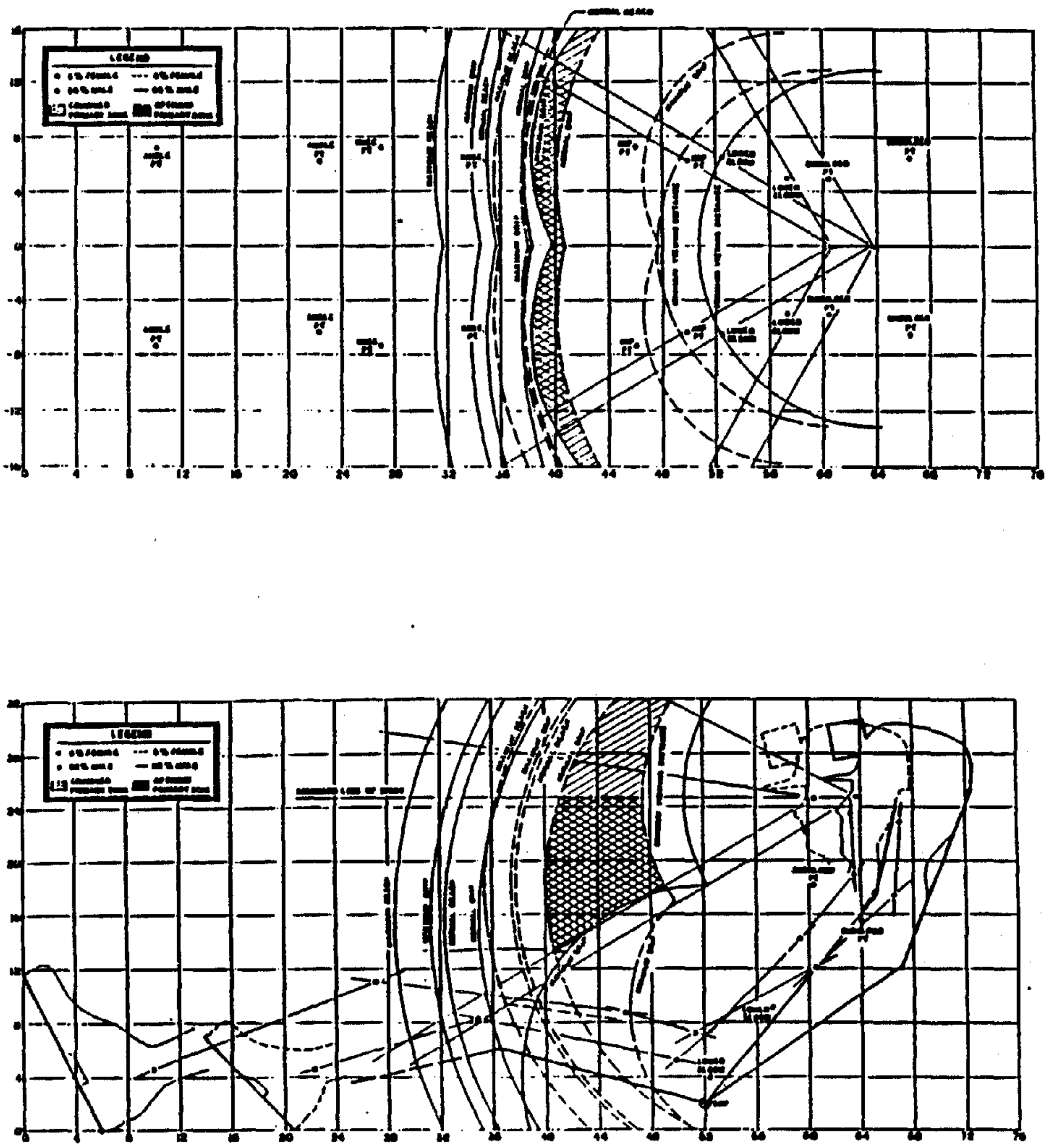


Figure 7: Primary And Secondary Control Location Zones for 32" Workstation.

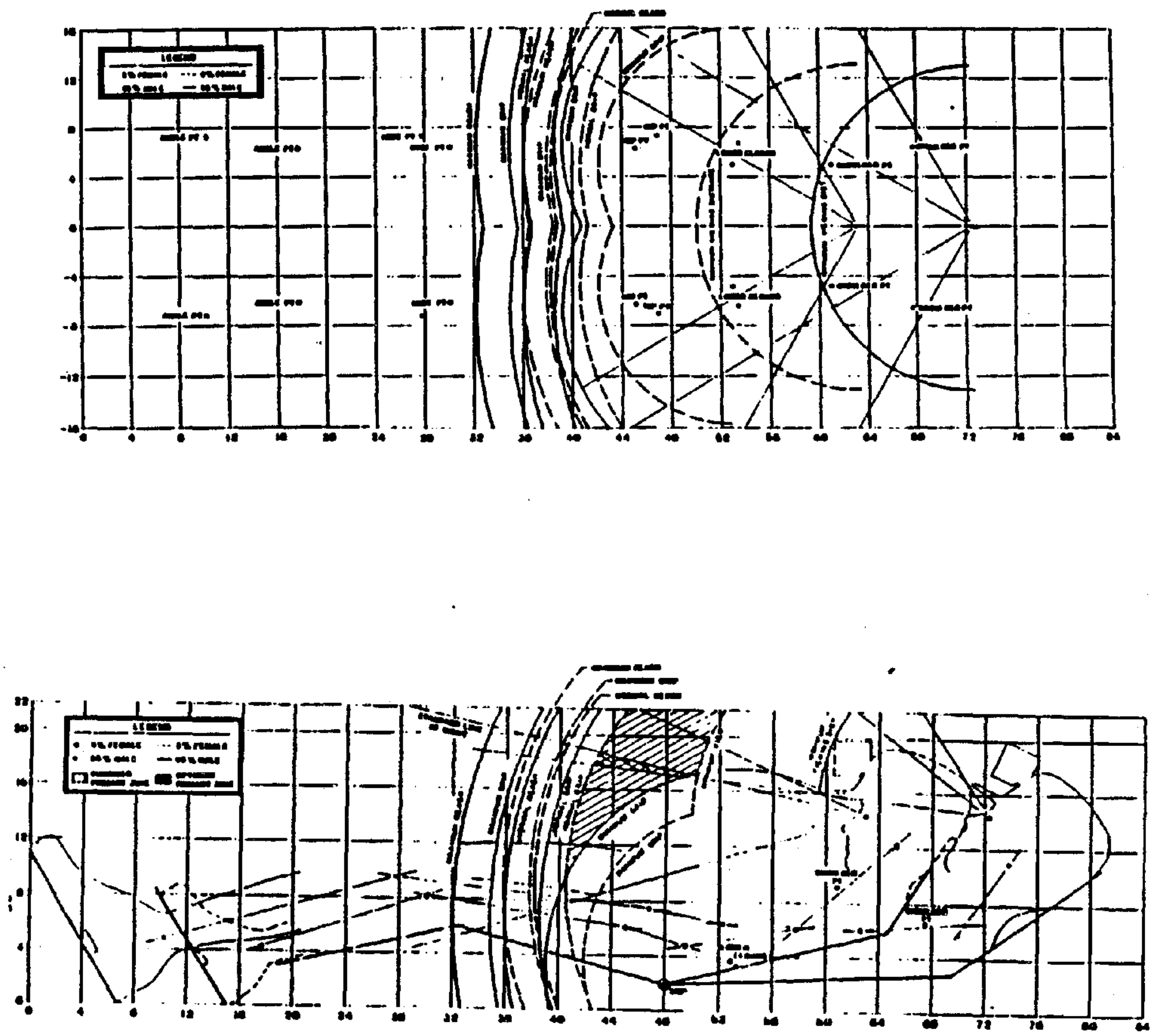


Figure 8: Primary And Secondary Control Location Zones For 22" Workstation.

his/her shoulders or head. All safety related controls and displays should be included in this primary zone. Secondary control activation may require limited shoulder or head movement while tertiary control activation may require whole body movement.

Operator controls should all be designed or selected for use in the underground mining environment. For example, critical controls should be protected from roof falls, collisions, inadvertant activation by entering or exiting personnel or damage or action by shifting loads. Controls should be designed so that they cannot be rendered inoperable through the accumulation of dirt, mud, coal or other obstructions. Similiarly, they should also be designed and installed to facilitate maintenance or replacement. Control design and placement should be standardized from machine to machine for each workstation.

DESIGN OF SPECIFIC WORKSTATIONS

This section presents recommendations for the design of specific workstations unique to one or more categories of machines.

DRILL STATIONS (SINGLE POSITION)

Roof drills with a single drill station should incorporate the following additional recommended practices.

- The drill station should be designed and located to keep the operator under the protective canopy or roof support system at all times. The operator should not have to reach out from under the protected area to activate controls, inspect drill penetration, or access drill steel or roof bolts.
- Canopy controls should be located so that the canopy can be raised or lowered without contacting the operator's body. The operator should not have to crawl under a lowered canopy in order to elevate it to a work position.
- The drill station should be designed so that the operator has an unobstructed exit route down the side of the roof bolter towards protected roof when he/she is bolting close to the face or rib.
- Panic bars should be installed to prevent the operator from tramming the bolter onto himself/herself or from pinning himself/herself against the face or rib.
- Repositioning or "inch" stations should be located down the side of the bolter so as to place the operator under protected roof.
- Hand grips should be installed on a protected area on the side of the drill boom for the operator to use to maintain balance and to provide the operator with tactile feedback as he/she drills.

- Automatic temporary roof support (ATRS) controls should be installed towards the rear of the roof drill on the tram station side of the machine and under protected roof.
- Stab jack controls should be located so that the operator cannot lower the jack on his/her foot.

DRILL STATION (DUAL POSITION)

Roof drills with dual drilling stations should have the following features:

- Controls for each drill station should be located to permit continuous visual contact by the two operators.
- Repositioning stations or controls should be located to permit direct visual contact with the operator at the other drill station.
- Mirror image control configurations should be avoided, where possible.
- Temporary roof support controls should be located where the user can observe the drill station on the other side of the roof drill.
- Both drill stations should be designed to permit emergency escape down th side of roof drill towards protected roof.

TRAM STATIONS

For mining machines with designated tram stations, the following recommended practices should be included:

- All tram controls should be designed so that the operator must be completely inside the operator's compartment in order to move the machine. Operators should not be able to walk alongside or ride on the top of the machine and operate the tram controls.
- For machines with sharply reclined seatbacks (e.g.,; 45 degrees or more) or with supine operator positions, footrests, handholds, bumpers, or other body support devices should be provided to permit the operator to brace himself/herself against rapid decelerations, bumps and other machine movements.
- Tram station controls should be designed to minimize operator injury in the event of collision or impact.
- Tram station visibility should be adequate to permit the operator to visually inspect the roadway a minimum of the necessary stopping distance ahead of the machine when tramming at maximum speed.

DUAL DIRECTION TRAM STATIONS

Shuttle cars, personnel carriers and other vehicles equipped with dual direction tram stations should incorporate the following recommendations:

- o Control input should correspond to the direction of travel of the vehicle. An accelerator, for example, should be pushed down or forward to increase speed, regardless of the direction of travel of the vehicle.
- o Where possible, one set of controls should be provided for each direction of travel.
- o A direction of travel switch should be included which clearly indicates which direction the vehicle is configured to travel in.
- o Controls which require the operator to reverse control inputs as a function of the direction of travel should be avoided.

REFERENCES

1. Alexander, M. and Clausen, C. E., Anthropometry of Common Working Positions, Wright-Patterson AFB, Ohio Report AMRL-TR-65-73, 1965.

2. Conway, E. J. and Elliott, W., Human Factors Design Guidelines for Personnel Carriers. U. S. Bureau of Mines Contract H0308110, May 1982.

3. Conway, E. J. and Elliott, W., Standardization of Controls for Roof Bolter Machines, U. S. Bureau of Mines Contract H0292007, May, 1984.

4. Conway, E. J., Helander, M., and Curtin, R., Optimum Control Heights for Operators Sitting Cross-legged or Kneeling, U. S. Bureau of Mines Contract H0292007, 1982.

5. Neufert, E., Architech's Data - 2nd International Edition, Halsted Press, New York, 1980.

6. Helander, M. and Elliott, W., Human Factors Design Guidelines for Roof Bolters, U. S. Bureau of Mines Contract H-0308110, May 1982.

7. National Aeronautics and Space Administration, Anthropometric Source Book - Volume II: A Handbook of Anthropometric Data, HASA Publication, 1024, 1978.

8. Department of Defense, Military Standard 1472C, U. S. Government Printing Office, Washington, D.C., 1981.

9. Diffrient, N. Tilly, A., and Bardagjy, M., Human Scale 1/2/3, the MIT Press, Boston, 1974.

10. Hartley, C., Cooksey, R., and Krois, P., Operators' Compartment for Underground Continuous Miners, U. S. Bureau of Mines Contract H 0308110, May 1982.

11. Sanders, M., and Kelley, G., Visual Attention Locations for Continuous Miners, Shuttle Cars and Scoops, U. S. Bureau of Mines Contract J0387213, 1981.

12. Frankel, V. H., and Nordin, M., Basic Biomechanics of the Skeletal System, Lea and Febiger Publishers, Philadelphia, 1980.

13. Grandjean, E., Fitting the Task to the Man, Taylor and Francis, Ltd., London, 1981.

14. Van Cott, H. and Kinkade, R., Human Engineering Guide to Equipment Design, U. S. Government Printing Office, Washington, D. C., 1972.

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16. Abstract (Limit: 200 words)

This report covers the development of proposed Draft SAE Recommended Practice J1314 entitled "Human Factors Design Guidelines for Mobile Underground Mining Equipment." The initial work began in 1978 with the SAE Off Road Machinery Technical Committee (ORMTC) - Subcommittee 29, Working Group 3. In late 1980, a research contract was obtained with the Bureau of Mines to support development of additional data. Human factors engineering design criteria were needed to develop operator work stations for underground mining equipment. Contractors compiled accident histories for selected equipment types, prepared task and hazard analyses and defined minimum envelope dimensions. Additional tasks were to recommend location and activation of controls, define minimum visibility envelopes, and describe guidelines for seating and operator ingress and egress. As of June 1-90, a draft of SAE J1314 had been proposed, but not approved by the committee.

17. Document Analysis a. Descriptors

coal mine safety	operator compartments	continuous miners	scoop
mine safety	work stations	loaders	ram cars
safety research	standards	cutters	underground mining equipment
human factors	shuttle cars	face drills	
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