



Standard Practice for Human Engineering Design for Marine Systems, Equipment, and Facilities¹

This standard is issued under the fixed designation F 1166; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This practice establishes general human engineering design criteria for marine vessels, and systems, subsystems, and equipment contained therein. It provides a useful tool for the designer to incorporate human capabilities into a design.

1.2 The purpose of this practice is to present human engineering design criteria, principles, and practices to achieve mission success through integration of the human into the vessel system, subsystem, and equipment with the goals of effectiveness, simplicity, efficiency, reliability, and safety for operation, training, and maintenance.

1.3 This practice applies to the design of vessels, systems, subsystems, and equipment. Nothing in this practice shall be construed as limiting the selection of hardware, materials, or processes to the specific items described herein. Unless otherwise stated in specific provisions, this practice is applicable to design of vessel systems, subsystems, and equipment for use by both men and women.

1.4 Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.

1.5 This practice is not intended to be a criterion for limiting use of material already in the field in areas such as lift repetition or temperature exposure time.

1.6 *Force Limits*—If it is known that an item is to be used by an already established occupational specialty, for which physical qualification requirements for entry into that specialty are also established, any discrepancy between the force criteria of this practice and the physical qualification requirements shall be resolved in favor of the latter. In this event, the least stringent physical qualification requirement of all specialties which may operate, maintain, transport, supply, move, lift, or otherwise manipulate the item, in the manner being considered, is selected as a maximum design force limit.

1.7 *Manufacturing Tolerances*—When manufacturing tolerances are not perceptible to the user, this practice shall not be construed as preventing the use of components whose dimensions are within a normal manufacturing upper or lower limit tolerance of the dimensions specified herein.

1.8 This practice is divided into the following sections:

TABLE OF CONTENTS

Section	Title
1	Scope
2	Referenced Documents
3	Terminology
4	Significance and Use
5	Control/Display Integration
6	Visual Displays, General Information
7	Location and Arrangement of Visual Displays
8	Coding of Visual Displays
9	Transilluminated Displays
10	Scale Indicators
11	Cathode Ray Tube (CRT) Displays
12	Large-Screen Displays
13	Other Displays
14	Audio Displays, General Information
15	Audio Warnings
16	Characteristics of Audible Alarms
17	Signal Characteristics in Relation to Operational Conditions and Objectives
18	Verbal Warning Signals
19	Controls for Audio Warning and Caution Devices
20	Speech Transmission Equipment
21	Controls, General Information
22	Arrangement and Grouping of Controls
23	Coding of Controls
24	Rotary Controls
25	Discrete Linear Controls
26	Continuous Adjustment Linear Controls
27	General Requirements for Labeling
28	Label Content
29	Specific Requirements by Label Type
30	Anthropometry
31	Workspace Design Requirements
32	Environment
33	Maintainability
34	Accessibility
35	Cases
36	Lubrication
37	Fasteners
38	Unit Design for Efficient Manual Handling
39	Handwheel Torque
40	Equipment Mounting
41	Conductors
42	Connectors
43	Electrical Wires and Cables

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TABLE OF CONTENTS

Section	Title
44	Test Points
45	Test Equipment
46	Failure Indications and Fuse Requirements
47	Hydraulic Systems
48	Design of Equipment For Remote Handling
49	Small Systems and Equipment
50	Operational and Maintenance Vehicles
51	Hazards and Safety
52	User-Computer Interface
53	Data Display
54	Text/Program Editing
55	Audio Displays, Interface
56	Interactive Control

LIST OF FIGURES

Figure	Title
1	Angle of Incidence
2	Example of Display/Equipment Relationship in Main Propulsion Engine Room with Two Medium Speed Diesel Engines
3	Example of Control/Display/Equipment Relationship in Auxiliary Machinery Space with Two Ship Service Generators
4	Example of Control/Display/Equipment Relationship in Machinery Space with Pump, Motor Controller, and Gage Board Located at Vertical Beam
5	CHT Pump Room with Various Options for Locating the Two Motor Controllers and Their Corresponding Gage Boards Given the Location of the Two Pumps
6	Preferred and Acceptable Alternatives for Multiple Row/Column Display and Control Arrangement
7	Vertical and Horizontal Visual Field
8	Lines of Sight
9	Scale of Markings
10	Scale Graduation, Pointer Position, and Scale Numbering Alternatives
11	Fixed-Scale Azimuth Dials
12	Shape and Color Coding Operating Ranges
13	Zero Position and Pointer Movement for Circular Dial Displays
14	Aligned Pointers for Rapid Check Readings
15	Relative Position of Scale Marks, Numerals, and Pointers on Circular Dials
16	Relative Position of Scale Marks, Numerals, and Pointers on Arcs and Circular Dials
17	Drum-Type Counter Design
18	Acceptable Alarm Types for Emergency and Primary Alarms
19	Control Motion Expectancy
20	Foot-Operated Switches
21	Pedals
22	Foot-Operated Controls
23	Leg Strength at Various Knee and Thigh Angles
24	Rotary Selector Controls
25	Rotating Knob Separation
26	Keylock Criteria
27	Keylock Switch Criteria
28	Thumbwheel Orientation and Movement
29	Discrete Thumbwheel Control
30	Knobs
31	Recommended Knob Shapes
32	Easily Recognizable Knob Shapes
33	Ganged Knobs
34	Thumbwheel Adjustment Controls
35	Cranks
36	Proper Mounting of Rapidly Operated Cranks
37	Handwheels
38	Recommended Mounting Heights for Valve Handwheels
39	Reaching Limits for Bending, Squatting, or Standing on Ladders
40	Pushbutton Switches
41	Toggle Switches
42	Toggle Switch Orientation for "ON"
43	Legend Switch
44	Rocker Switches
45	Slide Switches
46	Push-Pull Controls
47	Lever
48	Slide Levers
49	Isotonic Joysticks
50	Ball Controls

LIST OF FIGURES

Figure	Title
51	Independent Symbols
52	Label Specifications
53	Standing Body Dimensions
54	Seated Body Dimensions
55	Depth and Breadth Dimensions
56	Circumferences and Surface Dimensions
57	Hand and Foot Dimensions
58	Head and Face Dimensions
59	Anthropometric Data for Body Positions Involved in Work Activities
60	95th Percentile Gloved-Hand Dimensions (Male)
61	Helmet Dimensions
62	Aircrewman's Helmet (Size Extra Large)
63	Range of Human Motion
64	Mobile Workspace Dimensions
65	Standing Workspace Dimensions—Cabinets and Electrical Equipment Racks
66	Standing Workspace Dimension—CRTs and Table
67	Standing Workspace Dimensions—Consoles and Work Benches
68	Standing Workspace for Typical Work Positions
69	Display (Top) and Control (Bottom) Locations for Standing Crew Work Stations
70	Seated Workspace Dimensions
71	Dimensions for Single or Multiple Personnel at a Table or Other Duty Station Not Requiring a Desk
72	Seating at CRT-Type Work Stations
73	Swing-Away Seat for Short-Term Operations
74	Standard Console Dimensions Key
75	Example of One- or Two-Tier Wrap-Around Console
76	Examples of Three-Tier Consoles
77	Example of a Desk Top Console
78	Preferred Viewing Area
79	Seated Optimum Manual Control Space
80	Type of Ladder, Stair, or Ramp to be Used in Relation to Angle of Ascent
81	Stair Dimensions
82	Incline-Ladder Dimensions
83	Vertical-Ladder Dimensions
84	Well-Designed Work Platform
85	Door Dimensions
86	Hatches Mounted Overhead
87	Hatches Mounted on Vertical Walls
88	Hatch Dimensions
89	Walkway and Passageway Dimensions
90	Effective Temperature Scale
91	Windchill Chart
92	Equivalent Chill Temperature
93	Ventilation Requirements
94	Workspace Reflectance Values
95	Permissible Distance Between a Speaker and Listener's for Specified Voice Levels and Ambient Noise Levels
96	Range of Acceptable Reverberation Time
97	Vibration Exposure Criteria for Longitudinal (Upper Figure) and Transverse (Lower Figure) Directions with Respect to Body Axis
98	The 90 % Motion Sickness Protection Limits for Human Exposure to Very Low Frequency Vibration
99	Standing, Lateral Reach (Preferred Arm)
100	Seated, Forward Reach (Both Arms)
101	Crosslegged Seated, Forward Reach (Both Arms)
102	Standing, Forward Reach (Both Arms)
103	Standing, Forward Reach (Preferred Arm)
104	Access Opening Dimensions
105	Minimal Two-Hand and Finger Access
106	Covers and Accesses
107	Covers and Cases
108	Examples of Push-Pull Forces
109	Minimum Handle Dimensions
110	Handwheel Torque
111	Methods of Identifying Plugs and Receptacles to Prevent Mismatching
112	Cable Arrangements
113	Suggested Cable Arrangement in Junction Box for Easy Checking
114	Preformed Cables
115	Fluid Line Connector Recommendations
116	Anatomical Limits on Axially Symmetrical Ocular Metal Part Mounting Heights for Common Electrical Fixtures

LIST OF FIGURES

Figure	Title
118	Required Distance Between Hazard and Barrier

LIST OF TABLES

Table	Title
1	Metric Equivalents, Abbreviations, and Prefixes
2	Coding of Simple Indicator Lights
3	Application of Various Types of Mechanical Displays
4	Character Sizes for Mechanical Counters
5	Group Viewing of Optical Projection Displays
6	Range Ring Values
7	Functional Evaluation of Audio Signals
8	Intelligibility Criteria for Voice Communications Systems
9	Control Selection Criteria
10	Recommended Manual Controls
11	Conventional Control Movement Stereotypes
12	Minimum Separation Distances for Controls
13	Advantages and Disadvantages of Various Types of Coding
14	Recommended Control Colors (FED-STD-595)
15	Knob Detentes Placement
16	Keyboards, Inch-pound Units
17	Keyboards, SI Units
18	Limiting Dimensions for Free-Moving X-Y Controller
19	Arm Strength
20	Hand and Thumb-Finger Strength
21	Character Size Versus Luminance
22	Anthropometric Data
23	Range of Human Motion
24	Mobile Work Space Dimensions
25	Standing Work Space Dimensions for Work Clearances
26	Seated Work Space Dimensions
27	Standard Console Dimensions
28	Human Performance Effects at Various Effective Temperatures
29	Physical and Perceptual Responses to Various Temperatures
30	Temperature and Its Effect on the Comfort of the Extremities
31	Human Reaction to Windchill
32	Specific Task Illumination Requirements
33	Recommendations for Display Lighting
34	Low-Frequency and Infrasonic Noise Limits to Prevent Ear Injury
35	Sound Exposure to Avoid Deafness
36	Maximum Permissible Sound Pressure Level
37	OSHA Permissible Daily Noise
38	Effects of Noise on Human Performance
39	Effects of High-Level Noise on Human Performance
40	Upper Noise Limits Recommended for Military Facilities
41	Comfort Limits for Noise by Octave Band
42	Noxious Exhaust Products of Engine Fuels
43	Design Weight Limits
44	Static Muscle Strength Data
45	Weight and Dimensions of Portable Test Equipment
46	General Comparison Fuses and Circuit Breakers
47	Recommended Clearances Around Equipment Operator's Station to Accommodate 95th Percentile Male Dressed in Arctic Clothing. Operator Seat in Rear Most Position
48	Temperature Limits
49	Shock Current Intensities and Their Probable Effects
50	Allowable Exposure Limits to Some Toxic Gases
51	System Response Times

2. Referenced Documents

2.1 ASTM Standards:

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System²

2.2 Military Specifications:

MIL-C-25050, Colors, Aeronautical Lights and Lighting Equipment, General Requirements for³

2.3 Federal Standard:

FED-STD-595 Color³

² Annual Book of ASTM Standards, Vol 14.04.

³ Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

2.4 Military Standards:

MIL-STD-12, Abbreviation for Use on Drawings, Specifications, Standards, and in Technical Documents³

MIL-STD-740, Airborne and Structureborne Noise Measurements and Acceptance Criteria of Shipboard Equipment³

2.5 Military Handbook:

DOD-HDBK-743, Anthropometry of US Military Personnel³

2.6 Federal Regulations:

29 CFR 1910, Occupational Safety and Health Standards⁴

46 CFR 113.25-9, U.S. Coast Guard Regulation⁴

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *abort*—a capability that cancels all user entries in a defined transaction sequence.

3.1.2 *accessible*—unless otherwise specified herein or where specific design values are given, an item is considered accessible only where it can be operated, manipulated, removed, or replaced by the suitably clothed and equipped user with applicable fifth and ninety-fifth percentile body dimensions. Applicable body dimensions are those dimensions that are design critical to the operation, manipulation, removal, or replacement task. For example, an adjustment control behind an access opening should be located sufficiently close to the aperture to enable a suitably clothed and equipped user with a fifth percentile depth of reach to grasp and manipulate the adjustment control, while the opening should be sufficiently large to enable passage of a similarly clothed and equipped ninety-fifth percentile hand and arm.

3.1.3 *advisory signal*—a signal that indicates safe or normal configuration, condition of performance, operation of essential equipment, or that attracts attention and imparts information for routine action purposes.

3.1.4 *angle of incidence*—the angle between the line of direction of anything (such as a ray of light or line of sight) striking a surface and a line perpendicular to that surface drawn to the point of contact as shown in Fig. 1.

⁴ Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

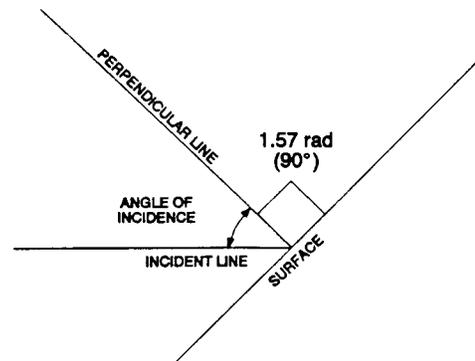


FIG. 1 Angle of Incidence

3.1.5 *backup*—a capability that returns a user to the last previous display in a defined transaction sequence. Also refers to the practice of preserving a second copy of files for data protection purposes.

3.1.6 *brightness*—the amount of emitted or reflected light visible to the eye.

3.1.7 *cancel*—a capability that regenerates or reinitializes the current display without processing or retaining any changes made by the user.

3.1.8 *caution signal*—a signal that alerts the operator to an impending hazardous condition requiring attention, but not necessarily immediate action.

3.1.9 *command and control system equipment*—the main mission element equipment and related ground equipment used in collecting, transmitting, processing, and displaying information for command and control.

3.1.10 *command language*—a type of dialogue in which a user composes control entries with minimal prompting by the computer.

3.1.11 *common hand tools*—items of tools found in common usage or applicable to a variety of operations or to a single operation on a variety of material. Screwdrivers, hammers, and wrenches are examples of common hand tools.

3.1.12 *control entry*—user input for sequence control, such as function key actuation, menu selection, command entry, and so forth.

3.1.13 *data*—the raw materials from which a user extracts information. Data may include numbers, words, pictures, and so forth.

3.1.14 *data display*—output of data from a computer to its users. Generally, the phrase denotes visual output, but it may be qualified to indicate a different modality, such as “auditory display.”

3.1.15 *data entry*—user input of data for computer processing and computer responses to such inputs.

3.1.16 *data field*—an area of the display screen reserved for user entry of a data item.

3.1.17 *data item*—a set of characters of fixed or variable length that forms a single unit of data. Examples of a data item might be a person’s name or a zip code. Data items may be entered by a user or may be supplied by the computer.

3.1.18 *data protection*—functional capabilities that guard against unauthorized data access and tampering, user errors, and computer failure.

3.1.19 *4a decibel (dB)*—sound level, measured between acoustic signals, equal to ten times the common logarithm of the ratio of the two levels.

3.1.20 *4a dB (A)*—the sound level measured through the A-weighting network of a sound level meter.

3.1.21 *de-emphasis*—the inverse of preemphasis, used for the purpose of restoring original vowel-consonant amplitude relationships in preemphasized speech; primarily useful in maintaining the “natural” sound quality. (See 3.1.56)

3.1.22 *default value*—a predetermined, frequently used value for a data field or control entry, intended to reduce required user entry actions.

3.1.23 *dialogue*—a structured series of interchanges between a user and a computer terminal. Dialogues can be computer initiated, for example, question and answer, or user initiated, for example, command languages.

3.1.24 *dichotic*—the condition in which the sound stimulus presented at one ear differs from the sound stimulus presented at the other ear. The stimulus may differ in sound pressure, frequency, phase, time, duration, or bandwidth.

3.1.25 *display format*—the organization of different types of data in a display, including information about the data such as labels, and other user guidance such as prompts, error messages, and so forth.

3.1.26 *effective temperature (ET)*—a single value combining the effect of temperature, humidity, and air movement on the sensation of warmth or cold felt by the human body. The numerical value is that of the temperature of still, saturated air, that would induce an identical sensation.

3.1.27 *emergency*—a condition of danger that requires immediate action.

3.1.28 *emergency alarm*—an alarm that indicates that danger exists and that immediate action must be taken. They include the general emergency alarm, fire alarms, those alarms giving warning of personnel hazard; including fire-extinguishing medium alarm, power-operated sliding water-tight door closure alarm, and fire detection alarm.

3.1.29 *enter*—an explicit user action that effects computer processing of user entries. For example, after typing a series of numbers, a user might press an ENTER key that will add them to a database, subject to data validation.

3.1.30 *equipment*—general term designating any item or group of items.

3.1.31 *equipment failure*—the cessation of the ability to meet the minimum performance requirements of the equipment specifications. Further, equipment failure shall imply that the minimum specified performance cannot be restored through permissible readjustment of operator controls.

3.1.32 *facilities*—a physical plant, such as real estate and improvements thereto, including building and equipment, which provides the means for assisting or making easier the performance of a system function. The facilities to which this practice apply are those in which personnel perform system operational or maintenance duties.

3.1.33 *fail-safe design*—a design that, upon failure or malfunction of a component, subsystem, or system, automatically reverts to a predetermined design state of least critical consequence.

3.1.34 *field*—see 3.1.16.

3.1.35 *file*—a collection of data, treated as a single unit, that is stored in a computer.

3.1.36 *function key*—a key whose actuation will effect a control entry.

3.1.37 *help*—a capability that displays information upon user request for on-line guidance. HELP may inform a user generally about system capabilities or may provide more specific guidance in information-handling transactions.

3.1.38 *highlighting*—emphasizing displayed data or format features in some way, for example, through the use of underlining, bolding, or inverse video.

3.1.39 *human engineering design criteria*—the summation of available knowledge that defines the nature and limits of human capabilities as they relate to the checkout, operation, maintenance, or control of systems or equipment, to achieve optimum compatibility between equipment and human performance.

3.1.40 *information*—organized data that users need to perform their tasks successfully. Information serves as an answer to a user’s questions about data. It is used here to refer to the effective assimilation of data by a user.

3.1.41 *interrupt*—stopping an ongoing transaction to redirect the course of the processing. Examples of interrupt options are ABORT, BACKUP, CANCEL, and RESTART.

3.1.42 *legibility*—the ability to see and identify the alphanumeric characters, symbols, or other visual information on a display.

3.1.43 *luminance contrast*—the contrast between background and a figure equals the absolute difference between the higher luminance, L_1 , and the lower luminance, L_2 , divided by the higher luminance; that is, $C = (L_1 - L_2)/L_1$. Conversions to the other contrast formulae are as follows:

L_1 (brighter)	L_2 (dimmer)	$\frac{L_1 - L_2}{L_2}$	$\frac{L_1 - L_2}{L_1}$	$\frac{L_1 - L_2}{L_1 + L_2}$	L_1/L_2
100	150	1.0	0.50 (50 %)	0.33	2.0
100	25	3.0	0.75 (75 %)	0.60	4.0
100	10	9.0	0.90 (90 %)	0.82	10.0

3.1.44 *luminance ratio (LR)*—the difference in luminance between the target subject and the surrounding field or background. For projection systems, the luminance ratio is equal to the light output of a projector (measured with no film in the projector) reflected off the screen (image luminance) divided by all the light falling on the screen (measured from the greatest viewing angle) other than that actually forming the image (non-image or background); as follows:

$$LR = L/L_n \tag{1}$$

where:

- L = image or subject luminance and
- L_n = non-image or background luminance.

3.1.45 *macro*—the capability to allow the user to assign a single name or function key to a defined series of commands for use with subsequent command entry. Sometimes called “smartkey.” Examples of use are storage of addresses or signature blocks that are frequently used.

3.1.46 *maintainability design*—design considerations directed toward achieving those combined characteristics of the equipment and human beings that will enable the accomplishment of necessary maintenance quickly, safely, accurately, and effectively with minimum requirements for personnel, skills, special tools, and cost.

3.1.47 *master caution (warning) signal*—a signal that indicates that one or more caution (warning) lights has been actuated.

3.1.48 *menu selection*—a type of dialogue in which the user selects one item out of a list of displayed alternatives, whether

the selection is by pointing, by entry of an associated option code, or by actuation of an assigned function key.

3.1.49 *metric equivalents, abbreviations, and prefixes*—Table 1 has been used herein to reflect the International System of Units (SI).

3.1.50 *noise-cancelling (microphone)*—a feature that reduces the masking effect of ambient noise upon speech impressed on a microphone, usually by providing equal access of the ambient noise to both surfaces of a diaphragm to achieve approximate equilibrium, effectively causing the noise to cancel itself out. Since the talker’s own voice output impinges on only one side of the microphone diaphragm, the talker’s signals are not subject to this cancellation, and are transmitted more favorably than if both ambient noise and speech fell simultaneously upon one face of the diaphragm.

3.1.51 *nuclear, biological, chemical (NBC), and other contaminated environment survivability*—NBC survivability includes both the instantaneous, cumulative, and residual effects of NBC weapons or environmental contamination upon a system, including its personnel. NBC or other environmental survivability describes the capability of a system to withstand the NBC environment, including decontamination, without losing the ability to accomplish its mission. For any system to be considered survivable in a contaminated environment, it must have at least three essential characteristics: decontaminability, hardness, and compatibility.

decontaminability—the ability of a system to be rapidly decontaminated to reduce the hazard to personnel operating,

TABLE 1 Metric Equivalents, Abbreviations, and Prefixes

NOTE—Each conversion factor is presented as a number, between one and ten, to six decimal places. The letter E (for exponent), a plus or minus sign and two digits following the number, represent the power of 10 by which the number is to be multiplied.

For example: 3.048 000 E - 01 = 3.048 000 × 10⁻¹ = 0.304 800 0
or: 1.076 391 E + 01 = 1.076 391 × 10¹ = 10.763 91

Examples of use of tables:

To convert 2 ft³ to m³ multiply 2 by 2.831 685 E - 02
(2 × 0.028 316 85 = 0.056 634 m³)

To convert 22 m³ to ft³ divide 2 by 2.831 685 E - 02
(2/0.028 316 85 = 70.629 325 ft³)

A more complete listing and discussion may be found in IEEE/ASTM

To convert from:	To:	multiply by:
Degree (angle) (deg)	radian (rad)	1.745 329 E - 02
Foot (ft)	metre (m)	3.048 000 E - 01
Foot ² (ft ²)	metre ² (m ²)	9.290 304 E - 02
Foot ³ (ft ³)	metre ³ (m ³)	2.831 685 E - 02
Footcandle (ft-C)	lux (lx)	1.076 391 E + 01
Footlambert (ft-L)	candela per metre ² (cd/m ²)	3.426 259 E + 00
Inch (in.)	metre	2.540 000 E - 02
Inch ² (in. ²)	metre ² (m ²)	6.451 600 E - 04
Inch ³ (in. ³)	metre ³ (m ³)	1.638 706 E - 05
Minute (angle) (min)	radian (rad)	2.908 882 E - 04
Ounce—force (ozf)	Newton (N)	2.780 139 E - 01
Ounce—inch (ozf in)	Newton metre (N-m)	7.061 552 E - 03
Pound (lb) avoirdupois	kilogram (kg)	4.535 924 E - 01
Pound—force (lbf)	Newton (N)	4.448 222 E + 00
Pound—inch (lbf-in)	Newton metre (N-m)	1.129 848 E - 01
Second (angle) (sec)	radian (rad)	4.848 137 E - 06

Prefixes					Temperature Conversion	
nano	n	10 ⁻⁹	centi	c	10 ⁻²	°C = $\frac{5}{9} (°F - 32)$
micro	μ	10 ⁻⁶	kilo	k	10 ³	
milli	m	10 ⁻³	mega	M	10 ⁶	°F = $\frac{9}{5} °C + 32$

maintaining, and resupplying it.

hardness—the ability of a system to withstand the material damaging effects of NBC contamination and any decontamination agents and procedures required to remove it.

compatibility—the ability of a system to be effectively operated, maintained, and resupplied by persons wearing the full NBC or other protective ensemble.

3.1.52 *page*—for this standard, the data appearing at one time on a single display screen.

3.1.53 *panel*—the front face of an assembly, normally used for mounting controls and displays.

3.1.54 *panning*—an orientation for display framing in which a user conceives of the display as moving over a fixed array of data. The opposite of scrolling.

3.1.55 *peak-clipping (of speech signals)*—a technique for controlling amplitude relationships in speech by limiting the instantaneous peak amplitudes to improve intelligibility of speech, usually followed by amplification of the signal to increase the amplitude of the clipped peaks to their original level, with proportional increase of the weaker speech sounds.

3.1.56 *preemphasis*—systematic distortion of the speech spectrum to improve intelligibility of speech sound by attenuating the low-frequency components of vowels (relatively unimportant for intelligibility) and proportionately increasing the amplitude of high-frequency vowel components and consonants (highly important for intelligible speech transmission).

3.1.57 *primary alarm (essential alarm)*—an alarm that indicates a condition that requires prompt attention to prevent an emergency condition. They include machinery alarms, control fault alarms, alarms indicating faults in emergency or primary (essential) alarm(s) or detection systems or failure of their normal power supplies, steering gear alarms, bilge alarms, engineer's alarms, and personnel alarms.

3.1.58 *prompt*—an indicator provided by the computer that alerts the user that the computer is ready, data should be entered, and so forth.

3.1.59 *query language*—a language that allows users to compose control entries for displaying specified data from a database.

3.1.60 *question and answer*—a type of dialogue in which the computer displays questions, one at a time, for a user to answer.

3.1.61 *readability*—the ability to understand the message imparted by printed material, characters, numbers, or other visual information from a visual display.

3.1.62 *remote-handling system*—the equipment (for example, manipulators, viewing devices, and other aids) that permits personnel to extend their capabilities into remote environments.

3.1.63 *scrolling*—an orientation for display framing in which the user conceives of data as moving behind a fixed display frame. The opposite of panning.

3.1.64 *seat reference point (SRP)*—the point at which the center line of the seat back surface (depressed) and seat bottom surface (depressed) intersect. When the seat is positioned at the midpoint of the adjustment range(s), this intersection point is called the neutral seat reference point.

3.1.65 *signals*—a secondary, nonessential, advisory, or call indication. (Call is a request for contact, assistance, or action from one location to another.)

3.1.66 *sound pressure level (SPL)*—the pressure of an acoustic wave; usually expressed in decibels (dB), equal to 20 times the logarithm to the base 10 of the ratio of the effective root-mean-square (rms) pressure of this sound to the reference pressure, as follows:

$$SPL = 20 \log_{10} \frac{P}{20 \mu\text{Pa}} \quad (2)$$

where:

P = the effective (rms) sound pressure in micropascals (μPa) or micronewtons per square metre ($\mu\text{N}/\text{M}^2$). ($20 \mu\text{Pa} = 20 \mu\text{N}/\text{M}^2 = 0.0002 \text{ microbar} = 0.0002 \text{ dynes}/\text{cm}^2$.)

3.1.67 *source documents*—user's documents, which are a source of data eventually processed by the computer program, such as target lists, supply codes, parts lists, maintenance forms, bills of lading, and so forth.

3.1.68 *spatial relationship*—the placement of controls, displays, and their related equipment so that it is visually obvious to an operator or maintainer that all components of a particular system are related. Further, when controls and displays are used for identical equipments or systems located in different parts of the same compartment, or in different compartments, the controls and displays shall be placed in the same location in respect to the equipments or systems at each installation. Consoles and overall work stations shall be designed and placed so the individual controls and displays on the consoles or work stations are arranged, as viewed by the operator facing the console or work station, in the same spatial arrangement as is the actual equipment being controlled or monitored at the console or work station.

3.1.69 *special tools*—tools not listed in the Federal Supply Catalog or meet the requirements of 3.1.75.

3.1.70 *speech intelligibility*—a measure of the percent of words, phrases, or sentences correctly understood over a given speech communication system in a given noise situation. It may be measured, when complying with this practice, by using either the phonetically balanced Monosyllabic Word Intelligibility Test or the Modified Rhyme Test (MRT), or may be calculated by the Articulation Index (AI).

3.1.71 *speech interference level (SIL)*—a measure of the effectiveness of noise in masking speech, defined as the arithmetic average of the same pressure levels of the interfering noise (in decibels re $20 \mu\text{Pa}$) in the four-octave bands centered on the frequencies 500, 1000, 2000, and 4000 Hz, respectively. The unit of speech interference is the decibel.

3.1.72 *speech signal processing*—the modification of the electrical signal representing speech to enhance the capability of a speech communications channel. Some examples are simple analog processing, Automatic Gain Control (AGC), frequency shaping, peak clipping, and syllabic compression.

3.1.73 *speech spectrum*—a segment of the range of audible frequencies containing the sounds of speech; defined as approximately the range from 80 to 8000 Hz.

3.1.74 *speech-to-noise ratio (peak speech to rms noise)*—the ratio between the arithmetic mean of peak amplitudes of speech and the root-mean-square (rms) amplitude of background noise.

3.1.75 *standard tools*—standard tools (normally hand tools) used for the assembly, disassembly, inspection, servicing, repair, and maintenance of the equipment, and which are manufactured by two or more recognized tool manufacturing companies and are listed in those companies' catalogs.

3.1.76 *string*—in the user's context, a word, phrase, or number (string of characters) in the text or file. Normally used in the context of causing the computer to search for, find, or replace a desired "string."

3.1.77 *text entry*—initial entry and subsequent editing of textual material, typified by messages.

3.1.78 *transaction*—an action by a user followed by a response from the computer. The term is used here to represent the smallest functional "molecule" of user-computer interaction.

3.1.79 *transillumination*—light passed through, rather than reflected off, an element to be viewed, for example, illumination used on console panels or indicators using edge or backlighting techniques on clear, translucent, fluorescent, or sandwich-type plastic materials.

3.1.80 *visibility*—the ability to see a visual display from its surrounding background.

3.1.81 *warning signal*—a signal that alerts the operator to a dangerous condition requiring immediate action.

3.1.82 *wet bulb globe temperature (WBGT)*—an index of the stress incorporating, as a major element, the evaporative cooling available to a natural wet bulb thermometer and calculated as follows:

$$WBGT = 0.7TWB_{np} + 0.2T_g + 0.1T_a \quad (3)$$

where:

TWB_{np} = nonpsychometric (np) wet-bulb (WB) temperature,

T_g = temperature at interior center of a 15.2-cm (6-in.) black globe, and

T_a = nonpsychometric, but shaded, dry bulb (air) temperature.

—In the absence of a radiant heat source (solar, engine, furnace, and so forth), a modified wet-dry (WD85) index shall be used where:

$$WD85 = 0.85TWB_{np} + 0.15T_a \quad (4)$$

4. Significance and Use

4.1 *Objectives*—Vessels, systems, and equipment shall provide work environments that foster effective procedures, work patterns, and personnel safety and health, and that minimize factors which degrade human performance or increase error. Design shall be such that operator workload, accuracy, time constraint, mental processing, and communication requirements do not exceed the operator's physical or mental capacities. Design shall also minimize personnel and training requirements within the limits of time, cost, and performance trade-offs.

4.2 *Standardization*—Controls, displays, marking, coding, labeling, and arrangement schemes (equipment and panel layout) shall be uniform for common functions of all equipment. One criterion for selecting off-the-shelf commercial or government equipment shall be the degree to which the equipment conforms to this practice. Where off-the-shelf equipment requires modification to interface with other equipment, the modification shall be designed to comply with the criteria herein. Redesign of off-the-shelf equipment shall have the approval of the procuring activity.

4.3 *Function Allocation*—The design shall reflect allocation of functions to personnel, equipment, and personnel-equipment combinations to achieve the following:

4.3.1 Required sensitivity, precision, time, and safety.

4.3.2 Required reliability of system performance.

4.3.3 Minimum number and level of skills of personnel required to operate and maintain the system.

4.3.4 Required performance in a cost-effective manner.

4.4 *Human Engineering Design*—The design of vessels, systems, and equipment shall include the human engineering, life support, and biomedical design criteria, when applicable, contained in this practice to provide the following:

4.4.1 Satisfactory atmospheric conditions including composition, pressure, temperature, and humidity, and also safeguards against uncontrolled variability beyond the limits contained herein.

4.4.2 Acceptable limits of acoustic noise, vibration, acceleration, shock, blast, impact forces, and safeguards against uncontrolled variability beyond the safe limits defined in this practice.

4.4.3 Protection from thermal, toxicological, radiological, mechanical, electrical, electromagnetic, pyrotechnic, visual, and other hazards.

4.4.4 Space for personnel, their equipment, and free volume for the movements and activities they are required to perform during operation and maintenance tasks under both normal and emergency conditions.

4.4.5 Physical, visual, auditory, and other communication links between personnel, and between personnel and their equipment, under both normal and emergency conditions.

4.4.6 Efficient arrangement of operation and maintenance workplaces, equipment, controls, and displays.

4.4.7 Natural or artificial illumination for the performance of operation, control, training, and maintenance.

4.4.8 Safe and adequate passageways, hatches, ladders, stairways, platforms, inclines, and other provisions for ingress, egress, and passage under normal, adverse, and emergency conditions.

4.4.9 Provision of acceptable personnel accommodations including body support and restraint, seating, rest, and sustenance, that is, food, water, and waste management.

4.4.10 Provision of nonrestrictive personal life support and protective equipment and clothing.

4.4.11 Provisions for minimizing psychophysiological stress effects of mission duration and fatigue.

4.4.12 Design features to ensure rapidity, safety, ease, and economy of operation and maintenance in normal, adverse, and emergency maintenance environments.

4.4.13 Satisfactory remote handling provisions and tools.

4.4.14 Emergency systems for contingency management, escape, survival, and rescue.

4.4.15 Compatibility of the design, location, and layout of controls, displays, workspaces, maintenance accesses, stowage provisions, and passenger compartments with the clothing and personal equipment (C/PE) to be worn by personnel operating, riding in, or maintaining all systems or equipment. Task allocation and control movements shall be compatible with restrictions imposed on human performance by C/PE.

4.4.16 Compatibility of control/display interfaces and procedures with human information processing capability, decision-making effectiveness, and the limits of short-term memory, long-term memory, and computation skill.

4.4.17 Immediate, accurate, and pertinent feedback to the operator of equipment or system performance after each control movement or other action taken by the operator.

4.5 *Fail-Safe Design*—A fail-safe design shall be provided in those areas in which failure can disable a vital system or cause catastrophe through damage to equipment, injury to personnel, or inadvertent operation of critical equipment.

4.6 *Simplicity of Design*—The equipment shall represent the simplest design consistent with functional requirements and expected service conditions. Where practical, it shall be capable of operation, maintenance, and repair in its operational environment by personnel with a minimum of training.

4.7 *Interaction*—The design of the system shall reflect the interaction requirements of crew-served equipment.

4.8 *Safety*—Design shall reflect applicable system and personnel safety factors, including minimization of potential human error in the operation and maintenance of the system, particularly under the conditions of stress.

4.9 *Ruggedness*—Systems and equipment shall be sufficiently rugged to withstand handling during operation, maintenance, supply, and transport within the environmental limits specified for those conditions in the applicable hardware or system specification.

4.10 *Design for NBC and Other Contaminated Environment Survivability*—As applicable, equipment design shall be compatible with NBC and other contaminated environment protection and shall permit performance of mission-essential operations, communications, maintenance, resupply, and decontamination tasks by suitably clothed, trained, and acclimatized personnel for the survival periods and NBC or other environments required by the system. Equipment design shall also facilitate contaminated environment hardness surveillance and shall minimize susceptibility to reduction of inherent contaminated environment hardness as a result of errors or damage induced by maintenance or operator personnel.

4.10.1 NBC or other contaminated environments hardness shall be easily verifiable by maintenance personnel before and after maintenance actions (hardness surveillance).

4.10.2 NBC or other contaminated environments hardness shall not be degraded when routine (scheduled) and corrective (unscheduled) maintenance are performed.

4.10.3 Maintenance of the equipment's inherent NBC or other contaminated environments hardness shall not be dependent

on maintenance personnel expertise and critical alignments/maintenance actions.

4.11 *Design for Electromagnetic Pulse (EMP) Hardening*—As applicable, equipment design shall be compatible with EMP-hardening requirements, including personal accommodations such as EMP-hardened electrical power outlets and antenna lead-ins within EMP-hardened facilities or spaces. Access shall be provided to EMP-hardened facilities or spaces without the need to open doors or hatches which form part of an electromagnetic barrier protecting the space. Items such as surge arrestors, terminal protection devices, and filters, which form part of an electromagnetic barrier for protection against EMP effects, shall be accessible.

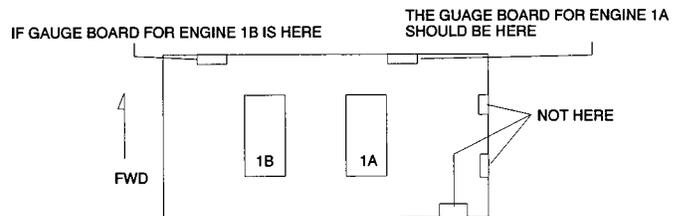
5. Control/Display Integration

5.1 *Control/Display Relationship*—The relationships of a control to its associated display and the display to the control shall be immediately apparent and unambiguous to the operator. Controls shall be located adjacent to (normally under or to the right of) their associated displays and positioned so that neither the control nor the hand normally used for setting the control will obscure the display.

5.2 *Control/Display/Equipment Relationships*—Where controls and displays (such as a motor controller and gage board) are associated with a specific piece of equipment (for example, a pump, filter, heater, and so forth) and the controls or displays are located for local operation of the equipment, they shall be located above, or immediately adjacent to, the equipment so that it is visually obvious that all of the components are functionally related. Where other design considerations or where a deliberate choice is made to place the controls and displays remote from the equipment which precludes this preferred location, the controls and displays shall be mounted in such a manner that the relationship of location of the controls and displays matches the arrangement of the equipment to which they belong. Controls and displays used on identical systems located in different locations in the same compartment, or in different compartments, shall be located in the same spatial relationship to the equipment in each compartment. Figs. 2-5 illustrate these principles.

5.3 *Design*—Control-display relationships shall be apparent through proximity, similarity of groupings, coding, framing, labeling, and similar techniques.

5.4 *Complexity and Precision*—The complexity and precision required of control manipulation and display monitoring shall be consistent with the precision required of the system.



FURTHER, IF A SECOND PROPULSION ENGINE ROOM EXISTS WITH THE SAME ENGINE LOCATIONS, THE GAUGE BOARD IN ENGINE ROOM #2 SHOULD BE PLACED IN THE SAME LOCATION AS IN ENGINE ROOM #1.

FIG. 2 Example of Display/Equipment Relationship in Main Propulsion Engine Room with Two Medium-Speed Diesel Engines

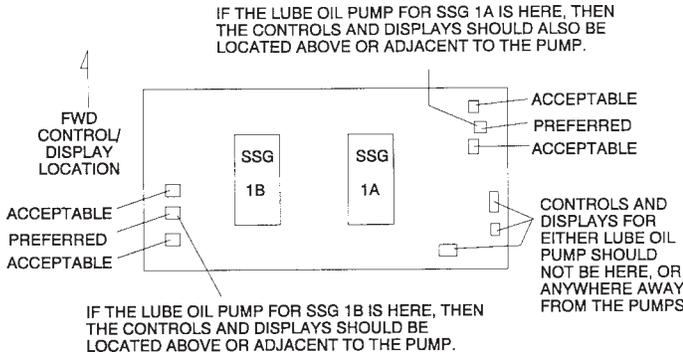


FIG. 3 Example of Control/Display/Equipment Relationship in Auxiliary Machinery Space with Two-Ship Service Generators

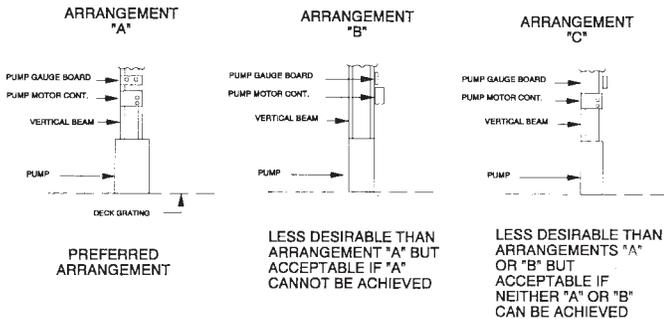


FIG. 4 Example of Control/Display/Equipment Relationship in Machinery Space with Pump, Motor Controller, and Gage Board Located at Vertical Beam

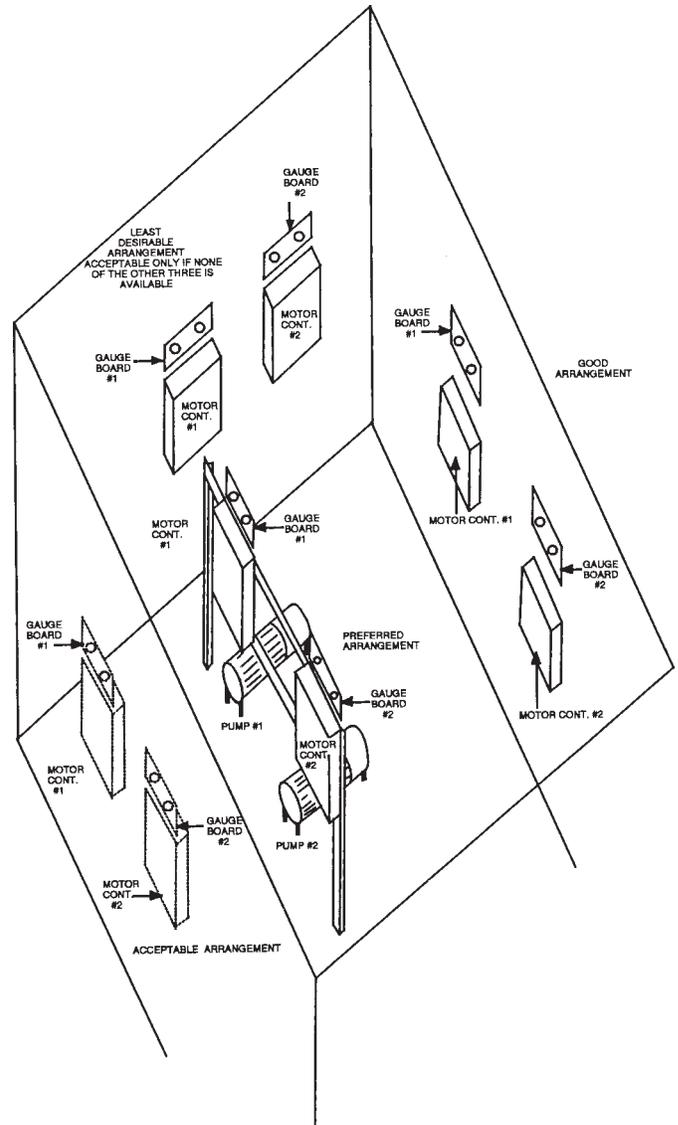


FIG. 5 CHT Pump Room with Various Options for Locating the Two Motor Controllers and Their Corresponding Gauge Boards Given the Location of the Two Pumps

Control/display complexity and precision shall not exceed the capability of the operator (in terms of discrimination of display detail) or exceed the operator's manipulative capability under the dynamic conditions and environment (in terms of manual dexterity, coordination, or reaction time) in which human performance is expected to occur.

5.5 Feedback—Feedback on control response adequacy shall be provided as rapidly as possible. For keyboards, feedback shall be provided to the operator before entry to ensure that the keyed entry is, in fact, errorless and the one that the operator desires to enter.

5.6 Illumination—Adjustable illumination shall be provided for visual displays, including display, control, and panel labels and critical markings, that must be read at night or under darkened conditions.

5.7 Simultaneous Access—If more than one crew member must have simultaneous access to a particular group of controls or displays to ensure proper functioning of a system or subsystem, the operator assigned to control and monitor a particular function or group of related functions shall have physical and visual access to all controls, displays, and communication capability necessary to perform assigned tasks adequately.

5.8 Position Relationships:

5.8.1 Functional Grouping—Functionally related controls and displays shall be located in proximity to one another and arranged in functional groups, for example, power, status, test.

5.8.2 Functional Group Arrangement:

5.8.2.1 Sequence—Functional groups of controls and displays shall be located to provide for left-to-right (preferred) or top-to-bottom order of use, or both.

5.8.2.2 Access—Providing that the integrity of grouping by function and sequence is not compromised, the more frequently used groups and the most important groups shall be located in areas of easiest access. Control-display groups required solely for maintenance purposes may be located in positions providing a lesser degree of access relative to operating groups.

5.8.2.3 Functional Group Marking—Functional groups may be set apart by outlining with contrasting lines that completely encompass the groups. Color numbers in this paragraph are in accordance with FED-STD-595. Where such coding is specified by the procuring activity, and where gray panels are used, noncritical functional groups (those not associated with emergency operations) shall be outlined with a

1.5-mm (1/16-in.) black border (27038), and those involving emergency or extremely critical operations shall be outlined with a 5-mm (3/16-in.) red border (21136). As an alternate method, contrasting color pads or patches may be used to designate both critical and noncritical functional areas, subject to prior approval by the procuring activity. When red compartment lighting is used, an orange-yellow (23538) and black (27038) striped border shall be used to outline functional groups involving emergency (hazardous or potentially hazardous conditions requiring immediate attention) or extremely critical operations.

5.8.2.4 *Consistency*—Location of recurring functional groups and individual items shall be similar from panel to panel. Mirror image arrangements shall be used only with the approval of the procuring activity.

5.8.3 *Location and Arrangement*—Whenever an operator must use a large number of controls and displays, their location and arrangement shall be designed to aid in determining which controls are used with which displays, which equipment component each control affects, and which equipment component each display describes.

5.8.4 *Arrangement Within Groups*—Controls and displays within functional groups shall be located according to operational sequence or function, or both.

5.8.4.1 *Left-to-Right Arrangement*—If there is more than one row of displays, and their corresponding controls cannot be located under each display, or placed in the same row arrangement under the displays as the displays are arranged, then the controls shall be located as shown in Fig. 6.

5.8.4.2 *Vertical and Horizontal Arrays*—If a horizontal row of displays must be associated with a vertical column of controls or vice versa, the farthest left item in the horizontal array shall correspond to the top item in the vertical array, and so forth. However, this type of arrangement shall be avoided whenever possible.

5.8.4.3 *Simultaneous Use*—A visual display that must be monitored concurrently with manipulation of a related control shall be located so that the operator is not required to observe the display from an extreme visual angle and thus introduce the possibility of parallax error.

5.8.4.4 *Multiple Displays*—When the manipulation of one control requires the reading of several displays, the control

shall be placed as near as possible to the related displays and preferably beneath the middle of the displays, but not to obscure displays when manipulating the control.

5.8.4.5 *Combined Control*—When separate displays are affected by a combined control (for example, concentrically ganged knobs), the display shall be arranged from left to right with the combined control underneath the center of the displays, but not to obscure displays when manipulating controls.

5.8.4.6 *Separate Panels*—When related controls and displays must be located on separate panels and both panels are mounted at approximately the same angle relative to the operator, the control positions on one panel shall correspond to the associated display positions on the other panel. The two panels shall not be mounted facing each other.

5.8.4.7 *Component Groups*—When a group of equipment components has the same function, the related control and display positions shall be oriented to correspond to those of the controlled and monitored components. (For example, the position of propulsion engine controls shall be oriented as if the operator faces the normal direction of vessel movement.)

5.8.4.8 *Emergency Use*—Emergency displays and controls are those associated with a hazardous or potentially hazardous condition that requires immediate action to prevent injury to the crew or damage to the ship. They shall be located where they can be seen and reached with minimum delay (for example, warning lights within a 30° cone about the operator’s normal line of sight; emergency control close to its related warning display or the nearest available hand in its nominal operating position).

5.9 *Movement Relationships:*

5.9.1 *Lack of Ambiguity*—Display indicators shall clearly and unambiguously direct and guide the appropriate control response. The response of a display to control movements shall be consistent, predictable, and compatible with the operator’s expectations.

5.9.2 *Time Lag*—The time lag between the response of a system to a control input and the display presentation of the response shall be minimized, consistent with safe and efficient system operation.

5.9.3 *Moving Pointer Circular Scales*—Clockwise movement of a rotary control or movement of a linear control forward, up, or to the right shall produce a clockwise movement of circular scale pointers and an increase in the magnitude of the reading.

5.9.4 *Moving Pointer Linear Scales*—Clockwise movement of a rotary control or movement of a linear control forward, up, or to the right shall produce a movement up or to the right for horizontal and vertical scale pointers and an increase in the magnitude of the reading.

5.9.5 *Fixed Pointer Circular Scale*—Displays with moving scales and fixed pointers or cursors shall be avoided. When circular fixed-pointer, moving-scale indicators are necessary, clockwise movement of a rotary control or movement of a linear control forward, up, or to the right shall normally produce a counterclockwise movement of the scale and an increase in the magnitude of the reading.

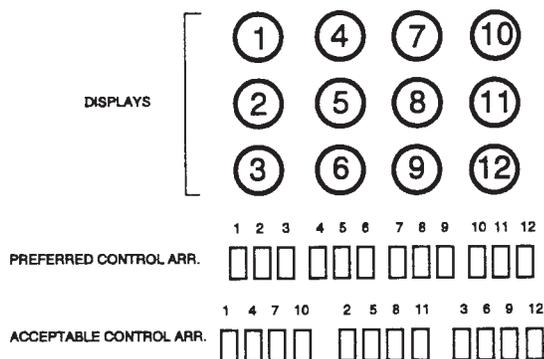


FIG. 6 Preferred and Acceptable Alternatives for Multiple Row/Column Display and Control Arrangement

5.9.6 *Fixed Pointer Linear Scale*—When use of vertical or horizontal fixed pointer, moving-scale indicators is necessary, clockwise movement of an associated rotary control or movement of a linear control forward, up, or to the right shall normally produce a movement of the scale down or to the left and an increase in the magnitude of the reading.

5.9.7 *Direct Linkage*—When there is a direct linkage between control and display (for example, radio frequency selector and station pointer), a rotary control shall be used if the indicator moves through an arc of more than 180°. If the indicator moves through an arc of less than 180° a linear control may be used, provided that the path of control movement parallels the average path of the indicator movement and that the indicator and control move in the same relative direction.

5.9.8 *Common Plane*—Controls shall be selected so that the direction of movement of the control will be consistent with the related movement of an associated display, equipment component, or vessel.

5.9.9 *Parallel Movement*—Direction-of-movement relationships shall be adhered to when control and display are parallel in line of movement.

5.9.10 *Labeling*—When control-display relationships specified herein cannot be adhered to, controls shall be clearly labeled (in accordance with Section 27) to indicate the direction of control movement required.

5.9.11 *Movement Direction*—When a rotary control and a linear display are in the same plane, the part of the control adjacent to the display shall move in the same direction as the moving part of the display.

5.10 *Control Display Movement Ratio:*

5.10.1 *Minimization of Time*—Control display ratios for continuous adjustment controls shall minimize the total time required to make the desired control movement (slowing time plus fine adjusting time), consistent with display size, tolerance requirements, viewing distance, and time delays.

5.10.2 *Range of Display Movement*—When a wide range of display element movement is required, small movement of the control shall yield a large movement of the display element. When a small range of display movement is required, a large movement of the control shall result in small movement of the display, consistent with final accuracy required.

5.10.3 *Knob, Coarse Setting*—When a knob is provided for making coarse display element settings on linear scales (0.4- to 2.5-mm (0.016- to 0.100-in.) tolerance), an approximately 150-mm (6-in.) display element movement shall be provided for one complete turn of the knob.

5.10.4 *Knob, Fine Setting*—For fine setting on linear scales (0.2- to 0.4-mm (0.008- to 0.016-in.) tolerance), a 25 to 50 mm (1 to 2 in.) of display element movement shall be provided for one complete turn of the knob.

5.10.5 *Bracketing*—When bracketing is used to locate a maximum or minimum rather than a specific value (for example, as in tuning a transmitter), the control knob shall swing through an arc of not less than 175 mrad (10°) nor more than 525 mrad (30°) either side of the target value to make the peak or dip associated with that value clearly noticeable.

5.10.6 *Lever, Coarse Setting*—When a lever is provided for coarse settings (0.4- to 2.5-mm (0.016- to 0.100-in.) tolerance), one unit of display element movement shall be used to three units of lever movement.

5.10.7 *Lever, Two-Dimensional Setting*—When a lever is provided to make settings in two dimensions to coarse tolerances (2.5 mm (0.100 in.)), one unit of display element movement shall be used to two and one-half units of lever movement.

5.10.8 *Counters*—When counters are provided, the control-display ratio shall be such that one revolution of the knob produces approximately 50 counts (that is, the right hand drum rotates 5 times).

6. Visual Displays, General Information

6.1 *General*—Visual displays shall be used to provide the operator with a clear indication of equipment or system conditions for operation under any eventuality commensurate with the operational and maintenance philosophy of the system under design.

6.2 *Alerting/Warning*—An alerting/warning display shall provide the operator with a greater probability of detecting the triggering condition than normal observation would provide in the absence of the display.

6.3 *Display Illumination and Light Distribution:*

6.3.1 *Display Illumination:*

6.3.1.1 *Normal*—When maximum dark adaptation is not required, low-brightness white light (preferably integral and adjustable as appropriate) shall be used; however, when complete dark adaptation is required, low-level illumination shall be accomplished by use of gray filter sleeves over the lamps. The white light transmittance through the sleeves shall be either 5.0, 2.5, or 1.0 %.

6.3.1.2 *Night Vision Device Compatibility*—When night vision devices will be worn or used by the operator(s), display illumination color shall be low-density blue-green light (incandescent filament through a high-pass filter with a 600-nm cutoff). The color selected shall provide the operator(s) with the capability to obtain required display information rapidly and accurately with unaided eye vision or via viewing with the night vision device. The color selected shall also provide the operator(s) with the ability to obtain required display information rapidly and accurately during any daylight condition. The lighting shall be continuously variable to the full OFF position. In the OFF position, no current shall flow through the lamps.

6.3.1.3 *Field Use Panel Dimming*—When control or annunciator panels will be viewed by personnel out of doors at night, maximum panel illumination shall be provided when a dimming rotary control is at its extreme clockwise rotation. Maximum illumination is that in accordance with 32.9. No current shall be provided to luminaries at extreme counterclockwise rotation of a dimming control. Panel light levels shall be continuously variable from 0.1 cd/m² (0.03 fL) near OFF to 3.5 cd/m² (1 fL) at 50 % of clockwise rotation.

6.3.2 *Light Distribution*—Where multiple displays are grouped together, lighting shall be balanced across the instrument panel such that the mean indicator luminances of any two instruments shall not differ by more than 33 % across the range of full ON to full OFF. Light distribution shall be sufficiently

uniform within an integrally illuminated instrument such that the ratio of standard deviation of indicator element luminances to mean indicator luminance shall not be more than 0.25, using eight or more equally spaced test measurements.

6.3.3 *Contrast*—Sufficient contrast shall be provided between all displayed information and the display background to ensure that the required information can be perceived by the operator under all expected lighting conditions.

6.4 *Information:*

6.4.1 *Content*—The information displayed to an operator shall allow the operator to perform the intended mission, but shall be limited to that which is necessary to perform specific actions or to make decisions.

6.4.2 *Precision*—Information shall be displayed only within the limits and precision required for specified operator actions or decisions.

6.4.3 *Format*—Information shall be presented to the operator in a directly usable form. Requirements for transposing, computing, interpolating, or mentally translating into other units shall be prohibited.

6.4.4 *Redundancy*—Redundancy in the display of information to a single operator shall be avoided unless it is required to achieve specified reliability.

6.4.5 *Combining Operator/Maintainer Information*—Operator and maintainer information shall not be combined in a single display unless the information content and format are well suited to, and time is compatible for, both users.

6.4.6 *Display Failure Clarity*—A method shall be provided to determine if a display or circuit has failed.

6.4.7 *Display Circuit Failure*—Failure of the display circuit shall not cause a failure in the equipment associated with the display.

6.4.8 *Unrelated Markings*—Trademarks and company names or other similar markings not related to the panel function shall not be displayed on the panel face or on the displays.

6.4.9 *Duration*—For signals or displays that frequently or consistently change their outputs, the information displayed shall have durations of sufficient length to be reliably detected under expected operator workload and operational environment.

6.4.10 *Timeliness*—Displays, such as cathode ray tube displays, requiring refreshed information shall be updated in a synchronous manner, and be refreshed to a degree of timeliness required by personnel in the normal operating or servicing mode.

6.4.11 *Advisory and Alerting*—Displays such as multifunction displays, cathode ray tube displays, and other visual display devices displaying simultaneous and integrated information shall advise or alert operating personnel to information that becomes critical within the display.

6.4.12 *NBC Contamination*—As applicable, display characteristics (for example, clarity, legibility) shall be compatible with viewing while wearing an NBC or other protective mask. Displays or indicators that show the presence of NBC or other environmental contamination agents shall also show when such agent concentrations decrease to safe levels.

6.4.13 *Numeric Digital Displays*—Numeric digital displays shall not be used as the only display of information when trends in display change or perception of a display pattern is required of the operator. Numeric digital displays shall not be used when rapid or slow digital display rates inhibit perception of the display.

7. Location and Arrangement of Visual Displays

7.1 *Location*—Displays, including sight fill tubes on tanks, shall be located and designed so that they may be read to the degree of accuracy required by personnel in the normal operating or servicing positions without requiring the operator to assume an uncomfortable, awkward, or unsafe position. Dual gages providing an IN and OUT reading (that is, suction and discharge, voltage in and out, and so forth) shall be arranged so that the gage with the IN reading is on the left (preferred) or top, and the gage with the OUT reading is on the right (preferred) or bottom, unless the IN and OUT displays are a part of a system mimic that does not permit this arrangement.

7.2 *Access*—Visual displays shall be visually accessible from the normal work position without requiring the operator to stand on equipment components, handrails, wireways or wireway supports, or nearby pipes (especially if they are insulated). Flashlights or other special equipment shall not be required to read the display. No display shall require the removal of a cover (that is, sheathing, deck plate, and so forth) or any other component to be visible, unless the display is noncritical and a clearly marked quick access door is provided. Where possible, the access door shall be of transparent material. Light-emitting diodes (LEDs) used on PC boards inside consoles for calibration or troubleshooting shall be visible from the maintainer's normal work position once the console doors or maintenance access openings are open.

7.3 *Orientation*—Displays, such as thermometers, pressure gages, and so forth, that are attached directly to a pipe shall be mounted so they are read upright, or turned no more than 90°, from the upright position. Displays located immediately adjacent to walkways shall not be located lower than 460 mm (18 in.) above the deck to prevent them from being kicked and broken, unless the display face is protected by a nonbreakable transparent material. Armored sight gages shall be oriented so the sight gage is directly visible from the normal work position.

7.4 *Reflection*—Displays shall be constructed, arranged, and mounted to prevent reduction of information transfer as a result of the reflection of the ambient illumination from the display cover. Reflection of instruments and consoles in windows and other reflective enclosures shall be avoided. If necessary, techniques (such as shields and filters) shall be used to ensure that the system performance will not be degraded. Sight gages that contain clear liquid shall have a color backing so as to provide a color contrast between the liquid and the color backing to make the liquid more visible in the gage.

7.5 *Vibration*—Vibration of visual display shall not degrade user performance below the level required for mission accomplishment (see 32.13).

7.6 *Grouping*—All displays necessary to support an operator activity or sequence of activities shall be grouped together.

7.7 *Function and Sequence*—Displays shall be arranged in relation to one another according to their sequence of use or the

functional relations of the components they represent. They shall be arranged in sequence within functional groups, whenever possible, to provide a viewing flow from left to right or top to bottom.

7.8 *Frequency of Use*—Displays used most frequently shall be grouped together and placed in the primary visual zone in accordance with Fig. 7 and Fig. 8.

7.9 *Importance*—Important or critical displays shall be located in the primary visual zone or otherwise highlighted.

7.10 *Consistency*—The arrangement of displays within a system shall be consistent from application to application.

7.11 *Maximum Viewing Distance*—The viewing distance from the eye reference point of the seated operator to displays located close to their associated controls shall not exceed 635

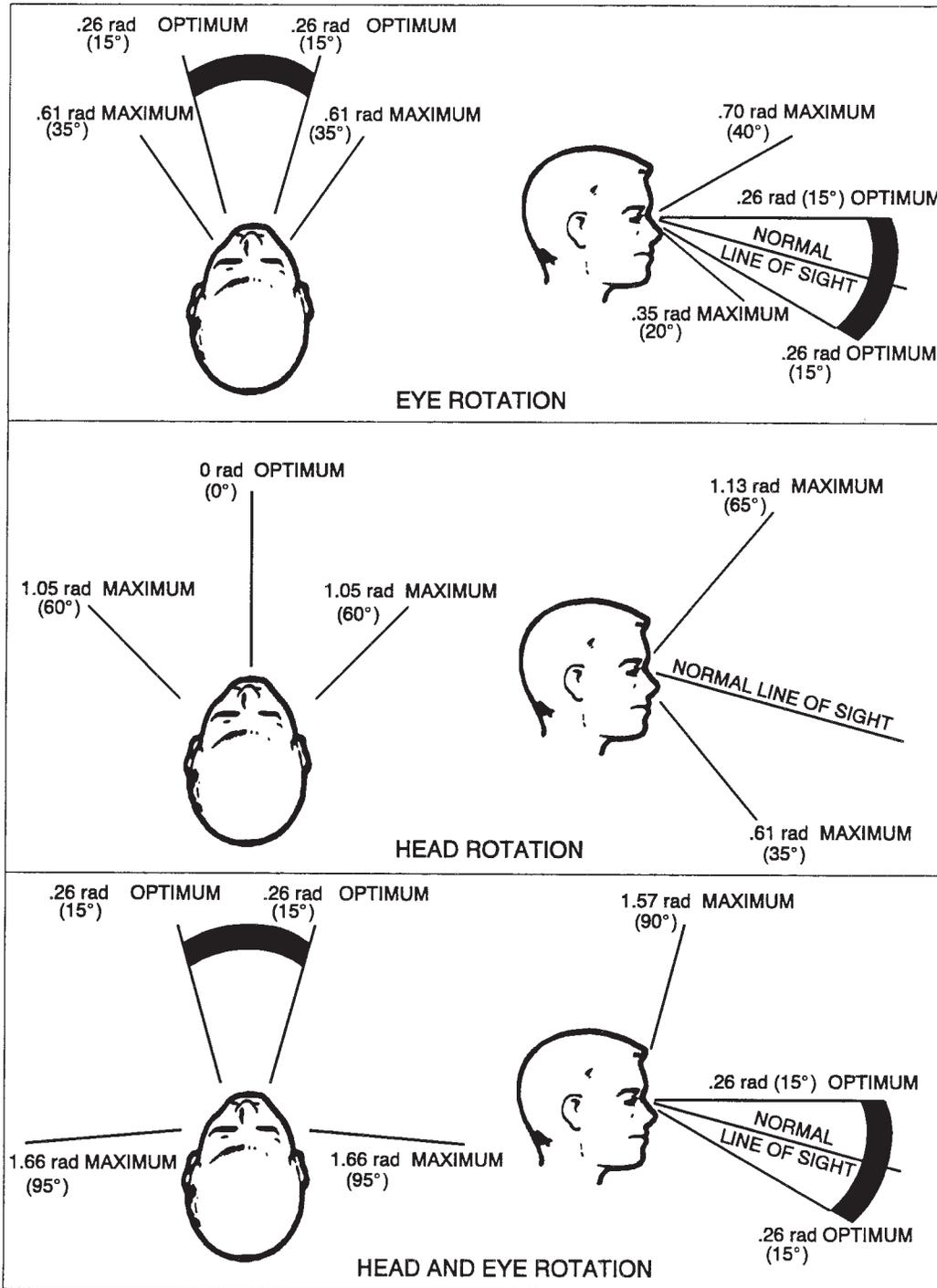


FIG. 7 Vertical and Horizontal Visual Field

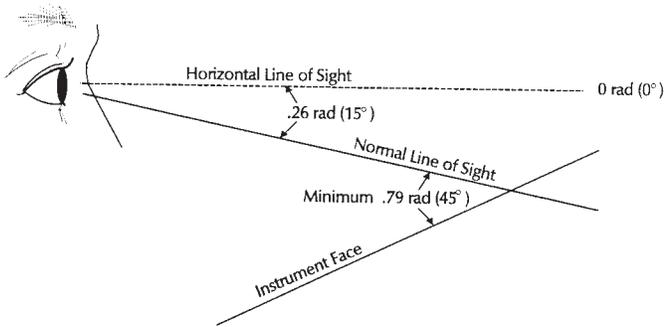


FIG. 8 Lines of Sight

mm (25 in.). Otherwise, there is no maximum limit other than that imposed by legibility limitations, which shall be compensated for by proper design.

7.12 *Minimum Viewing Distance*—The viewing distance from the operator’s eye to the face of the displays, with the exception of cathode ray tube displays and collimated displays, shall never be less than 330 mm (13 in.) and preferably not less than 510 mm (20 in.).

8. Coding of Visual Displays

8.1 *Objectives*—Coding techniques shall be used to facilitate discrimination between individual displays, identification of functionally related displays, indication of relationship between displays, and identification of critical information within a display.

8.2 *Techniques*—Displays shall be coded by color, size, location, shape, or flash coding, as applicable.

8.3 *Standardization*—All coding within the system shall be uniform and shall be established by agreement with the procuring activity.

9. Transilluminated Displays

9.1 Three general types of transilluminated displays that may be used include the following: single- and multiple-legend lights, which present information in the form of meaningful words, numbers, symbols, and abbreviations; simple indicator lights; and, transilluminated panel assemblies, which present qualitative status or system readiness information.

9.2 *Use*—Transilluminated indicators shall be used to display qualitative information to the operator requiring either an immediate reaction by the operator or to draw attention to an important system status. Such indicators may also be used occasionally for maintenance and adjustment function.

9.3 *Equipment Response*—Lights, including those used in illuminated push buttons, shall display equipment response and not control position (that is, a lighted ON push button for a pump means that the pump is running, not that the control has been pushed).

9.4 *Information*—Lights and related indicators shall be used sparingly and shall display only that information necessary for effective system operation.

9.5 *Positive Feedback*—Changes in display status shall signify changes in functional status rather than simply indicate that a control has been activated (for example, a lighted VALVE CLOSED indicator shall signify that the valve is actually closed, not that the VALVE CLOSED control has been activated). The absence or extinguishment of a signal or visual indication shall not be exclusively used to denote a malfunction, no go, or out-of-tolerance condition; however, the absence of a power on signal or visual indication shall be acceptable to indicate a power-off condition for operational displays only—not for maintenance displays. The absence or extinguishment of a signal or visual indication shall not be used to indicate a ready or in tolerance condition, unless the status or caution light filament and its associated circuitry can be easily tested by the operator and operator perception of such events is not time critical.

9.6 *Grouping*—Master caution, master warning, master advisory, and summation lights used to indicate the condition of an entire subsystem shall be discriminable from the lights which show the status of the subsystem components, except as required under 9.9.

9.7 *Location*—When a transilluminated indicator is associated with control, the indicator light shall be so located that it can be associated with the control without error and shall be visible to the operator during control operation. When a transilluminated indicator is used in conjunction with a meter or readout as an indication of an out-of-tolerance condition (such as, a LOW PRESSURE lighted annunciator associated with a pressure meter), it shall be placed directly above the meter. Other arrangements are permissible with the approval of the procuring activity.

9.8 *Location, Critical Functions*—For critical functions, indicators shall be located within 265 mrad (15°) of the operator’s normal line of sight (as shown in Fig. 8). Warning lights shall be an integral part of, or located adjacent to, the lever, switch, or other control device by which the operator is to take action, or placed as defined in 9.7.

9.9 *Maintenance Displays*—Indicator lights used solely for maintenance and adjustment shall be covered or nonvisible during normal equipment operation, but shall be readily accessible when required.

9.10 *Luminance*—The luminance of transilluminated displays shall be compatible with the expected ambient illuminance level, and shall be at least 10 % greater than the surrounding luminance. Where glare must be reduced, the luminance of transilluminated displays shall not exceed 300 % of the surrounding luminance.

9.11 *Luminance Control*—When displays will be used under varied ambient illuminance, a dimming control shall be provided. The range of the control shall permit the displays to be legible under all expected ambient illuminance. The control shall be capable of providing multiple-step or continuously variable illumination. Dimming to full OFF may be provided in noncritical operations, but shall not be used if inadvertent

failure to turn on an indicator could lead to critical operator failures, such as failure to detect or to perform a critical step in an operation.

9.12 *False Indication or Obscuration*—Provision shall be made to prevent direct or reflected light from making indicators appear illuminated when they are not, or to appear extinguished when they are illuminated. Self-reflection shall be minimized by proper orientation of the display with respect to the observer.

9.13 *Contrast Within the Indicator*—The luminance contrast (see 3.1.43) within the indicator shall be at least 50 %. This 50 % luminance contrast requirement does not apply to special displays specifically designed for legibility in sunlight or where legibility is obtained through color contrast (and other techniques) rather than luminance contrast. For low ambient illumination applications, this ratio shall be at least 90 %, with the background luminance less than the figure luminance.

9.14 *Lamp Redundance*—Meters, counters, and other displays that use incandescent bulbs to illuminate the display face may incorporate filament redundancy or dual lamps. When one filament or bulb fails, the intensity of the light shall decrease sufficiently to indicate the need for lamp replacement, but not so much as to degrade operator performance. Lighted annunciators need not have this capability provided a lamp test button is provided.

9.15 *Lamp Testing*—When indicator lights using incandescent bulbs are installed on a control panel or console, a master light test control shall be incorporated. Panels containing three or fewer lights may be designed for individual press-to-test bulb testing. Circuitry shall be designed to test the operation of the total indicator circuit. If dark adaptation is a factor, a means for reducing total indicator light brightness during test operation shall be provided.

9.16 *Lamp Removal, Method*—Where possible, lamps shall be removable and replaceable from the front of the display panel. The procedure for lamp removal and replacement shall not require the use of tools and shall be easily and rapidly accomplished. If a tool is required, special stowage for it will be provided on the panel.

9.17 *Lamp Removal, Safety*—Display circuit design shall permit lamp removal and replacement while power is applied without causing failure of indicator circuit components or imposing personnel safety hazards.

9.18 *Indicator Covers*—If design of legend screen or indicator covers does not prevent inadvertent interchange, a means shall be provided for checking the covers after installation to ensure that they are properly installed.

9.19 *Color Coding*—Transilluminated displays shall conform to the following color coding scheme.

9.19.1 *Flashing Red*—Flashing red shall be used to denote emergency conditions that require immediate operator action to avert impending personnel injury, equipment damage, or both. Flash rates shall be in accordance with 9.20. Flashing red lights not installed on consoles shall be limited to general alarm signals only in accordance with U.S. Coast Guard Reg. 113.25-9.

9.19.2 *Yellow*—Yellow shall be used to advise an operator that a condition exists that is marginal or beyond operational

limits, but does not require immediate operator action. Yellow shall also be used to alert the operator to situations in which caution, recheck, or unexpected delay is necessary.

9.19.3 *Green*—Green shall be used to indicate that the monitored equipment is operating satisfactorily or that a condition is satisfactory and it is all right to proceed.

9.19.4 *White*—White shall be used to indicate system conditions that do not have right or wrong implications, such as alternative functions (for example, Missile No. 1 selected for launch, and so forth) or transitory conditions (for example, action or test in progress, function available), provided such indication does not imply success or failure of operations.

9.19.5 *Blue*—Blue may be used for an advisory light, but use of blue shall be avoided whenever possible.

9.19.6 Ship specifications shall not mandate the use of any transilluminated display (such as LEDs) that cannot meet the color codes described.

9.20 *Flashing Lights*—The use of flashing lights shall be minimized. Flashing lights shall be used only when it is necessary to notify the operator of some condition that is out of tolerance and requires attention. The flash rate shall be within three to five flashes per second with approximately equal amounts of ON and OFF time. Flashing lights shall become steady beaming once the operator acknowledges the flashing light by activating a control that deactivates the flasher circuit. Flashing lights that could be simultaneously active shall have synchronized flashes. If the indicator is energized and the flasher device fails, the light shall illuminate and burn steadily (see 15.2) or a separate indicator showing flashing circuit failure, shall be provided.

9.20.1 *Red*—Shall be used to alert an operator that the system or any portion of the system is inoperative or that a successful mission is not possible until appropriate corrective or override action is taken. Examples of indicators that shall be coded red are those which display such information as “no-go,” “error,” “failure,” “malfunction,” and so forth.

9.21 *Legend Lights*—Legend lights (also called annunciators) shall be used in preference to simple indicator lights except where design considerations demand that simple indicators be used. The number of legend lights shall be kept to a minimum. Legend lights shall be used to provide qualitative information, not to give commands.

9.21.1 *Color Coding*—Legend lights shall be color coded in conformance with 9.19.

9.21.2 *Positive Versus Negative Legend*—When the operator’s dark adaptation must be maintained, or where legibility in high ambient illumination is critical, the illuminated label/opaque background format shall be used and the illuminated background/opaque label format shall be used only for critical alerting indicators (for example, master warning lights). Where operator dark adaptation is not required, the illuminated background/opaque label format shall be used. Contrast reversal may be used under these conditions to designate displays that have physical appearance similar to legend switches on the same panel.

9.21.3 *Lettering*—The size and other characteristics of lettering shall conform to Section 27 herein or as otherwise specified by the procuring activity.



9.21.4 *Visibility and Legibility*—With the exception of danger and caution indicators, the lettering on single-legend indicators shall be visible and legible whether or not the indicator is energized.

9.21.5 *Multifunction Legends*—Indicators designed to provide alternately presented legends shall present only one legend at a time, that is, only the legend in use shall be visible. If the indicator device uses stacked legends, it shall be designed so that:

9.21.5.1 When the rear legend is energized, it shall not be obscured by the front legend.

9.21.5.2 Parallax is minimized.

9.21.5.3 Rear legends have approximately equal brightness to front legends, and the contrast between rear legends and background is equal to that of the front legend and its background.

9.22 *Simple Indicator Lights*—Simple indicator lights shall be used only when design considerations preclude the use of legend lights.

9.22.1 *Spacing*—The spacing between adjacent edges of simple round indicator light fixtures shall be sufficient to permit unambiguous labeling, signal interpretation, and convenient bulb removal.

9.22.2 *Coding*—Simple indicator lights shall be coded in conformance with Table 2.

9.23 *Transilluminated Panel Assemblies*—Transilluminated (integrally lighted) panel assemblies may be used to perform the following:

9.23.1 Provide illuminated labels for a control panel.

9.23.2 Provide a light source for illuminating transilluminated control knobs.

9.23.3 Provide illuminated association markings on a control panel, such as connecting lines between controls, outlines around a functionally related group of controls or displays, or both.

9.23.4 Create a pictorialized representation of a system process, communication network, or other information/component organization.

9.24 *Large, Single Pictorial Graphic Panels*—Large, single pictorial graphic panels, used to display system processing, communications networks, or similar applications, shall comply with requirements for visibility, legibility, color, and illumination as specified herein.

9.25 *Relamping*—When replaceable incandescent lamps are used as the illuminant source for integral lighting of panel assemblies, lamps shall be accessible without disconnecting the panel(s). A sufficient number of lamps shall be provided so that failure of one lamp will not cause any part of the display to be unreadable.

9.26 *Brightness*—Brightness of illuminated markings and transilluminated controls shall be compatible with the ambient environment and operating conditions (for example, dark adaptation requirements). Brightness control (dimming) by the operator shall be provided where applicable to control/maintain appropriate visibility and operator dark adaptation level.

10. Scale Indicators

10.1 *Types of Scale Indicators*—The types of scale indicators that may be used include the following:

10.1.1 Moving pointer, fixed scale, circular, curved (arc), horizontal straight, and vertical straight.

10.1.2 Fixed pointer, moving scale, circular, curved (arc), horizontal straight, and vertical straight.

10.2 *Use*—The use of scale indicators shall conform to the criteria in Table 3 as well as the specific criteria contained in this section. Moving-pointer, fixed-scale indicators are preferred to fixed-pointer, moving-scale indicators. The latter should be used only when necessitated by operational requirements or other conditions, and when approved by the procuring activity.

10.3 *Type of Information*—Scale indicators shall be used to display quantitative information in combination with qualitative information (such as trend and direction of motion) and where only quantitative information is to be displayed and there is no requirement (such as speed and accuracy of response) which demands the use of printers or counters.

10.4 *Linear Scales*—Linear scales shall be used except where system requirements and the scale clearly dictate non-linearity to satisfy operator information requirements. Non-linear scales shall be used only with the approval of the procuring activity.

10.5 *Scale Marking and Numbering:*

10.5.1 *Graduation Markings*—Scale graduations shall be in increments of one, two, or five units or decimal multiples thereof (except as noted in 10.5.2). No more than three sizes of marks shall be used on any scale. The scales that require three sizes of marks include those which have numbered values in multiples of ten but are graduated in 5 and 10° intervals.

10.5.1.1 *Intermediate Marks*—The number of intermediate marks between numbered scale pointers shall not exceed nine as shown in Fig. 9 and illustrations of scales graduated in various ways are provided in Fig. 10.

10.5.1.2 *Major Marks*—Except for measurements that are normally expressed in decimals, whose numbers shall be used for major graduation marks.

10.5.2 *Scale Numerals*—Intermediate marks shall ordinarily not be numbered. On fixed scales, numerals shall be

TABLE 2 Coding of Simple Indicator Lights

Size/Type	Color			
	Red	Yellow	Green	White
13-mm (0.5-in.) DIAMETER or SMALLER/STEADY	Malfunction; action stop-ped; failure; stop action.	Delay; check; recheck.	Go ahead; in tolerance; acceptable; ready.	Functional or physical position; action in progress.
25-mm (1-in.) DIAMETER or LARGER/STEADY	Master summation (system or subsystem)	Extreme caution (impending danger).	Master summation (system or subsystem).	
25-mm (1-in.) DIAMETER or LARGER/FLASHING (3 to 5/s)	Emergency condition (impending personnel or equipment disaster).			



TABLE 3 Application of Various Types of Mechanical Displays

Use	Scalar Indicators		Mechanical Counters	Pictorial Instruments	Plotters, Recorders, Printers	Flags
	Moving Pointer	Moving Scale				
Quantitative information	FAIR Difficult to read while pointer is in motion.	FAIR Difficult to read while scale motion.	GOOD Minimum time and error for exact numerical value, but difficult to read when moving.	FAIR Direction of motion/scale relations sometimes conflict, causing ambiguity in interpretation.	GOOD Minimum time and error for exact numerical.	N/A
Qualitative	GOOD Location of pointer easy. Numbers and scale need not be read. Position change easily detected.	POOR Difficult to judge direction and magnitude of deviation without reading numbers and scale.	POOR Numbers must be read. Position changes not easily detected.	GOOD Real world situation more quickly assimilated.	POOR Numbers must be read. Position changes not easily detected.	GOOD Easily detected. Economical of space.
Setting	GOOD Simple and direct relation of motion of pointer to motion of setting knob. Position change aids monitoring.	FAIR Relation to motion of setting knob may be ambiguous. No pointer position change to aid monitoring. Not readable during rapid setting.	GOOD Most accurate monitoring of numerical setting. Relation to motion of setting knob less direct than for moving pointer. Not readable during rapid setting.	GOOD General direct control-display relationship easy to observe.	N/A	N/A
Tracking	GOOD Pointer position readily controlled and monitored. Simplest relation to manual control motion.	FAIR No position changes to aid monitoring. Relation to control motion somewhat ambiguous.	POOR No gross position changes to aid monitoring.	GOOD Same as above.	N/A	N/A
Difference estimation	GOOD Easy to calculate positively or negatively by scanning scale.	FAIR Subject to reversal errors.	POOR Requires mental calculation.	GOOD Easy to calculate either quantitatively or qualitatively by visual inspection.	FAIR Can predict possible future pattern of pen trace.	N/A
Permanent Record General	N/A Requires largest exposed and illuminated area on panel. Scale length limited unless multiple pointers used.	N/A Saves panel space. Only small section of scale need be exposed and illuminated. Use of tape allows long scale.	N/A Most economical of space and illumination. Scale length limited only by numbers of counter drums.	N/A	GOOD Provides hard copy.	N/A

vertically oriented, and on rotating scales, numerals shall be radially oriented and positioned so as to be upright when read against the pointer. Bearing dials shall have numerals (and major graduation marks) at either 10 or 30° as shown in Fig. 11.

10.5.3 *Scale Length*—Scales shall start and end on a major graduation mark even if this puts either or both ends beyond the usable range of the scale (for example, if the maximum voltage which can be read on an instrument is 23 V, the scale shall go at least to 25 V where there could be a major graduation mark).

10.5.4 *Starting Point*—Display scales shall start at zero, except where this would be inappropriate for the function involved.

10.6 *Pointers*—For best legibility, indicators with scales should have pointers that are relatively wide at the pivot, tapering gradually to a fine tip, arrowhead, or teardrop that is the same width as the smallest graduation mark.

10.7 *Tip Configuration*—The pointer tip should be tapered at a 350-mrad (20°) angle [(40°) included angle], terminating in a flat tip equal in width to the minor scale graduations.

10.7.1 *Relationship of Tip to Graduation Marks*—Pointers shall meet, but not overlap, the shortest scale-graduation mark.

The tips shall never be more than 1.5 mm ($1/16$ in.) from the scale graduations. The tip shall be equal in width to the minor scale graduations.

10.7.2 *Normal Pointer Position*—The normal (or zero) pointer position of a scalar indicator shall be at 12 o'clock for right-left directional information, and at 9 o'clock for up-down directional information. For purely quantitative information, either position may be used.

10.7.3 *Pivot Point*—Pointers shall be pivoted at the right for vertical scales and at the bottom for horizontal scales.

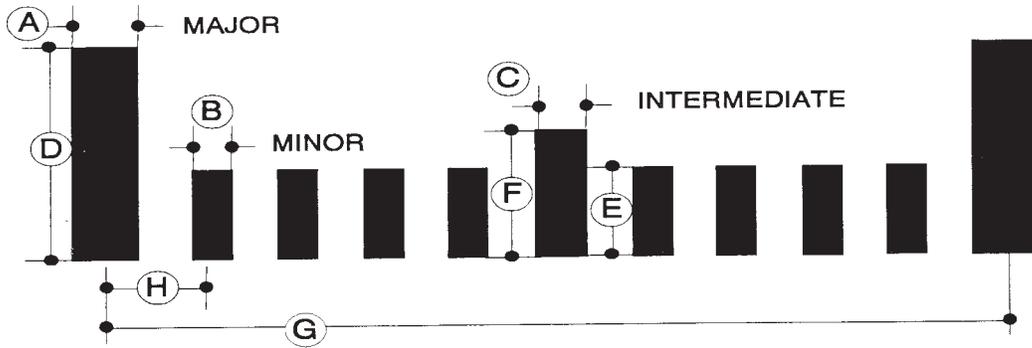
10.7.4 *Mounting*—The pointer shall be mounted as close as possible to the face of the dial to minimize parallax.

10.7.5 *Luminance Contrast*—Luminance contrast of at least 75 % shall be provided between the scale face, the markings, and the pointer.

10.7.6 *Color*—Pointers shall be the same color as the numbers and scale divisions.

10.7.7 *Pointers per Shaft*—There shall not be more than two pointers on a single shaft.

10.7.8 *Reciprocal Pointers*—With reciprocal (double-ended) pointers, it shall be easy to distinguish the end that indicates the reading.



Dimension, mm (in)	Viewing Distance		
	710 (28.0)	910 (35.9)	1525 (60.2)
A (Major index width)	0.89 (.035)	1.14 (.045)	1.90 (.075)
B (Minor index width)	0.64 (.025)	0.81 (.032)	1.37 (.054)
C (Intermediate index width)	0.76 (.030)	0.99 (.039)	1.63 (.064)
D (Major index height)	5.59 (.221)	7.19 (.283)	12.0 (.473)
E (Minor index height)	2.54 (.100)	3.28 (.129)	5.44 (.214)
F (Intermediate index width)	4.06 (.160)	5.23 (.206)	8.71 (.343)
G (Major index separation between midpoints)	17.8 (.701)	22.9 (.902)	38.0 (1.50)
H (Minor index separation between midpoints)	1.78 (.070)	2.29 (.090)	3.81 (.150)

FIG. 9 Scale of Markings

10.7.9 *Edgewise Indicators*—In edgewise indicators such as rectangular meters with straight scales, only the tip of the pointer may be visible. If so, it shall be distinctive and obvious: a flag, spade, or target pointer.

10.7.10 *Dial Faces*—If the display is used for making a setting, such as tuning in a desired wavelength, it is usually advisable to cover the unused portion of the dial face. The open window shall be large enough to show at least one numbered graduation on each side of any setting. If the display is used in tracking, for example, a heading indicator, the whole dial face shall be exposed.

10.7.11 *Coding*—When certain operating conditions (such as normal operating temperature or dangerous pressure level) always fall within a limited range of the total scale, these

ranges shall be made readily identifiable by means of pattern, color, or shape coding applied to the face of the instrument. Use of red color coding shall be limited to critical situations. Operating zones may be shape coded when the indicator must be viewed in very low-light-level work environments, for example, 0.07 to 0.7 cd/m² (0.02 to 0.2 ft-L), or where the illuminant color will cause difficulty in discrimination of colors. See Fig. 12.

10.7.11.1 *Use*—Coding on the face of scale indicators may be used to convey such information as desirable operating range, dangerous operating level, caution, undesirable, and inefficient.

10.7.11.2 *Pattern or Color Coding*—When certain operating conditions always fall within a given range on the scale,

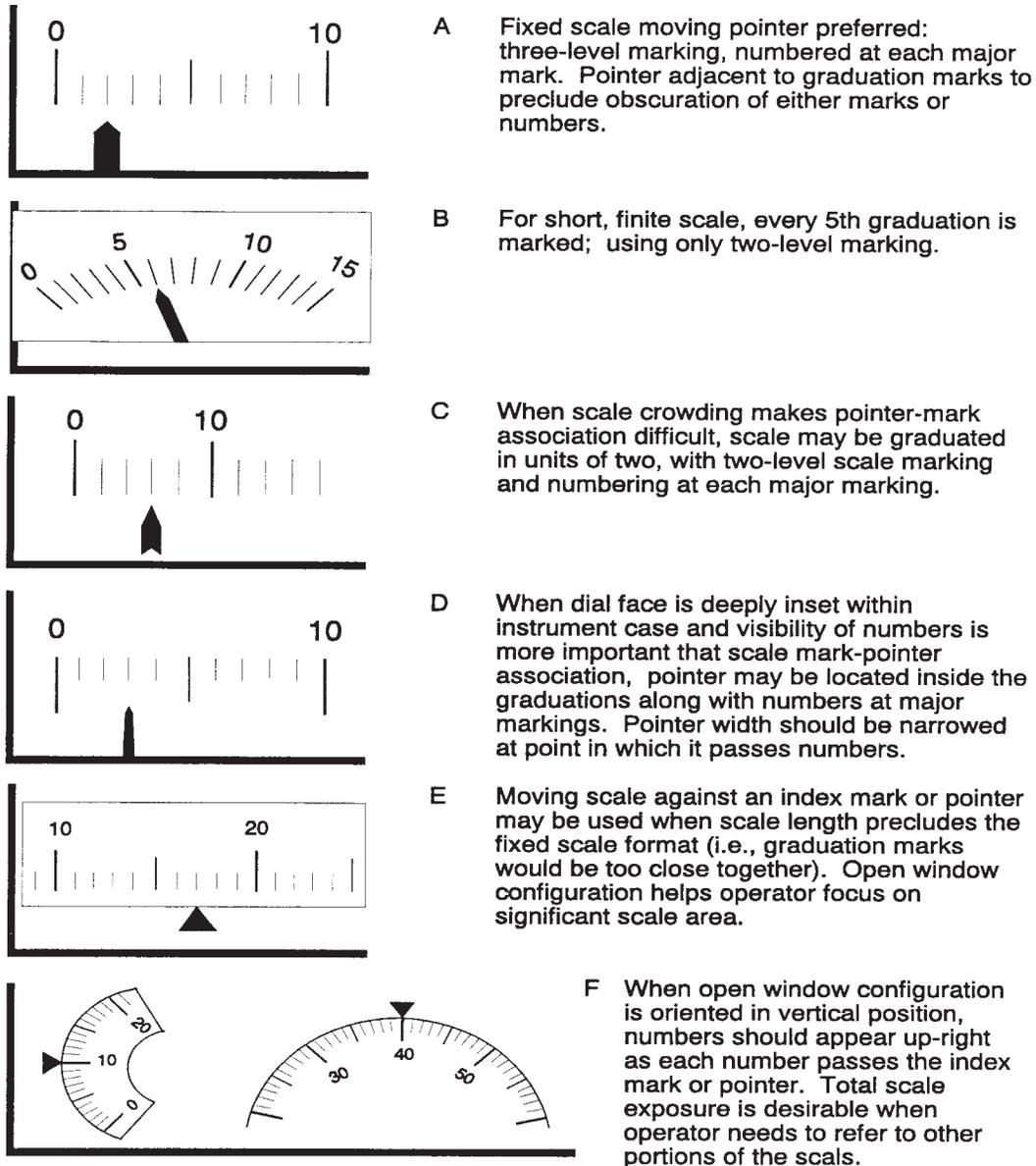


FIG. 10 Scale Graduation, Pointer Position, and Scale Numbering Alternatives

these areas shall be made readily identifiable by means of pattern or color coding applied to the face of the instrument. Color or pattern coding shall be applied to the face of the instrument, not outside the face on the panel or bezel around the instrument. No lines, labels, or any other marks shall be between the instrument pointer and the color or pattern coding.

10.7.11.3 *Choice of Colors*—Red, yellow, and green may be applied, provided they conform to the meanings specified in 9.19 and are distinguishable under all expected lighting conditions.

10.7.11.4 *Pattern Coding*—Zone scales may be shape coded when the indicator must be viewed in blackout stations or where the illuminant color will cause difficulty in color band discrimination.

10.8 *Moving-Pointer, Fixed-Scale Indicators:*

10.8.1 *Numerical Progression*—Numbered scales shown increase clockwise, from left to right, or from bottom to top,

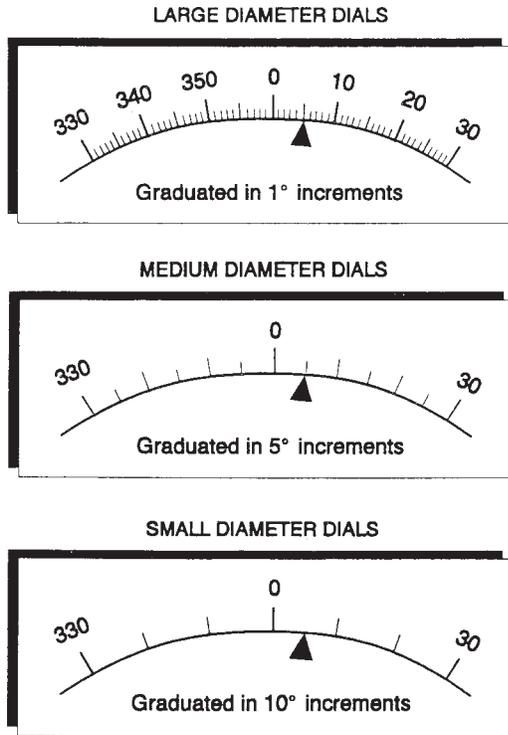
depending on scale layout (circumferential or linear in horizontal or vertical axis).

10.8.2 *Orientation of Numerals*—Numbers on fixed scales shall appear vertical (upright) to the observer.

10.9 *Circular Scales:*

10.9.1 *Scale Reading and Pointer Movement*—To display values ranging from negative through zero to positive, consistently locate the zero point at the 9 or 12 o'clock position. Positive values shall increase when the pointer moves clockwise (to the right), and negative values shall increase when the pointer moves counterclockwise (to the left).

10.9.2 *Zero Position and Pointer Movement*—When positive and negative values are displayed around a zero point, the magnitude of positive values shall increase with movement of the pointer up or to the right, and the magnitude of negative values shall increase with movement of the pointer down or to



NOTE - The above general scale marking concepts also apply to displays in which measure is in mils.

NOTE—The above general scale marking concepts also apply to displays in which measure is in mils.

FIG. 11 Fixed-Scale Azimuth Dials

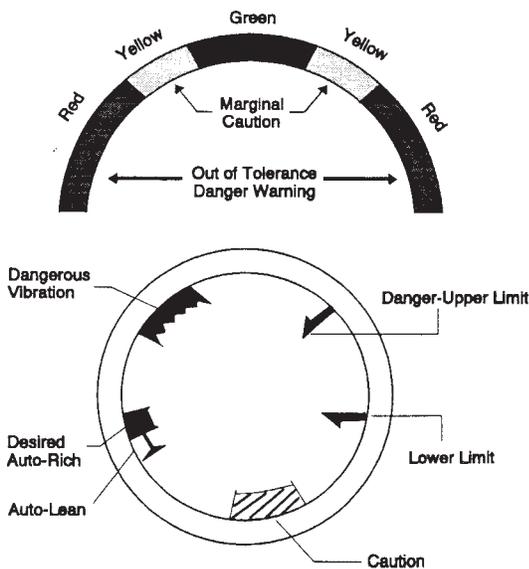


FIG. 12 Shape and Color-Coding Operating Ranges

the left. The position of the zero value on a numbered scale, and the relative pointer movement shall conform to criteria in Fig. 13.

10.9.3 *Scale Break*—There shall be an obvious break of at least 10° of arc between the two ends of the scale, except on multirevolution instruments such as clocks.

10.9.4 *Number of Pointers*—Except for clocks or watches (which often have three hands), not more than two coaxial pointers shall be used on a single-dial indicator without approval from the procuring activity.

10.9.5 *Aligned Pointers for Check Reading*—When a stable value exists for given operating conditions in a group of circular-scale indicators, they shall be arranged either in rows so that all pointers line up horizontally on the 9 o'clock position under normal operating conditions or in columns so that all pointers line up vertically in the 12 o'clock position under normal operating conditions in accordance with Fig. 14. If a matrix of indicators is needed, preference shall be given to the 9 o'clock position.

10.9.6 *Relative Position of Scale Marks and Numbers*—When reading time and accuracy are critical, circular scale markings and location of associated numbers shall be arranged to prevent pointers from covering any portion of scale marks or numerals, and scale marks/numbers shall be on, or close to, the plane of the pointer tip (that is, to avoid visual parallax) in accordance with Fig. 15. If readout accuracy is not critical (the gross relationship between the pointer and the numeral is all that is required), then arrangement of numerals inside the scale annulus is acceptable. (See examples in Fig. 16.)

10.10 *Curved (Arc), Horizontal, or Vertical Straight Scales:*

10.10.1 *Scale Reading and Pointer Movement*—The magnitude of the scale reading shall increase with movement of the pointer up or to the right.

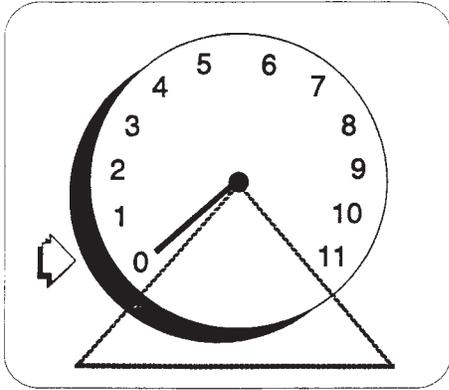
10.10.2 *Zero Position and Pointer Movement*—The position of the zero value on curved or straight scales shall conform to criteria in Fig. 13.

10.10.3 *Relative Position of Pointers, Scales, and Numerals*—The numbers shall be located on the side of the graduation marks opposite the pointer. The graduation marks shall be aligned on the side of the pointer and stepped on the side of the numbers. The relative position of pointers, scales, and numerals shall conform to criteria in Fig. 16.

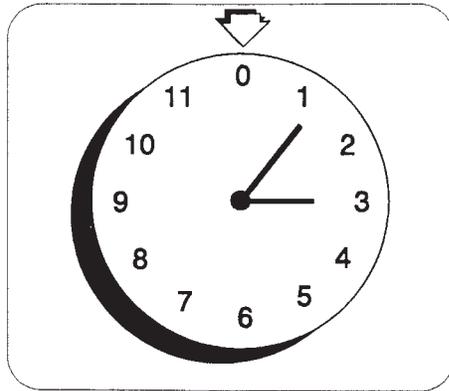
10.11 *Fixed-Pointer, Moving-Scale Indicators:*

10.11.1 *Open Window Display*—When the display will be used primarily for setting in a value (for example, tuning to a desired wavelength), only the portion of the scale of interest shall be exposed, that is, the rest of the scale is covered to reduce visual clutter and confusion. The open window shall be of sufficient size to permit view of at least one numbered graduation either side of the desired setting, that is, at least two number values shall appear within the window at all times unless the scale is finite and the dial cannot be rotated continuously through successive rotations in the same direction. If the display will be used for tracking (as in the case of a directional indicator), the entire face of the dial shall be exposed.

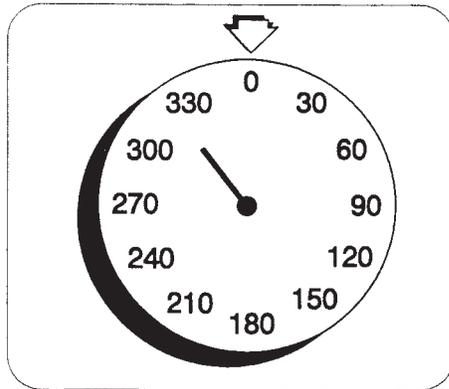
10.11.2 *Circular Scales*—There are ambiguities in associating moving circular scales with control movements; thus moving-scale fixed-pointer indicators are not recommended. Moving circular scales necessarily violates one of these principles of human engineering:



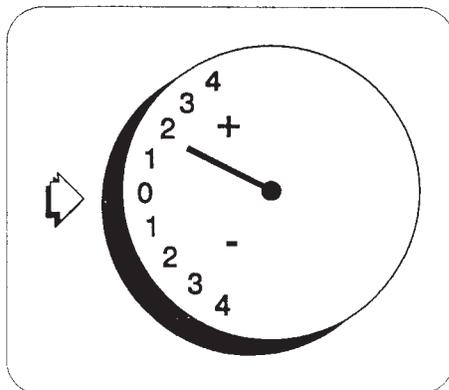
When a dial scale is of finite length, it should be numbered so that value increase is clockwise. The zero starting point should be approximately at the 7 o'clock position. There should be an obvious "break" between the two ends of the scale of at least 10° of arc.



When multirevolution pointer movement is involved, the zero reference should be at the top of the dial, and there should be no break between scale ends. No more than two pointers shall be used except for special cases, e.g., clock (with second hand).

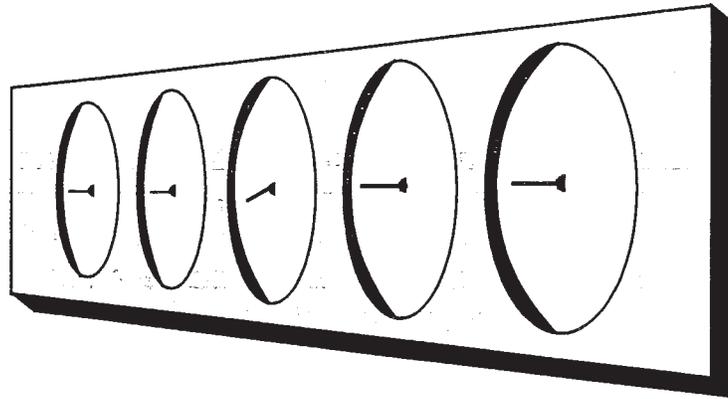


Azimuth dial scales shall be laid out with the zero (or north) reference at the top of the dial, and scale values shall increase clockwise at least every 30° reference should be numbered.

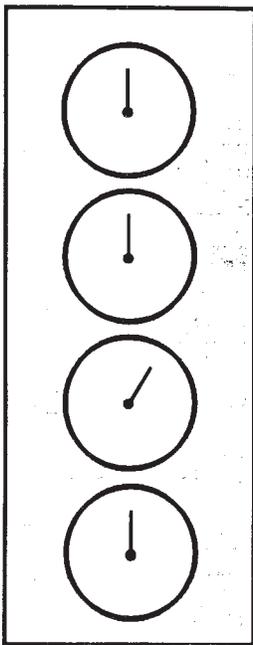


Positive/negative dial formats shall be laid out with the zero (or "null" position) located at the 9-, 12-, or 3-o'clock position. Scale values shall increase right or left, or up or down as appropriate to provide positive/negative pointer movement relationships.

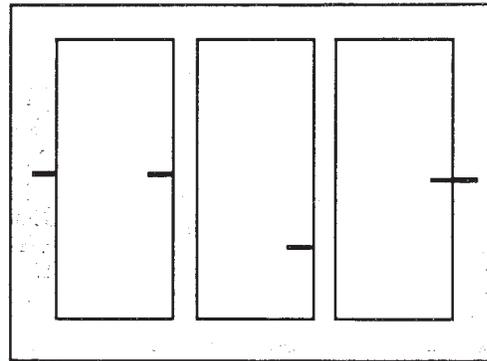
FIG. 13 Zero Position and Pointer Movement for Circular Dial Displays



9-o'clock pointer alignment for horizontal dial array.



12-o'clock pointer alignment for vertical dial array.



Straight-line scale format with "nominal" operating reference common among all displays at the midscale position. Also applicable for "moving-tape" indicators.

FIG. 14 Aligned Pointers for Rapid Check Readings

10.11.2.1 *Principle 1*—Scale numbers shall increase in a clockwise direction. Values on moving circular scales shall therefore increase with counterclockwise rotation of the dial face.

10.11.2.2 *Principle 2*—The direction of movement of the associated control shall be compatible with the direction of movement of the dial, for example, clockwise movement of the control shall result in clockwise movement of the dial.

10.11.2.3 *Principle 3*—Clockwise movement of a control shall result in an increase.

10.11.2.4 If Principle 2 is compromised, for example, clockwise movement of the control results in counterclockwise movement of the dial, operators err in the initial direction of turn. If Principle 3 is compromised, a standard control movement-system relationship is violated.

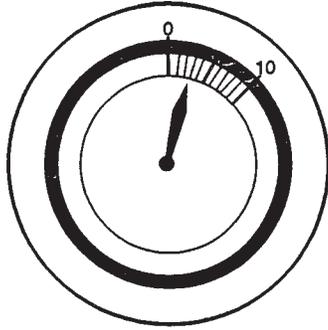
10.11.3 The following practices are recommended for designing circular moving scales to minimize the effects of incompatibilities:

10.11.3.1 The numbers shall increase clockwise around the face for controls without dial face masks. Therefore, the dial face moves counterclockwise to increase readings.

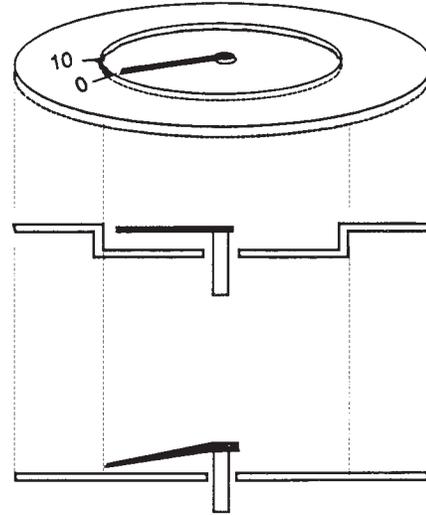
10.11.3.2 If the associated control has no direct effect on the performance of the equipment (such as tuning in radio stations, and so forth), the scale shall rotate counterclockwise (increase) when the associated knob or crank is turned counterclockwise.

10.11.3.3 If the associated control has a direct effect on the performance of the equipment (such as speed, direction, and so forth), the scale shall rotate counterclockwise (increase) with a clockwise, upward, or rightward movement of the associated control.

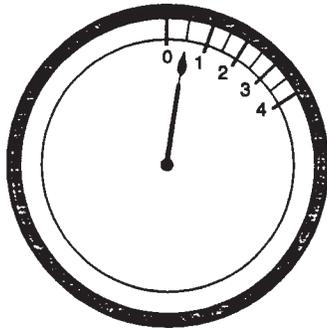
10.11.4 *Straight Scales Moving Vertically and Horizontally*—Straight scales that move vertically and horizontally exhibit the same direction-of-motion ambiguities as circular-moving scales. The numbers shall be printed so they increase from bottom to top or from left to right on the scale plate itself. Then the scale shall increase (move downward or



For maximum reading accuracy, numerals should be placed outside the scale and the inner annulus of scales marks provides an "even" border, against which the pointer tip rides; i.e., the pointer is an equal distance, nominal 0.8 - 1.6 mm (0.03 - 0.06 in), from all scale marks, never overlapping any mark or numeral.



The plane of the numeral/scale information should be coincident with that of the pointer tip - or as near as is practical to prevent or minimize visual parallax.



Alternate format when the instrument face is surrounded with a deep bezel, i.e., numerals are

FIG. 15 Relative Position of Scale Marks, Numerals, and Pointers on Circular Dials

to the left) when the associated knob or crank is moved clockwise or when the associated lever is moved upward or to the right.

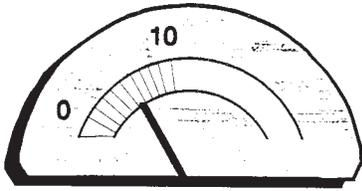
10.11.5 *Accepted Deviations*—Deviations from the previously listed scale-design principles may be made when other considerations have prime importance. Certain unique applications of scales require other design features and compromises may be required. For example, an azimuth indicator with the numerical progression of 30, 60, 90, and so forth, is less satisfactory than those previously recommended. However, this arrangement represents a compromise between the best numbering progression and a manageable size of the dial. Where the azimuth indicator is a small dial, the numbered cardinal points, north, east, south, west, serve as anchoring points in interpreting this indication, and a progression by 30s is a good solution. Where the dial can be made large enough, the major intervals shall be marked by 10's.

10.12 *Nonlinear Scales*—Nonlinear scales condense a large range into a relatively small space, yet permit sensitive readings at certain critical ranges of the scale. When error tolerances are a constant percentage of the indication, a logarithmic scale is very suitable. However, logarithmic scales shall show enough numbered graduation marks to prevent operators from reading the scale as if it were linear.

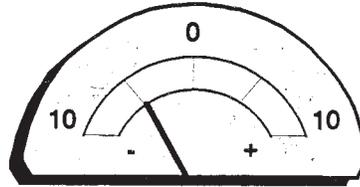
10.13 *Moving Tape Displays*—When the scale length required for acceptable readout accuracy exceeds the limits of the capacity of the display package, that is, compaction of scale markings would make the display legible or subject to readout error, moving-tape scale format shall be considered.

10.14 *Composite Scalar/Pictorial Displays*—Combination of scales, pointer, or pictorialized symbols may be used to combine functionally related information into a single instrument or display (for example, artificial horizon/command heading, true/relative bearing, and other similar combinations). Design of significant reference features (or ship symbols, or pitch scales, and so forth) shall conform to the general criteria herein relative to direction-of-motion, scale-pointer relationships, legibility, and so forth. Color contrast shall be used to aid the operator in differentiating between various elements of the combined or composite display (such as dark land versus light sky, and so forth).

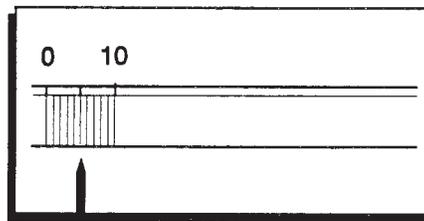
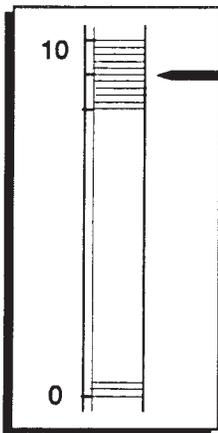
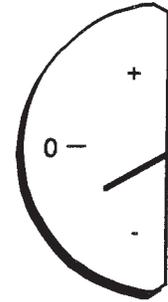
10.15 *Head-Up Display*—The head-up display (a positional/command type of display) typically projected on the windshield or window in front of an operator to provide information without the operator having to look at instrument panel or the console displays) may be considered only with the express approval of the procuring agency.



Numerals should be located outside scale marks, and pointers should ride against the inner scale annulus just short of the marking. The zero reference should be to the left so that increasing numbers and pointer motion is clockwise.



Zero reference (null) for arc scale formats should be centered on the scale, with positive value increase to the right or upward; negative increase to the left, and/or downward. A "mirror-image" of the vertical format is also acceptable.



Relative location of numerals, scale and pointer on "straight-line" display formats should be as shown, i.e., pointer should not cover either the scale marks or the numerals. The pointer should emanate from the right side of the vertical format, from the bottom of the horizontal format.

FIG. 16 Relative Position of Scale Marks, Numerals, and Pointers on Arcs and Circular Dials

11. Cathode Ray Tube (CRT) Displays

11.1 *Signal Size*—When a target of complex shape is to be distinguished from a nontarget shape that is also complex, the target signal shall subtend not less than 6 mrad (20 min) of visual angle and shall subtend not less than ten lines or resolution elements. Image quality shall be consistent with the operator's needs.

11.2 *Viewing Distance*—A 400-mm (16-in.) viewing distance shall be provided whenever practicable. When periods of scope observation will be short, or when dim signals must be detected, the viewing distance may be reduced to 250 mm (10 in.). Design shall permit the observer to view the scope from as close as desired. Displays that must be placed at viewing distances greater than 400 mm (16 in.) as a result of other considerations shall be appropriately modified in aspects such as display size, symbol size, brightness ranges, line-pair spacing, and resolution.

11.3 *Screen Luminance*—The ambient illuminance shall not contribute more than 25 % of screen brightness through diffuse reflection and phosphor excitation. A control shall be provided to vary the CRT luminance from 10 % of minimum ambient luminance to full CRT luminance. A control shall be provided

to vary the luminous symbol/dark background or dark symbol/luminous background contrast ratio. CRTs shall comply with 13.11.

11.4 *Faint Signals*—When the detection of faint signals is required and when the ambient illuminance may be above 0.25 fc (2.7 lx), scopes shall be hooded, shielded, or recessed. (In some instances, a suitable filter system may be used, subject to approval by the procuring activity.)

11.5 *Luminance Range of Adjacent Surfaces*—The luminance range of surfaces immediately adjacent to scopes shall be between 10 and 100 % of screen background luminance. With the exception of emergency indicators, no light source in the immediate surrounding area shall be of a greater luminance than the CRT signal.

11.6 *Ambient Illuminance*—The ambient illuminance in the CRT area shall be appropriate for other visual functions (setting controls, reading instruments, maintenance) but shall not degrade the visibility of signals on the CRT display. When a CRT display is used in variable ambient illuminance, illuminance controls shall be provided to dim all light sources, including illuminated panels, indicators, and switches in the immediate area. Automatic adjustment of CRT brightness may be used if the CRT brightness is automatically adjusted as a

function of ambient illuminance, and the range of automatic adjustment is adequate for the full range of ambient illuminance.

11.7 *Reflected Glare*—Reflected glare shall be minimized by proper placement of the scope relative to the light source, use of a hood or shield, or optical coatings or filter control over the light source.

11.8 *Adjacent Surfaces*—Surfaces adjacent to the scope shall have a dull matte finish.

11.9 *Pictorial/Graphic Situation Formats*—Pictorial or situation data such as plan position indicator data, shall be presented as luminous symbols/dark background.

11.10 *Font Legibility*—Where alphanumeric characters appear on CRT-like displays, the font style shall allow discrimination of similar characters, such as Letter 1 and Number 1; Letter Z and Number 2.

12. Large-Screen Displays

12.1 *Use*—Large-scale displays may be used when:

12.1.1 A group of operators frequently refer to the same information and are required to interact as a team based on the same information.

12.1.2 One or more members of a team of operators must move about, yet require frequent referral to information required to make decisions, and which they cannot carry with them, or do not have displayed at their assigned position(s).

12.1.3 Space or other constraints preclude the use of individual displays for each team member to call up commonly used information.

12.1.4 It may be desirable to have general information available to persons who shall not interrupt ongoing group operations by looking over the shoulder(s) of individual operator(s) to see their individual displays.

12.2 *Avoidance*—Large-screen displays shall not be used when the environmental conditions do not allow satisfactory observational geometry to ensure that all critical operators have appropriate visual access in terms of viewing distance, angle, and lack of interference from intervening objects, personnel, or ambient lighting. If the display is optically projected, see 13.8.

12.3 *Viewing Distance*—The display shall not be placed further from an observer than will provide appropriate resolution of critical detail presented on the display (see legibility requirements of Section 27). The display shall not be closer to any observer than one half the display width or height, whichever is greater.

12.4 *Physical Interruption of View*—Large-screen displays shall not be located with respect to critical observers so that the view of the display is obscured regularly by persons moving about by normal traffic patterns.

12.5 *Control of Displayed Information*—Large-screen group display systems shall be designed so that critical information cannot be modified or deleted inadvertently or arbitrarily, and therefore:

12.5.1 Control of changes in the group display shall be under the control of designed operators who operate according to preestablished procedures, upon command of a person in charge, or both.

12.5.2 When an individual must make changes that are of interest only to him or her, a separate, remote display shall be provided.

12.6 *Content of Displayed Information*—The content of displayed information shall be evident to a trained observer without requiring reference to display control settings.

12.7 *Mounting Height*—Large-screen displays, such as status boards in CIC rooms, which are mounted vertically, shall be no lower than 457.2 mm (18 in.) (preferred), 304.8 mm (12 in.) absolute, above the deck, or no higher than 1981.2 mm (78 in.) above the deck.

13. Other Displays

13.1 *Types*—Where applicable, direct-reading counters, printers, plotters, flags, optical projection, LED, gas discharge, liquid crystal, and electroluminescent displays may be used providing the color codes of 9.19 are not violated.

13.2 *Applications*—The selection of the above types of displays for various applications shall be based on the following specific criteria as well as the criteria in Table 2. Plotters, printers, and recorders shall not be used as the primary display for systems.

13.3 *Counters:*

13.3.1 *Use*—Counters shall be used for presenting quantitative data when a continuous trend indication is not required and when a quick, precise indication is required.

13.3.2 *Mounting*—Counters shall be mounted as close as possible to the panel surface so as to minimize parallax and shadows and maximize the viewing angle. When counters are used in equipment that is mounted on a vertical surface, the mounting height shall provide for full view of the counter wheel.

13.3.3 *Spacing Between Numerals*—The horizontal separation between numerals shall be between one quarter and one half the numeral width. Commas shall not be used.

13.3.4 *Movement:*

13.3.4.1 *Snap Action*—Numbers shall change by snap action in preference to continuous movement.

13.3.4.2 *Rate*—Numbers shall follow each other not faster than two per second when the observer is expected to read the numbers consecutively.

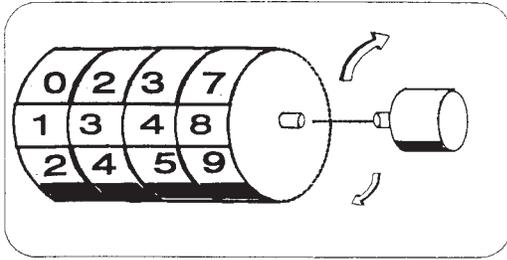
13.3.4.3 *Direction*—The rotation of the counter reset knob shall be clockwise to increase the counter indication or to reset the counter.

13.3.4.4 *Reset*—Counters used to indicate the sequencing of equipment shall be designed to be reset automatically upon completion of the sequence. Provision shall also be made for manual resetting. Where push buttons are used to reset mechanical counters manually, actuating force required shall not exceed 16.7 N (60 oz).

13.3.5 *Display Design*—Numeral design, movement (rate and direction), and arrangement shall be as shown in Fig. 17 and Table 4.

13.3.6 *Illumination*—Counters shall be self-illuminated when used in areas in which ambient illumination will provide display luminance below 3.5 cd/m (1 ft-L).

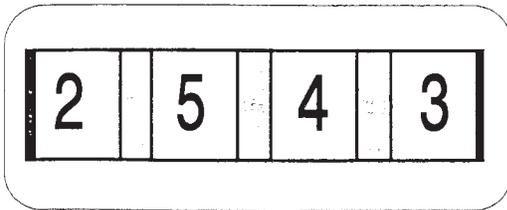
13.3.7 *Finish*—The surface of the counter drums and surrounding areas shall have a dull finish to minimize glare.



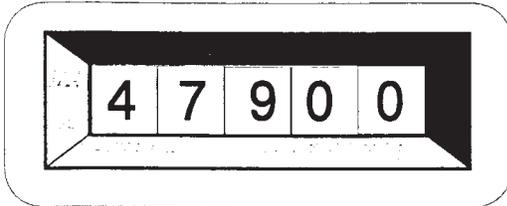
A Counter drums should be numbered so that a clockwise rotation of drums and/or reset control produce increasing numerical values.

Numerals should "snap" into position so that the entire numeral appears within the viewing window.

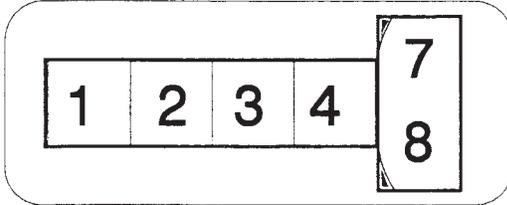
Number height : width proportions should be within the range of 5:3 to 1:1 (1:1 is the preferred ratio) except for number "1".



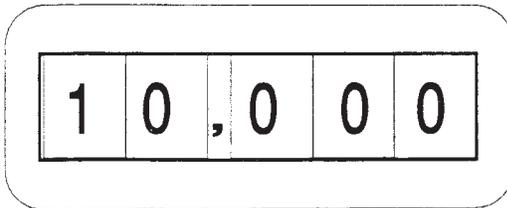
B Spacing between adjacent numerals should not exceed 1/4th width of wide numerals; 1/2 the width of narrow numerals when several numbers are to read as a total value.



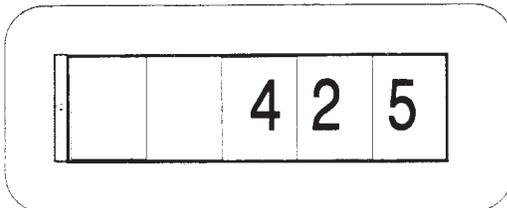
C Counter drums should be mounted as close to the front panel surface as practical, and the edges of the viewing window should be beveled to provide at least 45° off-angle view of the display.



D When numbers on right drums need not be read accurately, these may move in a continuous motion, in which case at least two of the numbers should be visible.



E Decimal points may be inserted within the viewing window or placed on the panel when the position remains constant. Commas should not be used unless more than four numbers appear in the window.



F If left-hand numbers are seldom used, provide a blanking system rather than present several preceding zeros (i.e., the blanking device exposes left-hand drums only when numerical value is displayed).

FIG. 17 Drum-Type Counter Design

13.3.8 *Contrast*—Color of the numerals and background shall provide high contrast (black on white or converse, as appropriate).

13.4 *Printers*:

13.4.1 *Use*—Printers shall be used when a visual record of data is necessary or desirable. Use of printers shall conform to Table 3.



TABLE 4 Character Sizes for Mechanical Counters

Viewing Distance, mm (in.)	Height, mm (in.)	Width, mm (in.)	Stroke Width, mm (in.)	Minimum Separation Between Numerals, mm (in.)
Normal Illumination (above 3.4 cd/m)				
710 (28.0 ^A)	3.8 (0.15)	3.8 (0.15)	0.94 (0.04)	0.64 (0.02)
910 (35.8)	4.8 (0.19)	4.8 (0.19)	1.2 (0.05)	0.81 (0.03)
1525 (60.0)	7.9 (0.31)	7.9 (0.31)	1.3 (0.05)	1.3 (0.05)
Low illumination (0.1 to 3.4 cd/m)				
710 (28.0 ^A)	5.6 (0.22)	5.6 (0.22)	0.94 (0.04)	0.94 (0.04)
910 (35.8)	7.1 (0.28)	7.1 (0.28)	1.2 (0.05)	1.2 (0.05)
1525 (60.0)	13.0 (0.51)	13.0 (0.51)	2.1 (0.08)	2.1 (0.08)

^AFor reading distances closer than 710 mm (28.0 in.), characters shall be at least 3 mm (0.118 in.) high.

13.4.2 *Visibility*—The printed matter shall not be hidden, masked, or obscured in a manner that impairs direct reading.

13.4.3 *Contrast*—A minimum of 75 % luminance contrast shall be provided between the printed material and the background on which it is printed.

13.4.4 *Illumination*—The printer shall be provided with internal illumination if the printed matter is not legible in the planned operational ambient illumination.

13.4.5 *Take-up Provision*—A take-up device for printed material shall be provided.

13.4.6 *Annotation*—Where applicable, printers shall be mounted so that the printed matter (for example, paper, metallized paper) may be easily annotated while still in the printer.

13.4.7 *Legibility*—The print output shall be free from character line misregistration, character tilt, or smear.

13.4.8 *Printed Tapes*—The information on the tapes shall be printed in such a manner that it can be read as it is received from the machine without requiring the cutting and pasting of tape sections.

13.4.9 *Control, Replenishment, and Service*—Printers shall conform to the criteria of 13.5.8 for plotters and recorders.

13.5 Plotters and Recorders:

13.5.1 *Use*—Plotters and recorders may be used when a visual record of continuous graphic data is necessary or desirable.

13.5.2 *Visibility*—Critical graphics (those points, curves, and grids that must be observed when the recording is being made) shall not be obscured by pen assembly, arm, or other hardware elements.

13.5.3 *Contrast*—A minimum of 50 % luminance contrast (see 3.1.43) shall be provided between the plotted function and the background on which it is drawn.

13.5.4 *Take-Up Device*—A take-up device for extruded plotting materials shall be provided when necessary or desirable.

13.5.5 *Job Aids*—Graphic overlays should be provided where they may be critical to proper interpretation of graphic data as it is being generated. Such aids shall not obscure or distort the data.

13.5.6 *Smudging/Smearing*—The plot shall be resistant to smudging or smearing under operational use.

13.5.7 *Annotation*—Where applicable, plotters and recorders shall be designed or mounted so that the operator can write on or mark the paper while it is still in the plotter/recorder.

13.5.8 *Control, Replenishment, and Service*—Plotters and recorders shall conform to criteria herein with regard to the following:

13.5.8.1 Controls and displays used to start, stop, or adjust the machine and critical operating elements.

13.5.8.2 Positive indication of the remaining supply of plotting materials (paper, ink, ribbon).

13.5.8.3 Insertion, adjustment for operation, and removal of paper, replenishment of ink supply, replacement of pen, or other items determined to be operator tasks, without requiring disassembly, special equipment, or tools.

13.5.8.4 Minor servicing on site by a technician, such as the adjustment of the drive system, cleaning, or replacement of operating items that ordinarily would not be available to an operator.

13.6 Flags:

13.6.1 *Use*—Flags shall be used to display qualitative, nonemergency conditions. Use of flags shall conform to Table 3.

13.6.2 *Mounting*—Flags shall be mounted as close to the surface of the panel as possible without restricting their movement or obscuring necessary information.

13.6.3 *Snap Action*—Flags shall operate by snap action.

13.6.4 *Contrast*—A minimum of 75 % luminance contrast (see 3.1.43) shall be provided between flags and their backgrounds under all expected lighting conditions.

13.6.5 *Malfunction Indication*—When flags are used to indicate the malfunction of a visual display, the malfunction position of the flag shall obscure part of the operator's view of the malfunctioning display and shall be readily apparent to the operator under all expected levels of illumination.

13.6.6 *Legend*—When a legend is provided on the flag, the lettering shall appear upright when the flag assumes the active or no-go position.

13.6.7 *Test Provision*—A convenient means shall be provided for testing the operation of flags.

13.7 Large-Screen Optical Projection Displays:

13.7.1 *Use*—Providing ambient light can be properly controlled, optical projection displays are suitable for applications requiring group presentation, pictorial and spatial information, past history versus real-time presentation, synthetically generated pictures, simulation of the external world, and superposition of data from more than one source. Rear projection shall be used where physical obstructions to front projection result in poor visibility or where work areas require high ambient illumination for other activities.

13.7.2 *Seating Area*—Viewing distance/image width relationship and off-centering viewing of optical projection displays for group viewing shall conform to the preferred limits of Table 5 and shall not exceed the acceptable limits indicated. For individual viewing from a fixed location, off-centerline viewing shall not exceed 175 mrad (10°).

13.7.3 *Image Luminance and Light Distribution*—Image luminance and light distribution shall conform to the preferred limits and shall not exceed the acceptable limits of Table 5. In



TABLE 5 Group Viewing of Optical Projection Displays

Factor	Optimum	Preferred Limits	Acceptable Limits
Ratio of viewing distance/ screen diagonal	4	3–6	2–8
Angle off centerline	0° (0 mrad)	20° (350 mrad)	30° (525 mrad)
Image luminance (no film in operating projector) ^A	10 ft-L (35 cd/m ²)	8–14 ft-L (27–48 cd/m ²)	5–20 ft-L (17–70 cd/m ²)
Luminance variation across screen (ratio of maxi- mum to minimum luminance)	1	1.5	3.0
Luminance variation as a function of viewing location (ratio of maximum to mini- mum luminance)	1	2.0	4.0
Ratio of ambient light/ brightest part of image	0	0.002–0.01	0.1 max ^B

^AFor still projections, higher values may be used.

^BFor presentations not involving gray scale or color (for example, line drawings, tables), 0.2 may be used.

any case, the luminance of the screen center at maximum viewing angle shall be at least half its maximum luminance.

13.7.4 Legibility of Projected Data:

13.7.4.1 *Style*—A simple style of numerals and letters shall be used. Capital letters shall be used, rather than lowercase, except for extended copy or lengthy messages. Stroke width shall be 1/6 to 1/8 of numeral or letter height, but may be narrower for light markings on a dark background. Stroke width shall be the same for all letters and numerals of equal height. Letter and numeral widths, character spacing, and word spacing shall conform to 28.10.

13.7.4.2 *Size*—The height of letters and numerals (except single-stroke characters, such as the Number 1) shall not be less than 4.5 mrad (15 min) of visual angle and, in no instance, shall be less than 3 mrad (10 min) as measured from the longest anticipated viewing distance.

13.7.5 Contrast:

13.7.5.1 *Luminance Ratio*—Under optimal ambient lighting conditions, the luminance ratio (see 3.1.44) for optically projected displays shall be 500:1. The minimum luminance ratio for viewing charts, printed text, and other line work via slides or opaque projectors shall be 5:1. For projections that are limited in shadows and detail, such as animation and photographs with limited luminance range, the minimum luminance ratio shall be 25:1. For images that show a full range of colors or grays (in black-and-white photographs), the minimum luminance ratio shall be 100:1.

13.7.5.2 *Direction of Contrast*—Contrast may be either light on a dark background or vice versa, except where superposition is used. For subtractive superposition (at the source), data shall be presented as dark markings on a transparent background. For additive superposition (at the screen), data shall be presented as light markings on an opaque background. Colored markings against colored backgrounds of comparable brightness shall be avoided.

13.7.6 *Alignment*—Misregistration of superimposed alphanumeric data or other symbols shall be minimized.

13.7.7 *Keystone Effects*—Projector-screen arrangement shall minimize the keystone effect, that is, the distortion of

projected data proportions caused by nonperpendicularity between projector and screen.

13.8 Light-Emitting Diodes (LEDs):

13.8.1 *General*—The standard for LEDs will be the same as the requirements for transilluminated displays, Section 9 of this practice, unless otherwise specified herein.

13.8.2 *Use*—LEDs may be used for transilluminated displays, including legend and simple indicator lights, and for matrix (alphanumeric) displays, only if the display is bright enough to be readable in the environment of intended use enclosure, bright sunlight, low temperature.

13.8.3 *Intensity Control*—The dimming of LEDs shall be compatible with the dimming of incandescent lamps.

13.8.4 *Color Coding*—LED color coding shall conform to 9.19 herein, with the exception that red alphanumeric displays and red bar segments for vertical, horizontal, and circular meters may be used with approval from the procuring activity. However, red LEDs shall not be located in the proximity of emergency red lights used as outlined in 9.19.1.

13.8.5 *Lamp Testing*—LED indicator lights with 100 000 h or longer MTBF (Mean Time Between Failure) shall not require the lamp test capability specified in 9.15.

13.9 Dot Matrix/Segmented Displays:

13.9.1 *General*—The design criteria below shall be applied to those displays (LED, CRT, gas discharge, liquid crystal, and incandescent) used for presentation of alphanumeric and symbolic information.

13.9.2 *Use*—Dot matrix, 14-segment, and 16-segment displays may be used for applications involving interactive computer systems, instruments, navigation, and communication equipment, where the presentation of alphanumeric, vector-graphic, symbolic or real-time information is required. Seven-segment displays shall only be used for applications requiring numeric information.

13.9.3 *Symbol Definition*—The smallest definition for a dot matrix shall be 5 by 7 dots, with 7 by 9 preferred. If system requirements call for symbol rotation, a minimum of 8 by 11 is required, with 15 by 21 preferred.

13.9.4 *Alphanumeric Character and Symbol Sizes*—Alphanumeric and symbolic characters shall not subtend less than 4.7 mrad (16 min) of visual angle.

13.9.5 *Use of Uppercase*—Alphanumeric characters shall be uppercase.

13.9.6 *Viewing Angle*—The optimum viewing angle is perpendicular to the display. Dot matrix or segmented displays shall not be presented for viewing at an angle larger than 610 mrad (35°) off axis.

13.9.7 *Emitter Color*—Monochromatic displays shall use the following colors in order of preference: green (555 nm), yellow (575 nm), orange (585 nm), and red (660 nm). Blue emitters shall not be used.

13.9.8 *Intensity Control*—Dimming controls shall be provided where applicable to maintain appropriate legibility and operator dark adaptation level.

13.9.9 *Lamp Testing*—See 9.15.

13.9.10 *Location of Red Alphanumeric LEDs/Segmented Displays*—Red LEDs/segmented displays shall not be grouped with or located adjacent to red warning lights.



13.10 Electroluminescent Displays:

13.10.1 *Use*—Electroluminescent displays may be used wherever system requirements dictate the use of transilluminated displays provided they comply with 9.19. In addition, they may replace existing mechanical instrumentation while offering advantages of lighter weight, conservation of panel space, lower power requirements, lack of heat production, uniform distribution of illumination, longer life, elimination of parallax, and flexibility of display. Electroluminescent displays may also be used where sudden lamp failure could result in catastrophic consequences.

13.10.2 *Alphanumeric Character and Symbol Sizes*—The height of alphanumeric characters and geometric and pictorial symbols shall not subtend less than 4.5 mrad (15 min) of visual angle. Alphanumerical characters shall be composed of uppercase letters.

13.11 Special Requirements for TV Display:

13.11.1 *Resolution*—Resolution shall be 400 lines or greater both horizontally and vertically except that for low-resolution applications; line spacing need not be closer than needed to subtend 1 min of arc from the normal viewing position.

13.11.2 *Rate and Interlacing*—Except for slow-scan systems for reproduction of static images, the frame rate for sampling of video material shall be a minimum of 30/s. There shall be two display scan fields per frame period (or a minimum of 60/s) with the lines of the second scan in the frame period interlaced with the lines of the first scan.

13.11.3 *Phosphors*—The phosphors for TV screens shall have short or medium persistence and high output such as the P-4 or P-23 for black-and-white monitors and the P-22 or P-27 for color monitors.

13.11.4 *Distortion*—Spot diameter shall not vary by more than a ratio of 1.5 to 1.0 at any two points on the screen. Distortion shall not be sufficient to cause obvious nonlinearity anywhere on the screen when viewing alphanumeric formats or picture images.

13.11.5 *Gray Scale*—There shall be a minimum of at least five distinguishable gray scale levels. When the requirements include interpretation of handwriting, resolution of fine detail, or complex image interpretation, up to eight gray scale levels shall be provided.

13.12 Special Requirements for Radar/Sonar Displays:

13.12.1 *Types of Scans*—The type of scan selected shall be appropriate to the operator's task in using the radar/sonar data. Commonly used scan types shall be selected in preference to novel or experimental scan types except as approved by the procuring activity.

13.12.2 *Display Scale Sizes and Range Ring Values*—Display scale shall be selected on the basis of the following criteria.

13.12.2.1 If rings are to be used, the display scales selected shall be compatible with the use of a constant number of range rings regardless of the scale, as given in Table 6.

13.12.2.2 Display systems capable of presenting alphanumerics shall present range ring values on the CRT.

13.12.3 Appropriate scale limits considering radar/sonar characteristics such as maximum range, range resolution, bearing resolution, and maximum range of detection. For

TABLE 6 Range Ring Values

3 Range Rings Any Decimal Multiples of:	4 Range Rings Any Decimal Multiples of:	5 Range Rings Any Decimal Multiples of:
15-unit scale	4-unit scale	5-unit scale
30-unit scale	8-unit scale	10-unit scale
60-unit scale	20-unit scale	25-unit scale

example, the display scales for use with a shipboard surface search radar having a minimum range of 200 m (656.2 ft) and a maximum range of 60 km (57.3 miles) might be as follows:

13.12.3.1 *Minimum*—2 km (1.24 miles) not more than ten times the minimum range value, to capitalize on range determination at close-in ranges as in station keeping.

13.12.3.2 *Maximum*—75 km (46.6 miles) accommodates maximum range of the radar and is a good scale for estimation and interpolation.

13.12.4 Area and scaling limits suggested by representative operational situations including warfare operations, search patterns, maneuvers, flight operations, and so forth. For example, an aircraft carrier that may have a number of missions involving close-in aircraft operations at ranges from 15 to 30 km (9.3 to 18.6 miles) shall have a 30-km (18.6-miles) display scale for monitoring and control of aircraft on such missions.

14. Audio Displays, General Information

14.1 *Use*—Audio displays shall be provided when:

14.1.1 The information to be processed is short, simple, and transitory, requiring immediate or time-based response.

14.1.2 The common mode of visual display is restricted by overburdening; ambient light variability or limitation; operator mobility; degradation of vision by vibration, hypoxia, or other environmental considerations; or anticipated operator inattention.

14.1.3 The criticality of transmission response makes supplementary or redundant transmission desirable.

14.1.4 It is desirable to warn, alert, or cue the operator to subsequent additional response.

14.1.5 Custom or usage has created anticipation of an audio display.

14.1.6 Voice communication is necessary or desirable.

14.1.7 *Signal Type*—When an audio presentation is required, the optimum type shall be presented in accordance with Table 7.

14.2 *False Alarms*—The design of audio display devices and circuits shall preclude false alarms.

14.3 *Failure*—The audio display device and circuit shall be designed to preclude warning signal failure in the event of system or equipment failure and vice versa.

14.4 *Circuit Test*—All audio displays shall be equipped with circuit test devices or other means of operability test.

14.5 *Use with Several Visual Displays*—One audio signal may be used in conjunction with several visual displays, provided that immediate discrimination is not critical to personnel safety or system performance.

15. Audio Warnings

15.1 *Audible Alarms*—Audible alarms shall be provided, as necessary, to warn personnel of impending danger, to alert an



TABLE 7 Functional Evaluation of Audio Signals

Function	Type of Signal		
	Tones (Periodic)	Complex Sounds (Nonperiodic)	Speech
Quantitative indication	POOR Maximum of five to six tones absolutely recognizable.	POOR Interpolation between signals inaccurate.	GOOD Minimum time and error in obtaining exact value in terms compatible with response.
Qualitative indication	POOR-TO-FAIR Difficult to judge approximate value and direction of deviation from null setting unless presented in close temporal sequence.	POOR Difficult to judge approximate deviation from desired value.	GOOD Information concerning displacement, direction, and rate presented in form compatible with required response.
Status indication	GOOD Start and stop timing. Continuous information where rate of change of input is low.	GOOD Especially suitable for irregularly occurring signals (for example, alarm signals).	POOR Inefficient; more easily masked; problem of repeatability.
Tracking	FAIR Null position easily monitored; problem of signal-response compatibility.	POOR Required qualitative indications difficult to provide.	GOOD Meaning intrinsic in signal.
General	FAIR Good for automatic communication of limited information. Meaning must be learned. Easily generated.	POOR Some sounds available with common meaning (for example, fire bell). Easily generated.	GOOD Most effective for rapid (but not automatic) communication of complex, multidimensional information. Meaning intrinsic in signal and context when standardized. Minimum of new learning required.

operator to a critical change in system or equipment status, and to remind the operator of a critical action, or actions, that must be taken. An alerting/warning system or signal shall provide the operator with a greater probability of detecting the triggering condition than his normal observation would provide in the absence of the alerting/warning system or signal.

15.2 *Audible Alarms and Visual Displays at Consoles and Other Work Stations*—Audible alarms shall be used as a supplement to visual alarms at operator consoles and other work stations to notify an operator that a serious malfunction has occurred, the nature of which is discernible through some visual display(s). When a supplemental audible alarm is used at a console or work station, it shall be a siren (used in conjunction with a flashing red light) for a danger situation or a horn (used with a yellow light) for a caution situation. Caution signals shall be readily distinguishable from danger signals and shall be used to indicate conditions requiring awareness, but not necessarily immediate action. The audible alarm shall be silenced when the operator acknowledges the visual alarm display. If a second malfunction occurs in the same equipment or system before the first malfunction has been corrected, both the audible and visual alarms shall operate again. Other types of audible alarms may be used in lieu of the two listed here with the written approval of the procuring agency. Whichever signals are selected, the danger and caution alarms must be readily distinguishable from each other and used consistently throughout the ship. Acceptable alarm types for emergency and primary alarms are shown in Fig. 18.

15.3 *General Use Audible Alarms*—Audible alarms shall be used throughout the ship to notify crew (and passengers for commercial ships) of hazardous situations such as fire and smoke detection, release of fire-extinguishing material in a closed space, impending collision, and ship exposure to biological, chemical, or radiological agents. In addition, audible alarms may be placed in certain crew accommodation spaces (for example, the engineer’s berthing compartment) to notify

EMERGENCY ALARMS

FUNCTION	DEVICE
General Emergency Alarm	Whistle Siren Bell Klaxon
Fire Alarm	Bell Klaxon Siren
Fire (Smoke) Detection Alarm	Bell Klaxon Siren Horn
Machinery Space Fire	Bell Klaxon Siren Horn
Fire Extinguishing Medium Release	Siren Horn
Class 3 Watertight Door Closing	Horn

PRIMARY ALARMS

FUNCTION	DEVICE
Machinery Alarm	Horn Buzzer
Personnel Alarm	Buzzer
Bilge Alarm	Horn Buzzer
Steering Gear Alarm	Bell Horn Buzzer
Engineers Alarm	Horn Buzzer

SIGNALS

FUNCTION	DEVICE
Telephone	Horn Buzzer
Engine Room Telegraph	Bell Buzzer

FIG. 18 Acceptable Alarm Types for Emergency and Primary Alarms

them of a malfunction or problem in a part of the ship for which they are responsible. Audible alarms may also be used to notify an operator of an incoming telephone call or a change in the engine room telegraph (EOT) when the possibility exists that the operator would be in an area where such supplemental alarms would be needed. When general audible alarms are used, they shall comply with the following requirements.

15.4 *Visual Alarms Used with General Audible Alarms*—Visual alarms (that is, rotating or flashing lights) shall be used



in conjunction with general audible alarms in spaces with high ambient noise levels or under other circumstances where the audio alarms may not be discernible. When used the visual alarms shall comply with the following:

15.4.1 Be clearly visible and distinguishable, either directly or by reflection, in all parts of the space in which they are used;

15.4.2 Be of a color in accordance with 9.19, color coding (for Navy ships) or IMO standards for commercial ships;

15.4.3 Flash in accordance with 9.20; and

15.4.4 Flash as long as the audible alarm is activated, and for those audible alarms which are cancelled by activation of an alarm acknowledge switch the visual alarm shall be cancelled by the same alarm acknowledge switch that is used to silence the audible alarm.

16. Characteristics of Audible Alarms

16.1 Frequency:

16.1.1 *Range*—The range shall be between 200 and 5000 Hz and, if possible, between 500 and 1500 Hz. When signals must travel over 300 m (985 ft), frequencies below 1000 Hz shall be used. Frequencies below 500 Hz shall be used when signals must bend around obstacles or pass through partitions.

16.1.2 *Different Characteristics*—When several different audible alarms are to be used concurrently, discernible differences in the spectral composition or the temporal pattern, or both, shall be provided. When specific recognition of individual alarms is important (for example, the differences between a general alarm and fire detected alarm), their differences shall be coded (that is, the waveforms altered) to ensure that each alarm is quickly and easily distinguished.

16.1.3 *Spurious Signals*—The frequency of a warning tone shall be different from that of the electric power used in the system to preclude the possibility that a minor equipment failure may generate a spurious signal.

16.2 Intensity:

16.2.1 *Compatibility with Acoustical Environment*—The intensity, duration, and source location of audio alarms and signals shall be compatible with the acoustical environment of the intended receiver as well as the requirements of other personnel in the signal areas. See 17.1.

16.2.2 *Compatibility with Clothing and Equipment*—As applicable, audio signals shall be loud enough to be heard and understood through equipment or garments (for example, parka hood, NBC protective hood, hearing protective devices) covering the ears of the listener.

16.2.3 *Discomfort*—Audio warning signals shall not be of such intensity as to cause discomfort or “ringing” in the ears as an aftereffect.

17. Signal Characteristics in Relation to Operational Conditions and Objectives

17.1 *Audibility*—A signal-to-noise ratio of at least 20 dB shall be provided in at least one-octave band between 200 and 5000 Hz at the operating position of the intended receiver. However, in no case shall an audible alarm exceed 120 dB (A) (except in extremely noisy compartments in which case the alarm shall exceed the maximum ambient noise level by 10 dB (A) up to a maximum of 140 dB (A)).

17.2 Alerting Capability:

17.2.1 *Attention*—Signals shall not be so startling as to preclude appropriate responses or interfere with other functions by holding attention away from other critical signals.

17.2.2 *Onset and Sound Pressure Level*—The onset of critical alerting signals shall be sudden, and high sound pressure level shall be provided as specified in 17.1.

17.2.3 *Dichotic Presentation*—When earphones will be worn in the operational situation, a dichotic presentation shall be used whenever feasible, alternating the signal from one ear to the other by means of a dual-channel headset.

17.2.4 *Headsets*—Operators who normally wear earphones covering both ears shall have the audible alarms presented in the headset as well as in the work area. A dichotic presentation shall be used so as to provide the audible alarm to one ear and the normal auditory signals to the other on an alternating basis. Binaural headsets shall not be used in an operational environment below 85 dB (A) when that environment may contain sounds that provide the operator with useful information which cannot be presented through the headsets.

17.3 Discriminability:

17.3.1 *Use of Different Characteristics*—When several different audio signals are to be used to alert an operator to different types of conditions, discriminable difference in intensity, pitch, or use of beats and harmonics shall be provided. If absolute discrimination is required, the number of signals to be identified shall not exceed four.

17.3.2 *Coding*—Where discrimination of warning signals from each other will be critical to personnel safety or system performance, audio signals shall be appropriately coded. Alarms that are perceptibly different shall correlate with different conditions requiring critically different operator responses (such as maintenance, emergency conditions, and health hazards). Such signals shall be sufficiently different to minimize the operator’s search of visual displays.

17.3.3 *Critical Signals*—The first 0.5 s of an audio signal requiring fast reaction shall be discriminable from the first 0.5 s of any other signal that may occur. Familiar signals with established names or associations shall be selected. Speech shall be used whenever feasible.

17.3.4 *Action Segment*—The identifying or action segment of an audio warning signal shall specify the precise emergency or condition requiring action.

17.3.5 *Differentiation From Routine Signals*—Audio alarms intended to bring the operator’s attention to a warning or a caution condition shall be differentiated from routine signals, such as bells, buzzers, and normal operation noises.

17.3.6 *Prohibited Types of Signals*—The following types of signals shall not be used as warning devices where possible as a result of confusion that might exist because of the operational environment:

17.3.6.1 Modulated or interrupted tones that resemble navigation signals or coded radio transmissions.

17.3.6.2 Steady signals that resemble hisses, static, or sporadic radio signals.

17.3.6.3 Trains of impulses that resemble electrical interference whether regularly or irregularly spaced in time.



17.3.6.4 Simple warbles that may be confused with the type made by two carriers when one is being shifted in frequency (beat-frequency-oscillator effect).

17.3.6.5 Scrambled speech effects that may be confused with cross-modulation signals from adjacent channels.

17.3.6.6 Signals that resemble random noise, periodic pulses, steady or frequency modulated simple tones, or any other signals generated by standard countermeasure devices (for example, “bagpipes”).

17.3.6.7 Signals similar to random noise generated by air conditioning or any other equipment.

17.4 *Compatibility:*

17.4.1 *Existing Signals*—The meaning of audio warning signals selected for a system shall be consistent with warning signal meanings already established for that function.

17.4.2 *Acoustic Environment*—Established signals shall be used provided they are compatible with the acoustic environment and the requirements specified herein for the voice communication system. Standard signals shall not be used to convey new meanings. See 17.1.

17.5 *Masking:*

17.5.1 *Other Critical Channels*—Audio warning signals shall not interfere with any other critical functions or signals or mask any other critical audio signals.

17.5.2 *Separate Channels*—Where a warning signal delivered to a headset might mask another essential audio signal, separate channels may be provided to direct the warning signal to one ear and the other essential audio signal to the other ear.

18. Verbal Warning Signals

18.1 *Nature of Signals*—Verbal warning signals shall consist of the following:

18.1.1 An initial alerting signal (nonspeech) to attract attention and to designate the general problem.

18.1.2 A brief standardized speech signal (verbal message) that identifies the specific condition and suggests appropriate action.

18.2 *Intensity*—Verbal alarms for critical functions shall be at least 20 dB above the speech interference level at the operating position of the intended receiver.

18.3 *Vocal Criteria:*

18.3.1 *Type of Voice*—The voice used in recording verbal warning signals shall be distinctive.

18.3.2 *Delivery Style*—Verbal warning signals shall be presented in a formal, impersonal manner.

18.4 *Message Content*—In selecting words to be used in audio warning signals, priority shall be given to intelligibility, aptness, and conciseness in that order.

18.5 *Message Categories:*

18.5.1 *Critical Warning Signals*—Critical warning signals shall be repeated with not more than a 3-s pause between messages until the condition is corrected or overridden by the crew.

18.5.2 *Message Priorities*—A message priority system shall be established, and more critical messages shall override the presentation of any message occurring below it on the priority list. If two or more incidents or malfunctions occur simultaneously, the message having the higher priority shall be given first. The remaining messages shall follow in order of priority.

In the event of a complete subsystem failure, the system shall integrate previous messages via electronic gating and report the system rather than the component failure.

19. Controls for Audio Warning and Caution Devices

19.1 *Automatic or Manual Shutoff*—When an audio signal is designed to persist as long as it contributes useful information, a shutoff switch controllable by the operator, the sensing mechanism, or both, shall be provided, depending on the operational situation and personnel safety factors.

19.2 *Automatic Reset*—Whether audio and caution warning signals are designed to be terminated automatically, by manual control, or both, an automatic reset function shall be provided. The automatic reset function shall be controlled by the sensing mechanism which shall recycle the signal system to a specified condition as a function of time or the state of the signal system.

19.3 *Redundant Visual Warning*—All nonverbal aural annunciations shall be accompanied by a visual annunciation which defines the condition. This may be an illuminated display.

19.4 *Volume Control:*

19.4.1 *Automatic or Manual*—The volume (loudness) of an audio warning or caution signal shall be designed to be controlled by the operator, the sensing mechanism, or both, depending on the operational situation and personnel safety factors. Control movements shall be restricted to prevent reducing the volume to an inaudible level but in no case shall the volume be less than that of 20 dB.

19.4.2 *Ganging to Mode Switches*—Volume controls may be ganged to mode switches to provide maximum output during mission phases in which intense noise may occur and to provide reduced volume at other times. Ganging shall not be accomplished if there is a possibility that intense noise may occur in an emergency situation during a mission phase in which the volume would be decreased below an audible level.

19.4.3 *Caution Signal Controls*—Audio caution signals shall be provided with manual reset and volume controls.

19.5 *Duration*—Audio warning and caution signals shall continue until the appropriate operator response is made, alarm acknowledged, or malfunction corrected. Completion of a corrective action by the operator or by other means shall automatically terminate the signal.

19.6 *Duration Limitations*—In an emergency situation, signals that persist or increase progressively in level shall not be used if manual shutoff may interfere with the corrective action required.

20. Speech Transmission Equipment

20.1 *Frequency*—Microphones and associated system-input devices shall be designed to respond optimally to that part of the speech spectrum most essential to intelligibility (200 to 6100 Hz). Where system engineering necessitates speech-transmission bandwidths narrower than 200 to 6100 Hz, the minimum acceptable frequency range shall be 250 to 4000 Hz.

20.2 *Dynamic Range*—The dynamic range of a microphone used with a selected amplifier shall be great enough to admit variations in signal input of at least 50 dB.

20.3 *Noise-Cancelling Microphones*—In very loud, low-frequency noise environments (100 dB overall), noise-cancelling microphones shall be used and shall be capable of effecting an improvement of not less than 10-dB peak-speech to root-mean-square-noise ratio as compared with nonnoise-cancelling microphones of equivalent transmission characteristics.

20.4 *Preemphasis*—If necessary, speech system input devices shall use frequency preemphasis with a positive slope frequency characteristic no greater than 18 dB per octave from 140 to 1500 to and no greater than 9 dB per octave over the frequency range 1500 to 4800 Hz, when no clipping is used.

20.5 *Peak Clipping of Speech Signals*—Where speech signals are to be transmitted over channels showing less than 15 dB, peak-speech to root-mean-square-noise ratios, peak clipping of 12 to 20 dB may be used at system input and may be preceded by frequency preemphasis.

20.6 *Noise Shields*—When the talker is in an intense noise field, the microphone shall be put in a noise shield. Noise shields shall be designed to meet the following requirements:

20.6.1 A volume of at least 250 cm³ (15.25 in.³) to permit a pressure gradient microphone to function normally.

20.6.2 A good seal against the face with the pressure of the hand or the tension of straps.

20.6.3 A hole or combination of holes covering a total area of 65 mm² (0.1 in.²) in the shield to prevent pressure buildup.

20.6.4 Prevention of a standing wave pattern by shape or by use of sound-absorbing material.

20.6.5 No impediment to voice effort, mouth or jaw movement, or breathing.

20.7 *Speech Reception Equipment:*

20.7.1 *Frequency Range*—Headphones and loudspeakers shall be subject to the same frequency response restrictions as microphones and transmission equipment, except that loudspeakers for use in multispeaker installations and multiple channels fed into headphones (for example, where several speech channels are to be monitored simultaneously) shall respond uniformly (+5 dB) over the range 100 to 4800 Hz.

20.7.2 *Loudspeakers for Multichannel Monitoring:*

20.7.2.1 *Monitoring of Speakers*—When several channels are to be monitored simultaneously by means of loudspeakers, the speakers shall be mounted at least 175 mrad (10°) apart in the horizontal plane frontal quadrant, ranging radially from 788 mrad (45°) left to 788 mrad (45°) right of the operator's normal forward facing position. Loudspeakers used by a single person (in an area in which there is more than one speaker installed) shall be mounted directly in front of the user and be equipped with a volume control and a jack box for use with headphones.

20.7.2.2 *Filtering*—When additional channel differentiation is required, apparent lateral separation shall be enhanced by applying low-pass filtering (frequency cutoff, $F_c = 1800$ Hz) to signals fed to loudspeakers on one side of the central operator position. If there are three channels involved, one channel shall be left unfiltered, a high-pass filter with 1000-Hz cutoff shall be provided in the second channel, and a low-pass filter with 2500-Hz cutoff shall be provided in the third channel. A visual signal shall be provided to show which channel is in use.

20.7.3 *Use of Deemphasis*—When transmission equipment uses preemphasis and peak clipping is not used, reception equipment shall use frequency deemphasis of characteristics complementary to those of preemphasis only if it improves intelligibility, that is, deemphasis shall be a negative-slope frequency response not greater than 9 dB per octave over the frequency range 140 to 4800 Hz.

20.7.4 *Headsets*—If listeners will be working in high ambient noise (85 dB(A) or above), binaural rather than monaural headsets shall be provided. Unless operational requirements dictate otherwise, binaural headsets shall be wired so that the sound reaches the two ears in opposing phases. Their attenuation qualities shall be capable of reducing the ambient noise level to less than 85 dB(A). Provisions shall be incorporated to furnish the same protection to those who wear eyeglasses.

20.8 *Operator Comfort and Convenience:*

20.8.1 *Comfort*—Headphones and telephone headsets shall be designed for operator comfort, and no metal parts of the headset shall come in contact with the user's skin.

20.8.2 *Hands-Free Operation*—Operator microphones, headphones, and telephone headsets shall be designed to permit hands-free operation under normal working conditions.

20.8.3 *Accessibility of Handsets*—Where communication requirements necessitate the use of several telephone handsets, the accessibility of their standby locations shall be determined by operational priority, that is, the most frequently or urgently needed handset shall be the most accessible. Color coding may also be used where operating personnel will have visual contact with handsets under the working conditions.

20.9 *Operating Controls for Voice Communication Equipment:*

20.9.1 *Volume Controls*—Accessible volume or gain controls shall be provided for each communication receiving channel (for example, loudspeakers or headphones) with sufficient electrical power to drive sound pressure level to at least 110 dB overall when using two earphones. The minimum setting of the volume control shall be limited to an audible level, that is, it shall not be possible to disable the system inadvertently with the volume control. While separation of power (on-off) and volume control adjustment functions into a separation of power (on-off) and volume control adjustment functions into separate controls is preferred, shall conditions justify their combination, a noticeable detente position shall be provided between the OFF position and the lower end of the continuous range of volume adjustment. When combined power and volume controls are used, the OFF position shall be labeled.

20.9.2 *Squelch Control*—Where communication channels are to be continuously monitored, each channel shall be provided with a signal-activated switching device (squelch control) to suppress channel noise during no-signal periods. A manually operated, on-off switch to deactivate the squelch when receiving weak signals shall be provided.

20.9.3 *Foot-Operated Controls*—When normal working conditions will permit the operator to remain seated at the working position and access to "talk-listen" or "send-receive" control switches are required for normal operation, or if console operation requires the use of both hands, foot-operated

controls shall be provided. Hand-operated controls for the same functions shall be provided for emergency use and for use when the operator may need to move from one position to another.

20.10 *Speaker/Side Tone*—The speaker’s verbal input shall be in phase with its reproduction as heard on the headset. This side tone shall not be filtered or modified before it is received in the headset.

20.11 *Speech Intelligibility:*

20.11.1 *General*—When information concerning the speech intelligibility of a system is required, three recommended methods are available, with the appropriate selection being dependent upon the requirements of the test.

20.11.1.1 The ANSI standard method of measurement of phonetically balanced (PB) monosyllabic word intelligibility, S3.2-1960, shall be used when a high degree of test sensitivity and accuracy is required.

20.11.1.2 The Modified Rhyme Test (MRT) shall be used if the test requirements are not as stringent or if time and training do not permit the use of the ANSI method.

20.11.1.3 The Articulation Index (AI) calculations should be used for estimations, comparison and predictions of system intelligibility based upon ANSI S3.5-1969.

20.11.2 *Criteria*—The intelligibility criteria shown in Table 8 shall be used for voice communication. The efficiency of communications needed and the type of material to be transmitted shall determine which of the three communication requirements of Table 8 is to be selected.

21. Controls, General Information

21.1 *Selection Criteria*—Criteria in Table 9 and Table 10 should be used in determining the type of control to be used on control panels or other applications where controls are required.

21.2 *Users*—The type of control selected and the location of the motion envelope provided for control operation shall ensure that suitably clothed and equipped user personnel with applicable fifth through ninety-fifth percentile body dimensions and fifth percentile strength can operate them.

21.3 *Efficiency*—Since more operations are right handed than left handed, equipment shall normally be designed for right-handed operation. Other considerations are that hand manipulation is more precise than foot manipulation and that more force can usually be applied by the foot and leg than the hand and arm.

21.4 *Distribution of Work Load*—Controls shall be selected and distributed so that none of the operator’s limbs will be overburdened.

21.5 *G-loading*—Where applicable, control selection shall include consideration of operation under variable g-loading on the operator.

21.6 *Multitotation Controls*—Multitotation controls shall be used when precision is required over a wide range of adjustment.

21.7 *Detente Controls*—Detente controls shall be selected whenever the operational mode requires control operation in discrete steps.

21.8 *Stops*—Stops shall be provided at the beginning and end of the range of control positions if the control is not required to be operated beyond the indicated end positions or specified limits.

21.9 *Direction of Movement:*

21.9.1 *Consistency of Movement*—Direction of control movement shall be consistent with the related movement of an associated display, equipment component, or vessel (see Table 11 and Fig. 19). With the exception of valve controls, movement of a control forward, clockwise to the right, or up, or pressing a control, shall turn the equipment or component on, cause the quantity to increase, or cause the equipment or component to move forward, clockwise, to the right, or up.

21.9.2 *Multidimensional Operation*—When the vessel, the equipment, or the components are capable of motion in more than two dimensions, exception to Section 21.9.1 (Consistency of Movement) may be necessary to ensure consistency or anticipated response (such as forward motion of a directional control causes some vessels to dive, for example, a submarine, or otherwise descend rather than to simply move forward). When several controls are combined in one control device, caution shall be exercised to avoid conflicts (for example, control motion to the right is compatible with clockwise roll, right turn, and direct movement to the right).

21.9.3 *Operator-Control Orientation*—Controls shall be oriented with respect to the operator. Where the operator may use two or more vehicle operator stations, the controls shall cause movement oriented to the operator at the effecting station, unless remote visual reference is used.

21.9.4 *Valve Controls*—Rotary valve controls shall open the valve with a counterclockwise motion and close with a clockwise rotation. Valve controls shall be provided with double-ended arrows labeled OPEN in the counter-clockwise direction and CLOSE in the clockwise direction.

22. Arrangement and Grouping of Controls

22.1 *Grouping*—All controls that function in sequential operational necessary to a particular task, or that operate together, shall be grouped together along with their associated displays. When several steps of a sequence are selected by one control, the steps shall be arranged by order of occurrence to minimize control movements and event cycling through unnecessary steps. Cycling through the control’s ON/OFF position shall be avoided.

22.2 *Sequential Operation*—Where sequential operations follow a fixed pattern, controls shall be arranged to facilitate

TABLE 8 Intelligibility Criteria for Voice Communications Systems

Communication Requirement	Score		
	PB	MRT	AI
Exceptionally high intelligibility; separate syllables understood	90 %	97 %	0.7
Normally acceptable intelligibility; about 98 % of sentences correctly heard; single digits understood	75 %	91 %	0.5
Minimally acceptable intelligibility; limited standardized phrases understood; about 90 % sentences correctly heard (not acceptable for operational equipment)	43 %	75 %	0.3

TABLE 9 Control Selection Criteria

Function	Control ^A									
	Toggle Switch	Push Button	Bar Knob	Round Knob	Thumb Wheel D ^B	Thumb Wheel C ^C	Crank	Rocker Switch	Lever	Joystick/ Ball
Select system power state ON-OFF	2	1	3					2	1 ^D	
3-State (OFF-STBY-ON)	2		1					3		
Select between OFF/prime mode/ secondary mode(s)	3	2	1					3	1 ^D	
Select one or more of N-related functions	2	1						2		
Select one of N mutually exclusive functions of any order		1						2		
Select one of 3 to 24 discrete alternatives—sequential order			1							
Select digit—discrete		1 KEYBD	2 ^E		2 ^E					
Set value on—continuous scale				1		2	3		3	
Select value in—discrete steps		1	1		1					
Select operating condition	1	1	2					1	2	
Enter alphanumeric data		1 KEYBD								
Initiate test subfunction (momentary)	1	1	3					2		
Initiate directional function	1	2 multiple	3			3		1	1 multiple	
Create stepping impulse (momentary hold)	1	1						2		
Slew counters or other numeric readout	1	1		1 rate control			1 manual only			
Reset mechanical counter, manual				1	3	1		2		
Interrupt countdown sequence—"hold"	2	1								
Engage—disengage mechanical function									1	
Adjust light level, cont.				1	3	1			3	
Adjust sound level, cont.				1	3	1			3	
Coarse adjustment				1 small diameter		2 small motion	2 few turns		2 short throw	
Fine adjustment				1 large diameter		2 large motion	2 many turns		2 long throw	
Adjust to null position				1		2	3		3	
Single-coordinate tracking				3			2		1	
Two-coordinate tracking							3			1

^A1 = Most preferred, 3 = least preferred.

^B"D" means discrete.

^C"C" means continuous.

^DLever for heavy-duty power circuits.

^EOnly if sequential selection is acceptable.

operation (such as in a fixed pattern left to right and top to bottom, as a printed page).

22.3 Location of Primary Controls—The most important and frequently used controls shall have the most favorable position with respect to ease of reaching and grasping (particularly rotary controls and those requiring fine settings).

22.4 Consistency—The arrangement of functionally similar or identical controls shall be consistent from panel to panel throughout the system, equipment, or vessel.

22.5 Remote Controls—Where controls are operated at a position remote from the display, equipment, or controlled vessel, they shall be arranged to facilitate direction-of-movement consistency.

22.6 Maintenance and Adjustment—In general, controls used solely for maintenance and adjustment shall be covered during normal equipment operation, but shall be directly accessible and visible to the maintenance technician when required.

22.7 Spacing—Minimum spacing between control shall comply with Table 12 spacing between a control and any adjacent obstruction shall be as shown by the figures referenced by Table 12. Minimum spacing shown shall be increased for operation with gloves, mittens, NBC, or other protective handwear when such operation is a system requirement.

TABLE 10 Recommended Manual Controls

Control Function	Control Type
Small actuation force controls:	
2 Discrete positions	key lock pushbutton toggle switch legend switch slide switch
3 Discrete positions	rotary selector switch toggle switch pushbutton
4 to 24 Discrete positions	rotary selector switch
Continuous setting (linear and less than 360°)	continuous rotary knob joystick or lever
Continuous slewing and fine adjustment	crank continuous rotary knob
Large actuation force controls:	
2 Discrete positions	foot pushbutton hand pushbutton detente lever
3 to 24 Discrete positions	detente lever rotary selector switch
Continuous setting (linear and less than 360°)	handwheel joystick or lever crank
Continuous setting (more than 360°)	two-axis grip handle crank handwheel valve two-axis grip handle



TABLE 11 Conventional Control Movement Stereotypes

Direction of Movement	Function
Up, right, forward, clockwise, pull (push-pull-type switch)	on
Down, left, rearward, counterclockwise, push	off
Clockwise, right	right
Counterclockwise, left	left
Up, back	raise
Down, forward	lower
Up, rearward, pull	retract
Down, forward, push	extended
Forward, up, right, clockwise	increase
Rearward, down, left, counterclockwise	decrease
Counterclockwise (value)	open value
Clockwise (value)	close value

23. Coding of Controls

23.1 *Methods and Requirements*—The use of a coding mode such as size and color for a particular application shall be governed by the relative advantages and disadvantages of each type of coding. Where coding is used to differentiate among controls, application of the code shall be uniform throughout the system. (See Table 13 for advantages and disadvantages.)

23.2 *Location Coding*—Controls associated with similar functions shall be in the same relative location from operator work station to work station and from panel to panel.

23.3 *Size Coding*—No more than three different sizes of controls shall be used in coding controls for discrimination by absolute size. Controls used for performing the same function on different items of equipment shall be the same size. When knob diameter is used as the coding parameter, differences between diameters shall not be less than 13 mm (0.5 in.). When knob thickness is the coding parameter, differences between thicknesses shall not be less than 10 mm (0.4 in.).

23.4 *Shape Coding*—Primary use of shape coding for controls is for identification of control knobs or handles by “feel;” however, shapes shall be identifiable both visually and tactually. When shape coding is used:

23.4.1 The coded feature shall not interfere with ease of control manipulation.

23.4.2 Shapes shall be identifiable by the hand regardless of the position and orientation of the control knob or handle.

23.4.3 Shapes shall be tactually identifiable when gloves are worn, where applicable.

23.4.4 A sufficient number of identifiable shapes shall be provided to cover the expected number of controls that require tactual identification.

23.4.5 Shape-coded knobs and handles shall be positively and nonreversibly attached to their shafts to preclude incorrect attachment when replacement is required.

23.4.6 Where possible, control shapes shall resemble the equipment, system, or control function that the control operates.

23.4.7 *Color Coding:*

23.4.7.1 *Lighting*—Color coding of control surfaces shall not be used when visibility of the controls is restricted or obstructed, or when illumination lighting is below 0.35 cd/m² (0.1 ft-L) or of some color other than white.

23.4.7.2 *Related Controls*—When related controls and displays are color coded, they shall be coded the same color.

23.4.7.3 *Emergency Controls*—All emergency controls used under only white lighting shall be colored red. If red lighting is to be used during any portion of a mission, controls which would have been coded red shall be coded by orange-yellow and black striping. To give emergency controls visual emphasis, color coding of other controls shall be kept to a minimum.

23.4.7.4 *Choice of Colors*—Controls shall be black (17038, 27038, or 37038) or gray (26231 or 36231). If color coding is required, the following colors identified in Table 14 shall be selected for control coding.

23.4.7.5 *Relation to Display*—When color coding must be used to relate a control to its corresponding display, the same color shall be used for both the control and the display.

23.4.7.6 *Control Panel Contrast*—The color of the control shall provide contrast between the panel background and the control.

23.4.7.7 *Ambient Lighting and Color-Coding Exclusion*—Color coding shall be compatible with anticipated ambient lighting throughout the mission. Color coding shall not be used as a primary identification medium if the operator’s adaptation to that light, varies as the result of such factors as solar glare, filtration of light, and variation from natural to artificial light. If red lighting is to be used during a portion of the mission, controls which would otherwise be coded red shall be coded by orange-yellow and black striping.

23.5 *Labeling of Controls*—Control labeling shall conform to the criteria in 29.7.

23.6 *Compatibility with Handwear*—Controls shall be compatible with handwear to be used in the anticipated environment. Unless otherwise specified, all dimensions cited herein are for bare hands and shall be revised where necessary for use with gloves or mittens.

23.7 *Blind Operation*—Where “blind” operation is necessary, hand controls shall be shape coded or separated from adjacent controls by at least 125 mm (5 in.).

23.8 *Prevention of Accidental Actuation:*

23.8.1 *Location and Design*—Controls shall be designed and located so that they are not susceptible to being moved accidentally, particularly critical or emergency controls whose inadvertent operation might cause damage to equipment, injury to personnel, or degradation of system functions.

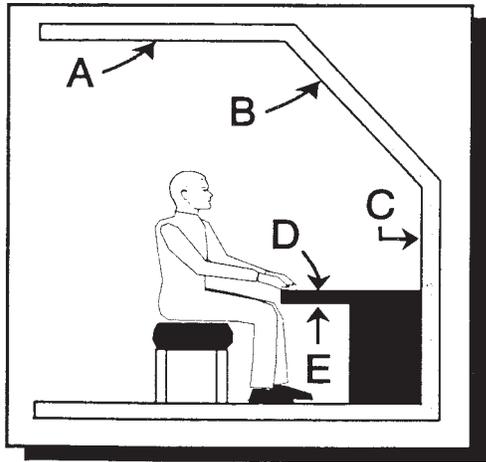
23.8.2 *Internal Controls*—Internal or hidden controls shall be protected, because it is usually not obvious that such controls have been disturbed and it may be difficult and time consuming to locate and readjust them.

23.8.3 *Rapid Operation*—Any method of protecting a control from inadvertent operation shall not preclude operation within the time required.

23.8.4 *Methods*—For situations in which controls must be protected from accidental actuation, one or more of the following methods, as applicable, shall be used:

23.8.4.1 Locate and orient the controls so that the operator is not likely to strike or move them accidentally in the normal sequence of control movements.

23.8.4.2 Recess, shield, or otherwise surround the controls by physical barriers. The control shall be entirely contained within the envelope described by the recess or barrier.



- A - CEILING
- B - 45° PANEL
- C - FRONT PANEL
- D - DESK / CONSOLE SURFACE
- E - UNDER CONSOLE
- F - LEFT PANEL
- G - RIGHT PANEL

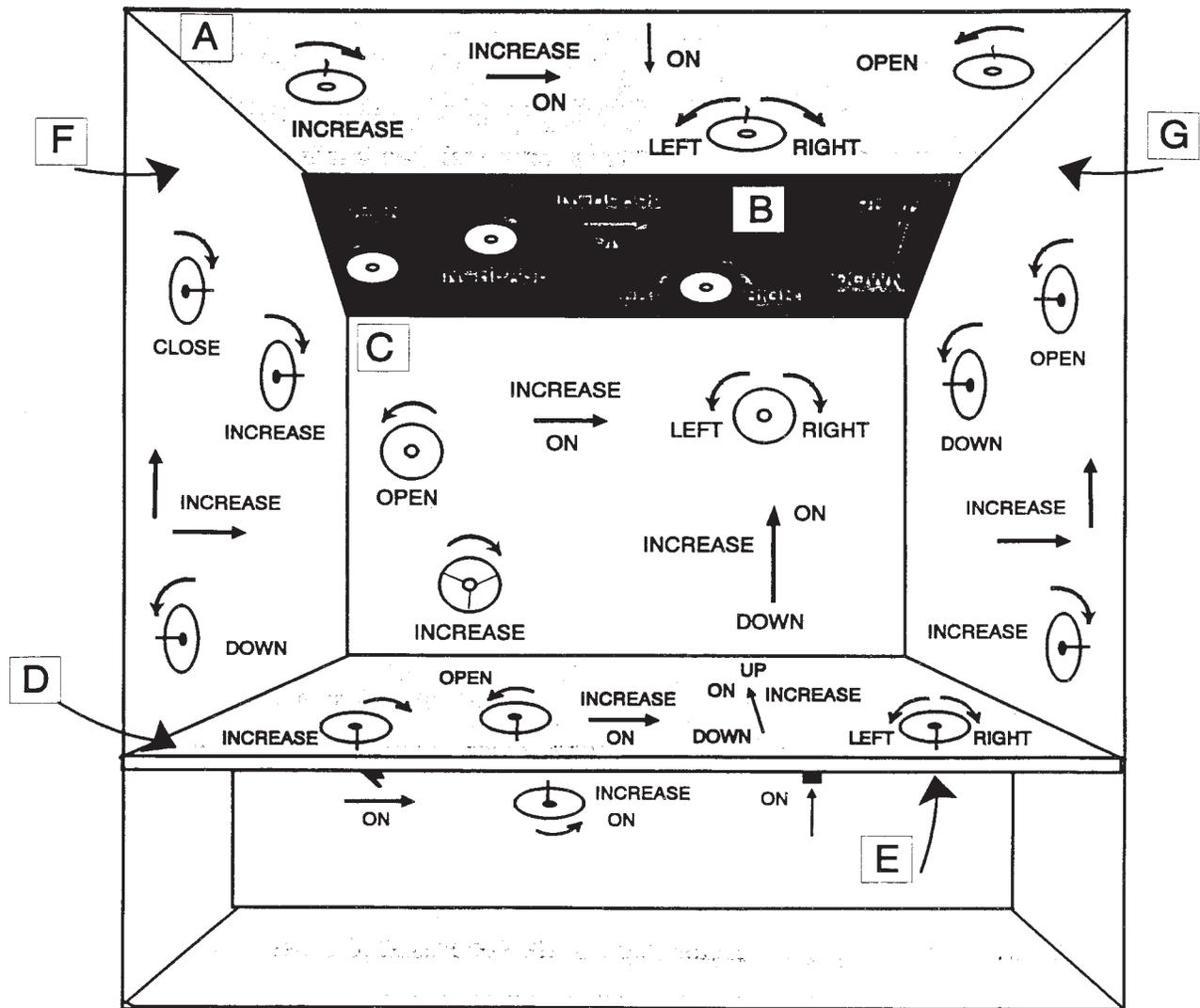


FIG. 19 Control Motion Expectancy



TABLE 12 Minimum Separation Distances for Controls

^A	Toggle Switches, mm (in.)	Pushbuttons, ^B mm (in.)	Continuous Rotary Controls, mm (in.)	Rotary Selector Switches, mm (in.)	Discrete Thumbwheel Controls, mm (in.)
Toggle switches	see Fig. 41	13 (0.5)	19 (0.75)	19 (0.75)	13 (0.5)
Pushbuttons ^B	13 (0.5)	see Fig. 40	13 (0.5)	13 (0.5)	13 (0.5)
Continuous rotary controls	19 (0.75)	13 (0.5)	see Fig. 30 and Fig. 33	25 (1.0)	19 (0.75)
Rotary selector switches	19 (0.75)	13 (0.5)	25 (1.0)	see Fig. 24	19 (0.75)
Discrete thumbwheel controls	13 (0.5)	13 (0.5)	19 (0.75)	19 (0.75)	see Fig. 29 and Fig. 34

^AAll values are for one hand operation. Distances are measured from edge to edge of each control.

^BFor pushbuttons not separated by barriers.

TABLE 13 Advantages and Disadvantages of Various Types of Coding

Advantages	Type of Coding					
	Location	Shape	Size	Model 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 (that is, must be within visual areas and with adequate illumination present).					X	X

TABLE 14 Recommended Control Colors (FED-STD-595)

Use	Color	Gloss	Semi-Gloss	Flat
Standard	black	17038	...	...
	gray	...	26238	...
	green	14187	...	...
	orange-yellow	13538	23538	33538
	white	17875	27875	37875
Supplement to standard if required	blue	15123	...	...
Emergency	red	11105	21105	31105

23.8.4.3 Cover or guard the controls. Safety or lock wire shall not be used.

23.8.4.4 Provide the controls with interlocks so that extra movement (for example, a side movement out of a detente position or a pull-to-engage clutch) or the prior operation of a related or locking control is required.

23.8.4.5 Provide the controls with resistance (that is, viscous or coulomb friction, spring loading, or inertia) so that definite or sustained effort is required for actuation.

23.8.4.6 Provide the controls with a lock to prevent the control from passing through a position without delay when strict sequential activation is necessary (that is, the control moved only to the next position, then delayed).

23.8.4.7 Design the controls for operation by rotary action.

23.8.5 *Dead Man Controls*—Dead man controls, which will result in system shutdown to a noncritical operating state when force is removed, shall be used wherever operator incapacity can produce a critical system condition.

23.9 *Foot-Operated Controls:*

23.9.1 *Use*—Foot-operated controls may be used under the following conditions:

23.9.1.1 Control operation requires either greater force than the upper body can provide or force close to an upper body fatigue threshold.

23.9.1.2 The operator's hands are generally occupied by other manual control tasks at the same moment that an additional control action is required.

23.9.1.3 A safety shutdown control is required during an operation in which the operator's hands cannot be freed to reach a safety switch.

23.9.2 *Avoidance*—Foot-operated controls shall not be used under the following conditions:

23.9.2.1 Where a standing operator is confronted with a sensitive balancing requirement (for example, a moving platform where balancing on the nonoperating foot may become difficult as the operating foot is moved from a support to actuating position).

23.9.2.2 Precise control operations are required.

23.9.2.3 Selection from among a great many separate controls is required.

23.9.3 *Operation*—Foot controls shall be located and designed so they can be operated in as natural a pattern as practicable. Specifically, the following shall be avoided:

23.9.3.1 Frequent, maximum reaching.

23.9.3.2 Requirement to hold the leg or foot in awkward position for extended periods of time.

23.9.3.3 Requirement for the operator to operate a control frequently or for an extended period of time while sitting in a twisted position, the pedals shall be laid out symmetrically with reference to the operator’s principal operating orientation.

23.9.3.4 Maximum force application frequently or for extended duration.

23.9.3.5 Requirement that the operator search for a particular foot control in order to select the proper one.

23.9.3.6 Placement of a foot control where it might be stepped on and inadvertently actuated or where typical shifting from one foot control to another creates conditions where the foot or clothing might be entrapped by an intervening control.

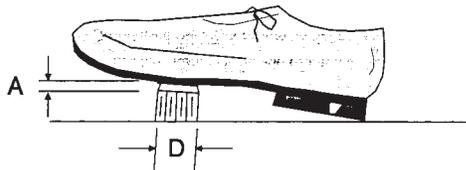
23.9.4 Configuration and Placement—Configuration and placement of foot operated controls shall accommodate the anthropometry of the operator’s foot wearing operational shoes or boots (See Section 30). They shall be located so that the activation of a control by one foot does not interfere with the activation of a control by another foot and so that the movements of feet and legs are natural and easily accomplished within the work station where foot controls are located.

23.9.5 Foot-Operated Switches:

23.9.5.1 Use—Foot-operated switches shall be used only where the operator is likely to have both hands occupied when switch activation may be required, or when load sharing among limbs is desirable. Because foot-operated switches are susceptible to accidental activation, their uses shall be limited to noncritical or infrequent operations such as press-to-talk communication or vehicle headlight dimming.

23.9.5.2 Operation—Foot switches shall be positioned for operation by the toe and the ball of the foot rather than by the heel. They shall not be located so near an obstruction that the operator cannot center the ball of the foot on the switch button. A pedal may be used over the button to aid in location and operation of the switch. When the switch may become wet and slippery, the switchcap surface shall possess a frictional surface to minimize the possibility of the foot slipping off the switch.

23.9.5.3 Dimensions, Resistance, and Displacement—Dimensions, resistance, and displacement of foot-operated switches shall conform to the criteria in Fig. 20. Although not recommended (only one switch per foot is preferred), when one foot is required to operate more than one switch, such switches shall be at least 75 mm (3 in.) apart (horizontal); 200 mm (18 in.) apart vertical.



	DIAMETER D	RESISTANCE		DISPLACEMENT A			
		Foot Will Not Rest On Control	Foot Will Rest On Control	Normal Operation	Heavy Boot Operation	Ankle Flexion Only	Total Leg Movement
Minimum	13 mm (1/2 in)	18 N (4 lb)	45 N (10 lb)	13 mm (1/2 in)	25 mm (1 in)	25 mm (1 in)	25 mm (1 in)
Maximum	—	90 N (20 lb)	90 N (20 lb)	65 mm (2 1/2 in)	65 mm (2 1/2 in)	65 mm (2 1/2 in)	100 mm (4 in)

FIG. 20 Foot-Operated Switches

23.9.5.4 Feedback—A positive indication of control activation shall be provided (for example, snap feel, audible click, association visual, or auditory display).

23.10 Foot Pedals:

23.10.1 Use—Pedal controls should be used only when the operator is likely to have both hands occupied when control operation is required or control system force is too high for manual force capability of the operator, or standardized use of pedals has created a stereotype expectancy (for example, vehicle pedal control configurations such as clutch, brake, accelerator, rudder).

23.10.2 Location—Pedal controls shall be located so that the operator can reach them easily without extreme stretching or torso twisting and can reach the maximally displaced pedals within anthropometric limits and force capabilities (see Fig. 21). Pedals that may be held or must be adjusted shall be located so the operator can “rest” and “steady” the foot, that is, the pedal shall be appropriate critical distance above the floor so the operator’s heel can rest on the floor while articulating the ankle/foot. When this cannot be done (and the pedal angle is more than 350 mrad (20°) from the horizontal floor), a heel rest shall be provided. Lateral spacing of individual pedals shall conform to criteria in Fig. 22. However, the overall array shall not exceed 760 mm (29 in.) as measured between the outermost pedal centerlines.

23.10.3 Control Return—Except for controls that generate a continuous output (for example, rudder controls), pedals shall return to the original null position without requiring assistance from the operator (for example, brake pedal). For pedals in which the operator may normally rest the foot on the control between operations, sufficient resistance shall be provided to prevent the weight of the foot from inadvertently actuating the control (for example, accelerator pedal).

23.10.4 Pedal Travel Path—The travel path shall be compatible with the natural articulation path of the operator’s limbs (that is, thigh, knee, ankle).

23.10.5 High-Force Application Aids—When foot controls requiring high control forces are to be used, the push force push exerted by the leg depends on the thigh angle and the knee angle. Fig. 23 specifies the mean maximum push at various knee and thigh angles. The maximum push is at about the 160° angle, referred to as the limiting angle of Fig. 23 apply to males only and shall be corrected for females. (Two thirds of each value is considered to be a reasonable value for females.) Appropriate aids shall be provided to assist the operator in applying maximum force including the following where applicable:

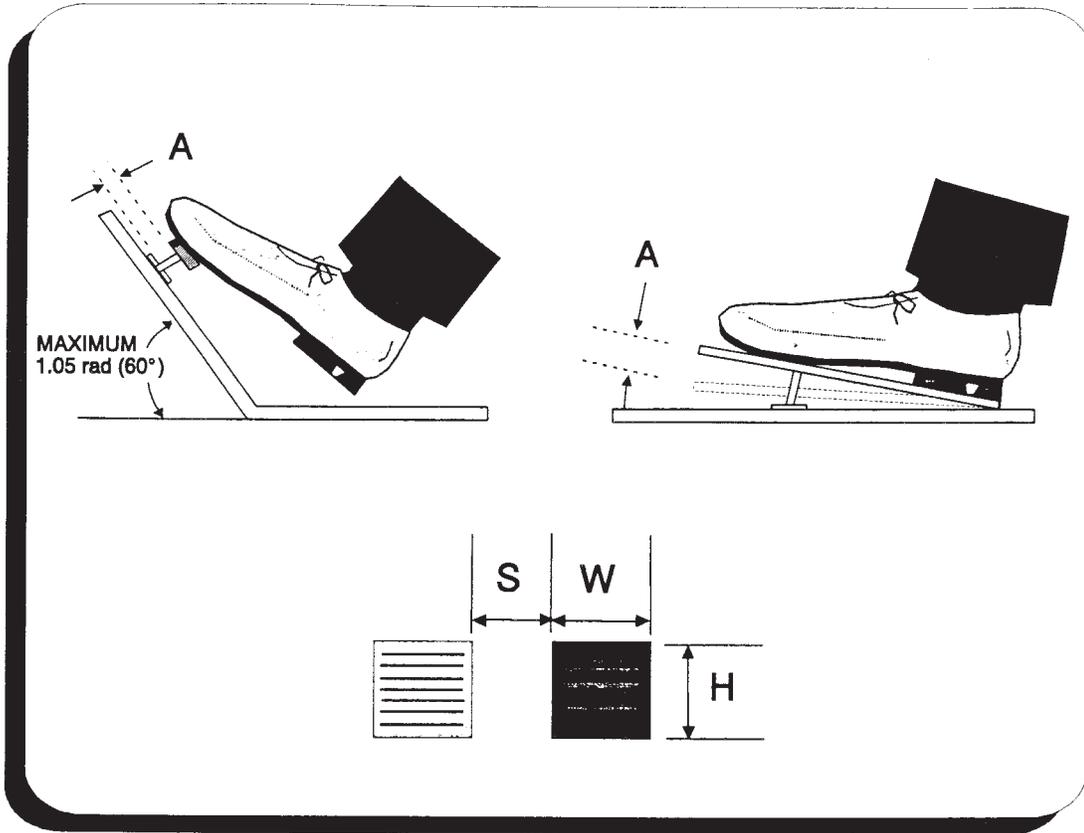
23.10.5.1 Seat backrest.

23.10.5.2 Optimized seat height-to-pedal and normal reach distance for maximum force, the seat reference point (SRP), and pedal are at the same vertical height.

23.10.5.3 Double-width pedal so that both feet can be used.

23.10.6 Nonslip Pedal Surface—Pedals used for high force applications shall be provided with a nonskid surface. Similar surfaces are desirable for all pedals.

23.10.7 Dimensions, Resistance, Displacement, and Separation—Dimensions, resistance, displacement, and separation of pedals shall conform to the criteria of Fig. 21.



	DIMENSIONS		DISPLACEMENT			
	H	W	A			
	Height	Width	Normal Operation	Heavy Boots	Ankle Flexion	Total Leg Movement
Minimum	25 mm (1 in)	75 mm (3 in)	13 mm (1/2 in)	25 mm (1 in)	25 mm (1 in)	25 mm (1 in)
Maximum	—	—	65 mm (2 1/2 in)	65 mm (2 1/2 in)	65 mm (2 1/2 in)	180 mm (7 in)
	RESISTANCE					
	Foot Not Resting on Pedal		Foot Resting on Pedal	Ankle Flexion Only	Total Leg Movement	
	Minimum	18 N (4 lb)	45 N (10 lb)	—	45 N (10 lb)	
Maximum	90 N (20 lb)	90 N (20 lb)	45 N (10 lb)	800 N (180 lb)		
	SEPARATION					
	One Foot Random		S	One Foot Sequential		
	Minimum	100 mm (4 in)		50 mm (2 in)		
Maximum	150 mm (6 in)		100 mm (4 in)			

FIG. 21 Pedals

23.10.8 *Foot Controls Force (High)*— Where foot controls requiring high control forces are to be used, the force push exerted by the leg depends on the thigh angle and knee angle. Fig. 23 specifies the mean maximum push at various knee and

thigh angles. The maximum push is about the 160° angle, referred to as the limiting angle. The values of Fig. 23 apply to males only and shall be corrected for females. For females, use two thirds of the male value.

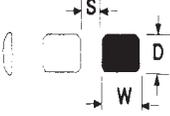
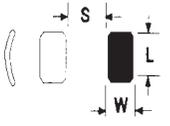
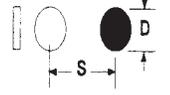
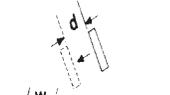
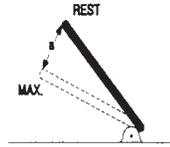
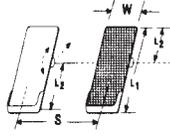
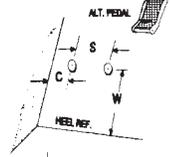
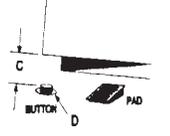
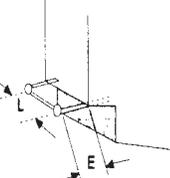
	APPLICATION CRITERIA	DESIGN CRITERIA			
		DIMENSIONS		DISPLACEMENT	SEPARATION
	BRAKE PEDAL APPLICATIONS CLUTCH-BRAKE-CONVEX-THREAD SURFACE	$W \times D - \text{MIN} - 75 \times 50 \text{ mm}$ $(3 \times 2 \text{ in})$			$S - \text{MIN TO PREVENT FOOT SLIPPING BETWEEN PEDALS} - 50 \text{ mm (2 in)}$
	FORCE REQUIREMENTS: CLUTCH - 450 N (MAX). BRAKE - 70 N (MIN), 450 N (MAX)				
	ALTERNATE PEDAL SHAPE ACCEPTABLE FLAT, TREAD SURFACE	$W + L - \text{MIN} - 50 \times 75 \text{ mm}$ $(2 \times 3 \text{ in})$			$S - \text{MIN SEPARATION TO ALLOW FOOT TO PASS BETWEEN PEDALS} - 125 \text{ mm (5 in); 180 mm (7 1/4 in) FOR HEAVY BOOTS}$
	ROUND PEDAL SHAPE ACCEPTABLE. FLAT, TREAD SURFACE	$D - \text{MIN} - 57 \text{ mm (2 1/4 in)}$	S - COMFORT SEPARATION $- 305 \pm 50 \text{ mm (12 1/4 in } \pm 2 \text{ in)}$ MAX - 405 mm (16 1/5 in) MIN - 200 mm (8 in)	$d - \text{MAX REST TO ACTIVATE} - 180 \text{ mm (7 1/4 in)}$ MIN - 25 mm (1 in) PREFERRED 65-100 mm (2 1/2-4 in)	(NOTE: EDGE E TO EDGE PEDAL SEPARATIONS OF BETWEEN 50 mm (2 in) AND 115 mm (4 1/2 in) SHOULD GENERALLY BE AVOIDED BECAUSE OF POSSIBILITY OF GETTING FOOT CAUGHT)
	ACCELERATOR PEDAL APPLICATIONS: a. FLOOR-HINGED, FULL PEDAL b. SUSPENDED PEDAL (PEDAL SHOULD BE FREE SWIVEL)	$W - 50 \text{ mm (2 in) MIN}$ $L_1 - 255 \pm 50 \text{ mm (10 1/4 } \pm 2 \text{ in)}$ $L_2 - 80 \text{ mm (3 1/2 in) MIN}$	$H - 150 \text{ mm (6 in)}$ OPTIMUM	$d - \text{MAX DISPLACEMENT} - 30^\circ (20^\circ \text{ WITH HEAVY BOOTS})$	
	ACTION DISPLACEMENT ENVELOPE, NOMINAL CRUISE ANGLE SHOULD CAUSE LOWER LEG/FOOT, INCLUDED ANGLE TO BE BETWEEN 90°-105°				
	FORCE REQUIREMENTS MAX - 80 N MIN - 4.5 N				
	NOMINAL CRUISE - LEVEL GRADE, AVG. SPEED FOR APPLICATION				
	TWO FOOT PEDAL ASSEMBLY. SHOULD HAVE MIN FOR AFT ADJUSTMENT OF 230mm.	$W - \text{MIN} - 150 \text{ mm (6 in)}$	$L_1 - \text{MIN} - 255 \text{ mm (10 1/4 in)}$ $L_2 - \text{MIN} - 125 \text{ mm (5 in)}$		$S - \text{MIN} - 380 \text{ mm (15 1/4 in)}$ MAX - 530 mm (21 1/4 in)
	FORCE REQUIREMENTS: SEE MIL-F-8785				
	FOOT SWITCHES. NORMALLY USE ONLY ONE PER FOOT (MAX TWO) FORCE REQUIREMENTS: MAX 4.5 N	$D - \text{MIN DIAM} - 25 \text{ mm (1 in)}$	$H - \text{DISTANCE FROM HEEL REF} - 180-255 \text{ mm (7 1/4-10 1/4 in)}$	C - CLEARANCE TO OBSTRUCTION MIN - 75 mm (3 in)	$S - \text{MIN} - 75 \text{ mm (3 in)}$
	FOOT SWITCHES, STAND OPN'S: NORMAL FREQUENT ACTIVATION, SPEED NOT CRITICAL	$D - \text{MIN BUTTON DIAM} - 25 \text{ mm (1 in)}$ LARGER PREFERRED		FOR BOOTS, INCREASE MIN 25 mm (1 in)	
	FORCE REQUIREMENTS PREFERRED MAX. 90 N EMERGENCY OPERATION, SPEED IMPORTANT	$E - \text{EXTENSION}$ MIN - 100 mm (4 in)	$L - \text{ACCESSIBLE TO EITHER FOOT FULL WIDTH OF THE EXPECTED WORK ENVELOPE}$	C - CLEARANCE BENEATH UNDE-PRESSED BAR FOR TOE. MIN - 65 mm (2 1/2 in) OR 75 mm (3 in) WITH BOOTS	

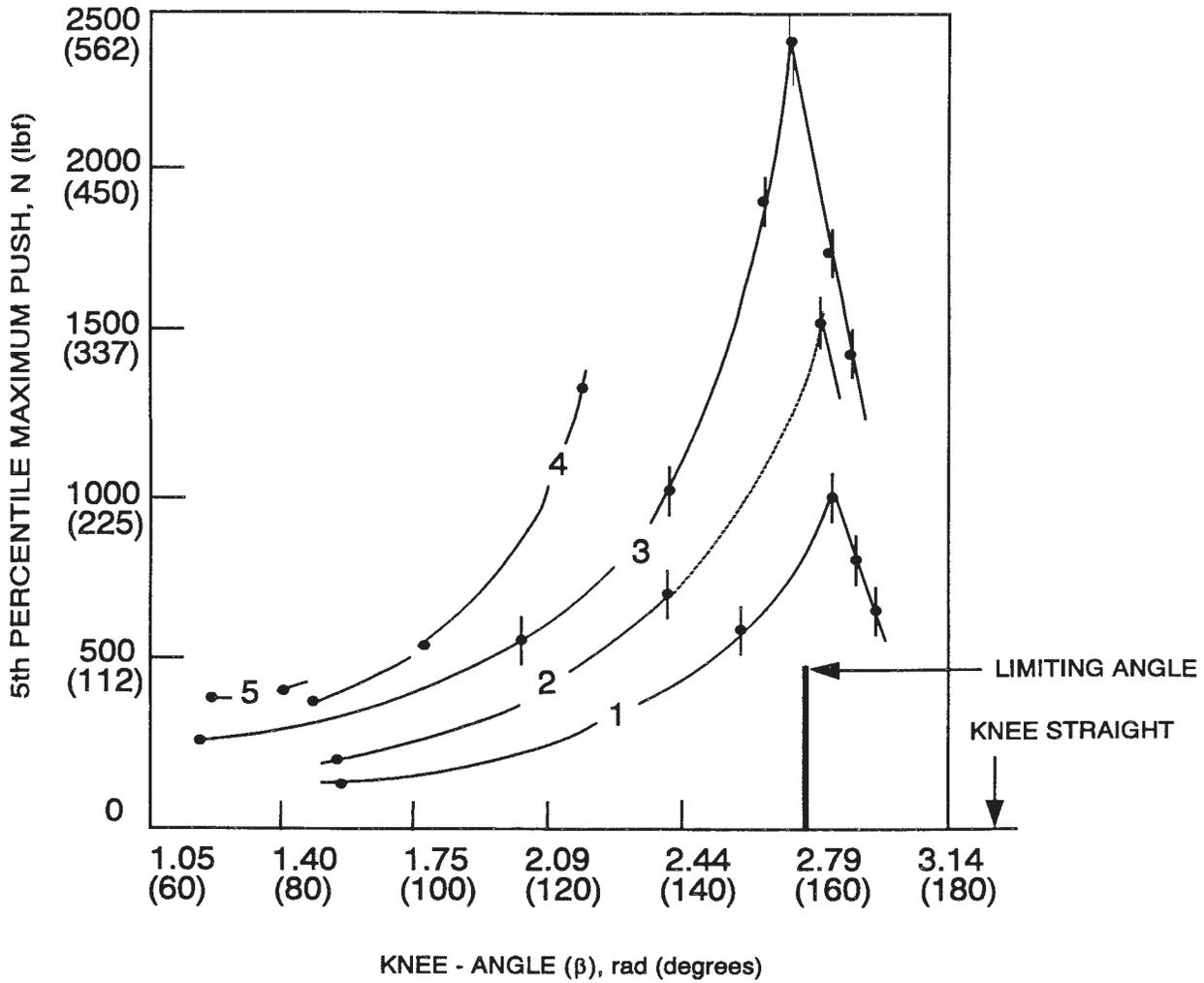
FIG. 22 Foot-Operated Controls

24. Rotary Controls

24.1 Discrete Rotary Controls:

24.1.1 Rotary Selector Switches—Rotary selector switches shall be used for discrete functions when three or more

detented positions are required. Rotary selector switches shall not be used for a two-position function unless prompt visual identification of control position is of primary importance and speed of control operation is not critical.



THIGH ANGLE (α) rad (degrees)	
1	-.26 - .10 (-15 - 6)
2	.09 & .17 (5 & 10)
3	.26 - .33 (15 - 19)
4	.58 - .63 (33 - 36)
5	.84 - .86 (48 - 49)

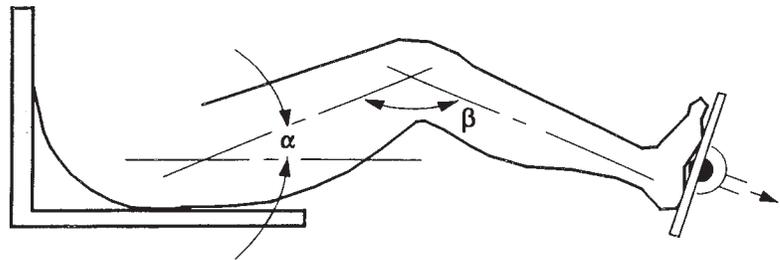


FIG. 23 Leg Strength at Various Knee and Thigh Angles

24.1.2 *Moving Pointer*—Rotary selector switches shall be designed with a moving pointer and a fixed scale.

24.1.3 *Shape*—Moving pointer knobs shall be bar shaped, with parallel sides, and the index end shall be tapered to a

point. Exceptions may be justified when pointer knobs are shape coded or when space is restricted and torque is light. Shape coding shall be used when a group of rotary controls, used for different functions, is placed on the same panel and control confusion might otherwise result.

24.1.4 *Positions*—A rotary selector switch that is not visible to the operator during normal system operation shall have no

more than 12 positions. A rotary switch that is constantly visible to the operator shall have not more than 24 positions. Recommended switch setting parameters are provided in Fig. 24. In addition, the following criteria shall apply:

24.1.4.1 Rotary switch positions shall not be placed opposite each other unless knob shape precludes confusion as to which end of the knob is the pointer.

	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS	DISPLACEMENT	SEPARATION		
	<p>PREFERRED FOR ACCURATE IDENTIF. OF KNOB POSITION BY FEEL, CONTROL PANELS WHERE HIGH</p> <p>FORCE SWITCHES ARE NOT REQUIRED, SKIRT OPTIONAL</p> <p>SWITCH RESISTANCE APPROX. MAX:</p> <p>L = 38 mm = 0.11 N m (1 in. (1-lb)) L = 50 mm = 0.34 N m (2 in. (3 in-lb)) L = 100 mm = 0.88 N m (4 in. (8 in-lb))</p>	L = 38 mm to 100 mm (1 1/2 in to 4 in) IF GLOVES ARE WORN, ADD 13 mm (1/2 in)	W = 13 mm to 25 mm (1/2 in to 1 in)	H = 16 mm to 75 mm (5/8 in to 3 in)	MIN = 15° MIN POS'N ID = 30° MAX = 40°; MAX FOR BLIND POSITIONING = 90°	SEE FIG. 25 FOR SIMULTANEOUS OPERATION OF ADJACENT KNOBS (TWO HANDS) ADD 25 mm (1 in), 38mm (1 1/2 in) FOR GLOVES
	<p>ACCEPTABLE ABOVE CRITERIA APPLICABLE AS LONG AS KNOB POS'NS REMAIN IN UPPER 180° HEMISPHERE</p> <p>(A) EXTENDED TAIL HELPFUL FOR TORQUE USE ONLY WHEN POINTER MARKING CLEARLY VISIBLE</p>	SEE ABOVE	SEE ABOVE	SEE ABOVE	SEE ABOVE	SEE ABOVE
	ACCEPTABLE ALTERNATIVE TO ABOVE	SEE ABOVE	SEE ABOVE	SEE ABOVE	SEE ABOVE	SEE ABOVE
	ACCEPTABLE ALTERNATIVE TO A ABOVE WHEN ONLY GROSS SETTING IS REQUIRED (MAJOR NUMBERED POS'N'S)	L = MIN 25 mm (1 in) OTHER SAME AS A	SEE ABOVE	SEE ABOVE	SEE ABOVE	SEE ABOVE
	ACCEPTABLE ONLY FOR APPLICATIONS WHERE PANEL SPACE IS LIMITED, GLOVES NOT WORK, SWITCH RESISTANCE LESS THAN .842 N m	L = MIN 19 mm (2/3 in)	W = MIN 6.5 mm (1 1/4 in)	Y = MIN 13 mm (1/2 in)	SEE ABOVE	25 mm (1 in)
	<p>FOR HEAVY DUTY, HIGH TORQUE SWITCHES:</p> <p>PREFERRED</p>	D = 18-25 mm (5/8 in - 1 in)	L = MIN 100 mm (4 in)	R = 32 mm (1 1/4 in.) MIN	MIN = 10°	END TO END HANDLE SEPARATION = 75 mm (3 in)
	ACCEPTABLE ALTERNATIVE	D = SAME	L1 = MIN 50 mm (2 in.)	H = SAME	SAME	SAME
	TACTILE CONTROL IDENTIFICATION PREFERRED METHOD FOR ROTARY CONTROLS	D = MIN 18 mm (5/8 in.)	H = MIN 3.2 mm TO 19 mm (2/3 in)	—	N/A	N/A
	TACTILE CAP FOR ROTARY SELECTOR KNOB	SAME AS ABOVE	SAME AS ABOVE			

FIG. 24 Rotary Selector Controls

24.1.4.2 The switch resistance shall be elastic, building up, then decreasing as each position is approached, so that the control snaps into position without stopping between adjacent positions.

24.1.4.3 Mechanical detentes shall be provided as the switch cannot be positioned in between nominal switch positions.

24.1.4.4 Stops shall be provided at the beginning and end of the range of control positions if the switch is not required to be operated beyond the end positions or specified limits (that is, if the switch is not a multirotation control, see 21.6).

24.1.5 *Contrast*—A reference line shall be provided on rotary switch controls. This line shall have at least 75 % luminance contrast with the control color under all lighting conditions.

24.1.6 *Parallax*—The knob pointer shall be mounted sufficiently close to its scale to minimize parallax between the pointer and the scale markings. When viewed from the normal operator's position, the parallax error shall not exceed 25 % of the distance between scale markings.

24.1.7 *Dimensions, Resistance, Displacement, and Separation*—Rotary control dimensions, switch displacement, and control separation shall conform to criteria in Fig. 24 and Fig. 25.

24.1.8 *Torque for Actuation*—Actuating torque requirements shall be compatible with control knob sizes, that is, knob dimensions of 25 mm (1 in.) or less shall not require a torque of more than 350 N/m (Newton per metre) (2 lbf·in) (pounds force per inch). Medium-sized knobs, 25 to 50 mm (1 to 2 in.), shall have a torque of less than 1050 N/m (6 lbf·in.). The larger knobs, diameters of 75 mm (3 in.), shall not require an actuation torque greater than 1576 M/m (9 lbf·in.).

24.2 *Key-Operated Switches (KOS)*—KOS are used to prevent unauthorized operation. Ordinarily, they control system operation by go no-go.

24.2.1 *Dimensions, Displacement, and Resistance*—Dimensions, displacement, and resistance shall conform to the criteria in Fig. 26 and Fig. 27.

24.2.2 *Color, Shape, and Size Coding*—Color, shape, or size coding or a combination may be used as follows:

24.2.2.1 Color may be used to aid in identifying various keys by function or use location and when illumination is adequate to differentiate the colors. Red shall be reserved for emergency functions.

24.2.2.2 Shape coding may be used when it is desirable to identify a given key by feel. When shape coding is used, sharp corners shall be avoided.

24.2.2.3 Size coding may be used as a valid discriminator such as shape if there are only two keys.

24.2.3 *Marking and Labeling*—Keylock switch applications shall include appropriate positional markings and labels (see Section 28).

24.2.4 *Other Requirements:*

24.2.4.1 Keys with teeth on both edges, which fit the lock with either side up or forward, are preferred.

24.2.4.2 Keys with a single row of teeth shall be inserted into the lock with the teeth pointing up or forward.

24.2.4.3 Locks shall be oriented so the key's vertical position is the OFF position.

24.2.4.4 Operators shall normally not be able to remove the key from the lock unless the switch is turned OFF.

24.2.4.5 Activation of an item by a key-operated switch shall be accomplished by turning the key clockwise from the vertical OFF position.

24.3 *Discrete Thumbwheel Controls*—Thumbwheel controls may be used if the function requires a compact digital control-input device (for a series of numbers) and a readout of these manual inputs for verification. The use of thumbwheels for any other purpose is discouraged. Detente indexing units shall provide ten positions (0 to 9) in digital or binary (three or four bits and complement) outputs.

24.3.1 *Shape*—Each position around the circumference of a discrete thumbwheel shall have a concave surface or shall be separated by a high-friction area which is raised from the periphery of the thumbwheel. The thumbwheels shall not preclude viewing the digits within 30° viewing angle to the left and right of a perpendicular to the thumbwheel digits.

24.3.2 *Coding*—Thumbwheel controls may be coded by location, labeling, and color (for example, reversing the colors of the least significant digit wheel as on typical odometers). Where used as input devices, thumbwheel switch OFF or NORMAL positions shall be color coded to permit a visual check that the digits have been reset to their normal position.

24.3.3 *Direction of Movement*—Moving the thumbwheel edge forward, or upward, or to the right shall increase the setting (see Fig. 28).

24.3.4 *Internal Illuminance of Numerals*—For areas in which ambient illumination will provide display brightness below 3.5 cd/m² (1 ft-L), the thumbwheel shall be internally illuminated. Digits shall appear as light- or white-illuminated characters on a black background, and their dimensions shall approximate the following:

24.3.4.1 Height, 4.8 mm (3/16 in.).

24.3.4.2 Height-to-width ratio, 3:2.

24.3.4.3 Height-to-stroke width ratio, 10:1.

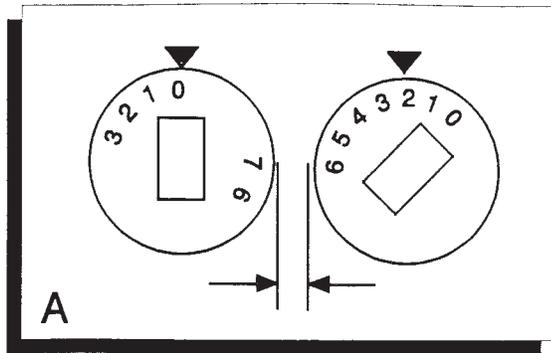
24.3.5 *External Illuminance of Numerals*—In areas in which ambient illumination will provide a display luminance above 3.5 cd/m² (1 ft-L), internal illumination is not required. Digits shall be bold, black numerals engraved on a light (or white) thumbwheel background. The dimensions shall approximate those specified in 24.3.4, except that the height-to-stroke width ratio shall be approximately 5:1.

24.3.6 *Visibility*—Thumbwheel design shall permit viewing of inline digital readout from all operator positions.

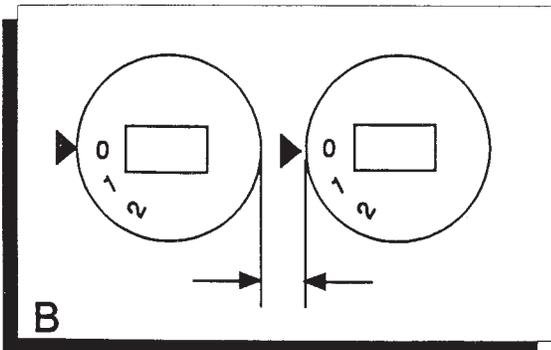
24.3.7 *Dimensions*—Control dimensions shall conform to the criteria in Fig. 29.

24.3.8 *Resistance*—Detentes shall be provided for discrete position thumbwheels. Resistance shall be elastic, building up and then decreasing as each detente is approached so that the control snaps into position without stopping between adjacent detentes. The resistance shall be within the limits indicated in Fig. 29.

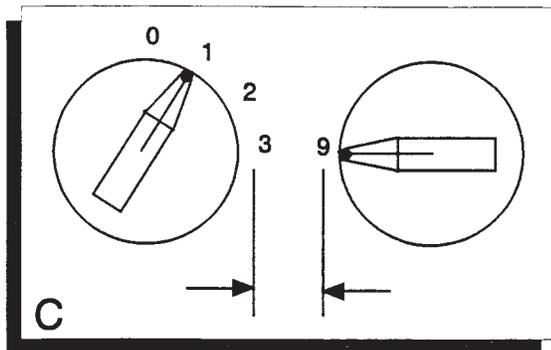
24.3.9 *Separation*—The separation between adjacent edges of thumbwheel controls shall conform to the criteria in Fig. 29



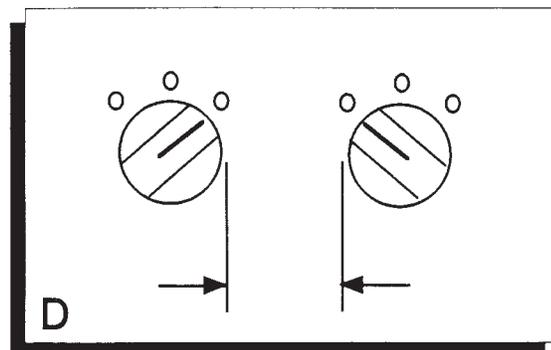
Nominal separation between moving-scale knobs requires only that there is adequate physical separation between the knob skirts to prevent knob movement interference when the zero or referencing index is at the 12-o'clock position.



Separation between moving-scale knobs that have the referencing index at the 3- or 9-o'clock position should be sufficient to ensure that there is not visual confusion regarding the knob to which the index mark refers. Minimum should be about twice the nominal character width.



Separation between moving-pointer / fixed-scale configurations should be based on clear visual separation of adjacent scale characters. The minimum should be at least four character widths. However, if the knob length extends the full width of the skirt and the handle is not tapered at the pointing end, there should be at least a 25 mm (1 in) separation between knobs when they are end to end.



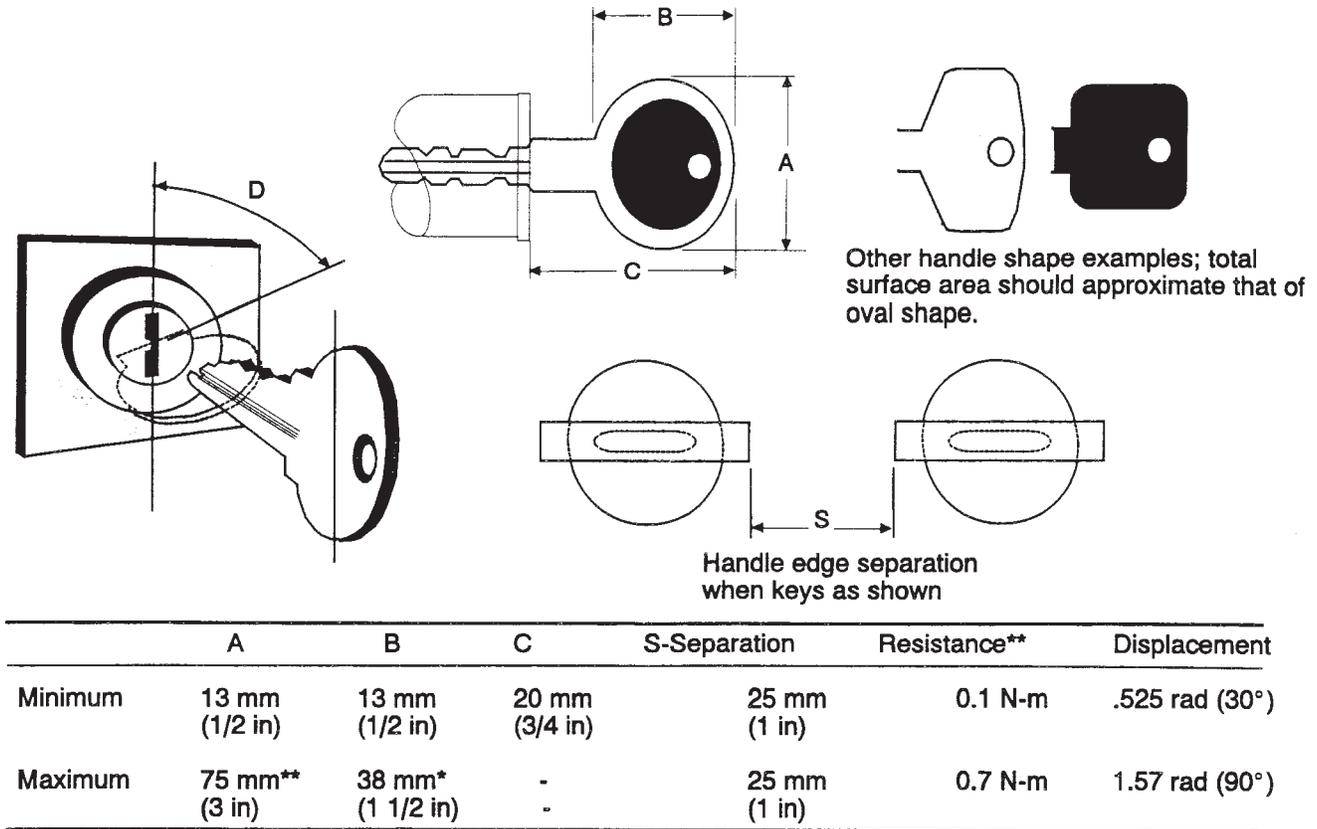
Separation between small, detented knob configurations as shown should be at least 25mm (1 in) unless there are adjacent panel referencing marks or characters, in which case separation minimums should be established on the basis of (C) above, or the 25 mm (1 in) criterion, whichever is greater.

FIG. 25 Rotating Knob Separation

and shall be sufficient to preclude accidental activation of adjacent controls during normal setting.

24.4 Continuous Adjustment Rotary Controls:

24.4.1 *Knobs*—Knobs shall be used when low forces or precise adjustments of a continuous variable are required. A moving knob with fixed scale is preferred over a moving scale



* Practical for carrying key in pocket.
 ** When locks are new.

FIG. 26 Keylock Criteria

with fixed index for most tasks. If positions of single revolution controls must be distinguished, a pointer or marker shall be available on the knob.

24.4.2 *Dimensions, Torque, and Separation*—The dimensions of knobs shall be within the limits specified in Fig. 30. Within these ranges, knob size is relatively unimportant, provided the resistance is low and the knob can be easily grasped and manipulated. When panel space is extremely limited, knobs shall approximate the minimum values and shall have resistance as low as possible without permitting the setting to be changed by vibrations or by merely touching the control. Resistance and separation between adjacent edges of knobs shall conform to Fig. 30.

24.4.3 *Shapes*—Knobs that perform the same function shall have the same shape. The shape shall be determined by the knob's function and use. Representative knob shapes are shown in Fig. 31.

24.4.4 *Tactual (Touch) Recognition*—For knobs that must be recognized by touch alone, use easily recognizable knob shapes as shown in Fig. 32. Some sets of knobs have been specially developed and validated experimentally for tactual recognition.

24.4.5 *Ganged Control Knobs*—Ganged knob assemblies may be used in limited applications when panel space is at a premium. Two-knob assemblies are preferred. Three-knob configurations shall be avoided. Ganged knob configurations shall not be used under the following conditions:

24.4.5.1 Extremely accurate or rapid operations are required.

24.4.5.2 Frequent changes are necessary.

24.4.5.3 Heavy gloves must be worn by the operator.

24.4.5.4 Equipment is exposed to the weather or used under field conditions.

24.4.6 *Dimensions, Torque, and Separation*—Dimensions, torque, and separation shall conform to Fig. 33.

24.4.7 *Shapes*—Knobs that perform the same function shall have the same shape. The shape shall be determined by the knob's function and use. Representative knob shapes are shown in Fig. 31.

24.4.8 *Tactual (Touch) Recognition*—For knobs that must be recognized by touch alone, use easily recognizable knob shapes (Fig. 32).

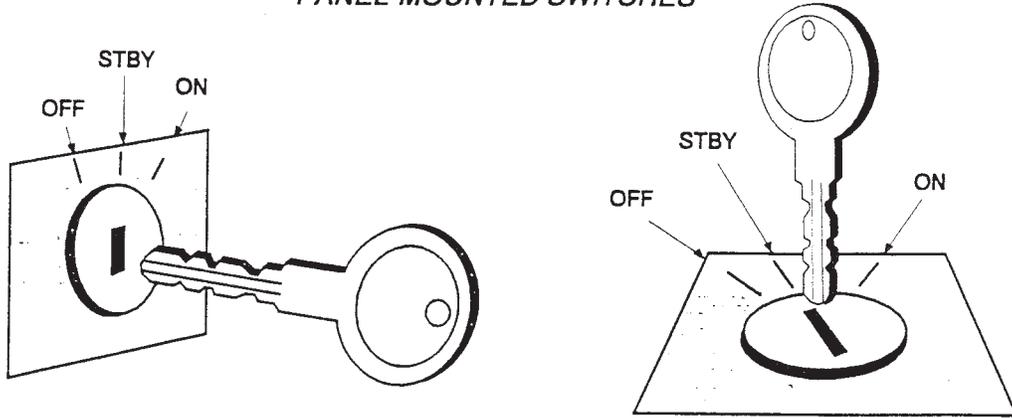
24.4.9 *Knob Serration*—Knobs shall be serrated. Fine serrations shall be used on precise adjustment knobs; coarse serrations shall be used on gross adjustment knobs.

24.4.10 *Marking*—An indexing mark or pointer shall be provided on each knob. Marks or pointers shall differ sufficiently to make it apparent which knob indexing mark is being observed.

24.4.11 *Detentes*—Knob detentes placement shall conform to Table 15.

24.4.12 *Knob/Display Relationship*—When each knob of a ganged assembly must be related to an array of visual displays,

PANEL-MOUNTED SWITCHES



- Note 1 - Switchlocks should generally be oriented so that the pivotal off key position is vertical or forward, or both (for example, horizontal panel).
- Note 2 - Key displacement between functional positions should be at least .53 rad (30°). Mechanical detents should preclude positioning the key in between designated positions.
- Note 3 - When only two functional positions occur (that is, on-off), displacement between the two positions shall be 1.57 rad (90°).
- Note 4 - Total displacement of multi-position keyswitches shall not exceed 2.09 rad (120°).

FIG. 27 Keylock Switch Criteria

DATE:	CALIBRAT BY:	CALIBRATOR DATA:	m	b
PROJECT:	CONE #:	CONE #:	0.00992	-0.012668
FEATURE:	FSO TIP:	FSO TIP:	20kN	
CLIENT:	FSO SLEEVE:	FSO SLEEVE:		
	TIP AREA:	TIP AREA:		
	SLEEVE AREA:	SLEEVE AREA:		

TARGET GAUGE READING	ACTUAL GAUGE READING	APPLIED FORCE X kN	FULL SCALE OUTPUT FSO - %	MEASURED SLEEVE RESISTANCE Y fs - kPa	MEASURED CONE RESISTANCE qc - mPa	ACTUAL SLEEVE RESISTANCE fsa kPa	BEST STRAIGHT LINE* Y'=mX+b kPa	LINEARITY Y-Y'/FSO % FSO	CALIBRATION ERROR fsa-Y'/fsa % MO
0.000	BASELINE			-9.8	-0.3				
0	0	-0.013	-0.1	0.0	0.0	-0.8	3.113	0.31	
30	30	0.285	1.9	20.3	0.0	19.0	22.970	0.27	
75	75	0.731	4.9	51.2	0.0	48.7	52.757	0.16	
150	149	1.465	9.8	101.2	0.0	97.6	101.739	0.05	
375	378	3.735	24.9	249.1	0.0	249.0	253.320	0.42	1.73
750	749	7.414	49.4	495.3	0.0	494.2	498.893	0.36	0.94
375	375	3.705	24.7	260.2	0.1	247.0	251.334	0.89	
150	153	1.504	10.0	110.7	0.0	100.3	104.387	0.63	
75	77	0.751	5.0	57.7	0.0	50.1	54.081	0.36	
30	32	0.305	2.0	24.1	0.0	20.3	24.294	0.02	
0	0	-0.013	-0.1	0.2	0.0	-0.8	3.113	0.29	
0.000	BASELINE			-9.8	-0.3				

	RESULT	UNIT	ALLOWABLE	APPROVAL
*BEST FIT LINE (Y=mX+b)	m= 66.760			
	b= 3.958			
MAXIMUM LOAD TRANSFER -CONE	0.1	%FSO	0.5	YES
MAXIMUM LINEARITY ERROR	0.9	%FSO	2.0	YES
MAXIMUM CALIBRATION ERROR	1.73	%MO	3.0%MO>20%FSO	YES
MAXIMUM ZERO LOAD ERROR -CONE	0.0	%FSO	0.5	YES
MAXIMUM ZERO LOAD ERROR - SLEEVE	0.0	%FSO	1.0	YES

COMMENTS:

FIG. 28 Thumbwheel Orientation and Movement

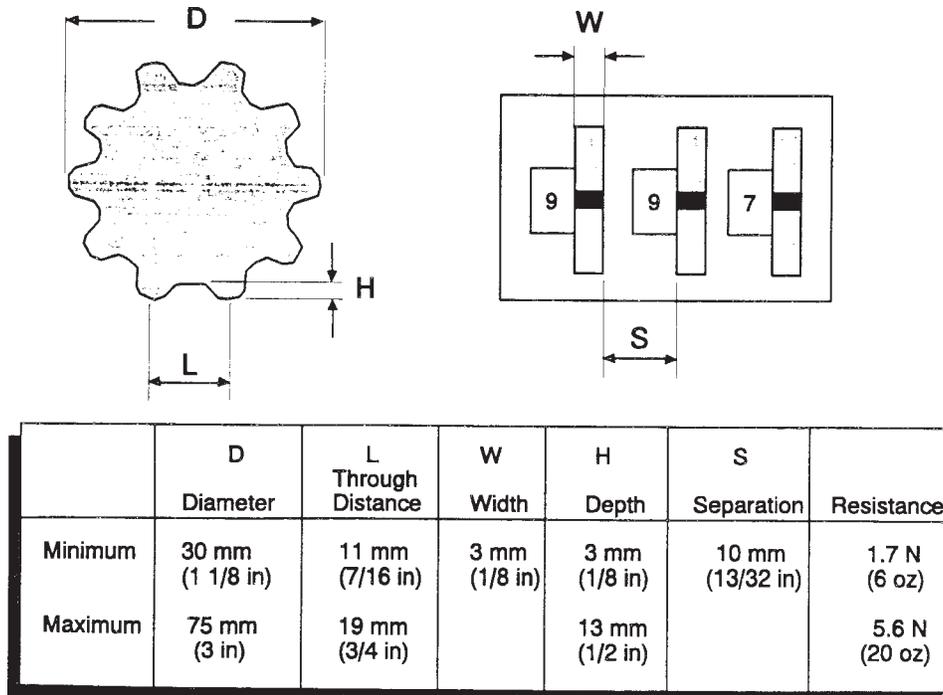


FIG. 29 Discrete Thumbwheel Control

the knob closest to the panel shall relate to the left-most display in a horizontal array, or the uppermost display in a vertical array.

24.4.13 *Inadvertent Operation*—When it is critical to prevent inadvertent actuation of one knob as the other is being adjusted, a secondary knob control movement shall be required (for example, pressing the top knob before it can be engaged with its control shaft). Where inadvertent movement is undesirable but not necessarily critical, knob diameter/depth relationships shall be optimized as shown in Fig. 33. Contrasting colors between knobs may also be used to improve individual knob identification.

24.4.14 *Continuous Adjustment Thumbwheel Controls:*

24.4.14.1 *Use*—Continuously adjustable thumbwheel controls may be used as an alternative to rotary knobs when the application will benefit from the compactness of the thumbwheel device.

24.4.14.2 *Orientation and Movement*—Thumbwheels shall be oriented and move in the directions specified in Fig. 34. If a thumbwheel is used as a continuous control that affects vehicle motion, movement of the thumbwheel forward or up shall cause the vehicle to move down or forward.

24.4.14.3 *Turning Aids*—The rim of the thumbwheel shall be serrated or provided with a high friction surface to aid the operator in manipulating the control.

24.4.14.4 *Dimensions, Separation, and Resistance*—Dimensions, separation and resistance shall conform to criteria in Fig. 34.

24.4.14.5 *Labeling and Visibility*—Marking and labeling shall conform to requirements herein, with respect to visibility of markings and legibility of label alphanumerics.

24.4.14.6 *OFF Position*—A detente shall be provided for continuous thumbwheels having an OFF position.

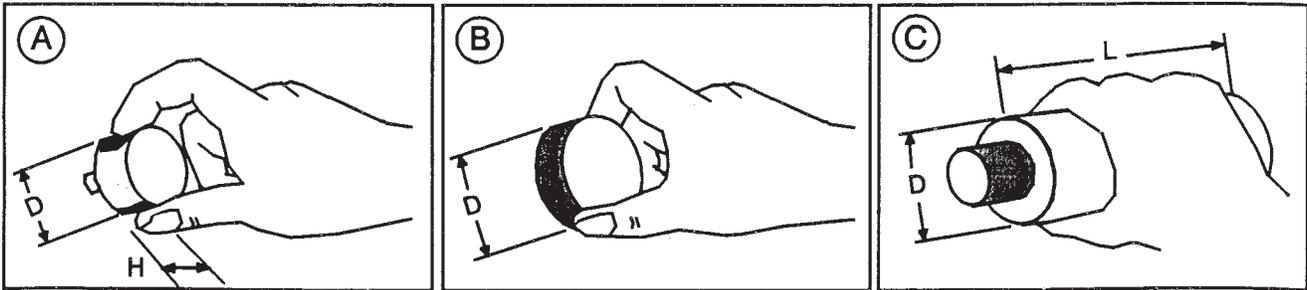
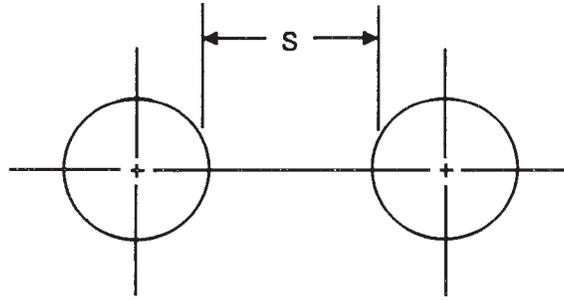
24.5 *Cranks:*

24.5.1 *Use*—Cranks shall be used for tasks requiring many rotations of a control, particularly where high rates or large forces are involved. For tasks involving large slowing movements, plus small, fine adjustments, a crank handle may be mounted on a knob or handwheel, with the crank for slowing and the knob or handwheel for fine adjustments. Where cranks are used for tuning, or other processes involving numerical selection, each rotation shall correspond to a multiple of 1, 10, 100, and so forth. Simultaneously operated handcranks shall be used in preference to other two-axis controllers where extreme precision is required in setting crosshairs or reticles as in map readouts or optical sighting mechanisms (as opposed to tracking). This type of control may also be used in other applications requiring x-y control provided there is no requirement for rapid or frequent operation. The gear ratio and dynamic characteristics of such cranks shall allow precise placement of the follower (for example, crosshairs) without overshooting or undershooting and successive corrective movements.

24.5.2 *Grip Handle*—The crank grip handle shall be designed so that it turns freely around its shaft.

24.5.3 *Dimensions, Resistance, and Separation*—Dimensions, resistance, and separation between adjacent swept circular areas of cranks shall conform to the criteria of Fig. 35.

24.5.4 *Folding Handle*—If a crank handle could become a hazard to persons passing by, or it is critical that the handle not be inadvertently displaced by being accidentally bumped, a folding handle-type control shall be used. Such a control shall be designed so that the handle is spring loaded to keep it extended in the cranking position when in use and folded when not in use.



DIMENSIONS					
	Ⓐ Fingertip Grasp		Ⓑ Thumb and Finger Encircled	Ⓒ Palm Grasp	
	H Height	D Diameter	D Diameter	D Diameter	L Length
Minimum	18 mm (1/2 in)	10 mm (3/8 in)	25 mm (1 in)	88 mm (11/2 in)	75 mm (3 in)
Maximum	25 mm (1 in)	100 mm (4 in)	75 mm (3 in)	75 mm (3 in)	
TORQUE			SEPARATION		
	*	**			
Minimum	-	-	25 mm (1 in)	50 mm (2 in)	
Optimum	-	-	50 mm (2 in)	125 mm (5 in)	
Maximum	32 nM-m (4 1/2 in - oz)	42 nM-m (6 in - oz)	-	-	

* - To and including 25 mm (1 in) diameter knobs.

** - Greater than 25mm (1 in) diameter knobs.

FIG. 30 Knobs

24.5.5 *Crank Balance*—In applications in which resistance is light, the crank shall be balanced to prevent the handle weight from turning the crank from its last setting.

24.5.6 *Positioning of Cranks*—Cranks that must be turned rapidly shall be mounted so their turning axis are between 60 and 90° from the frontal plane (Fig. 36). For standing operators, they shall be between 900 and 1200 mm (36 and 48 in.) above the floor.

24.6 *Handwheels:*

24.6.1 *Use*—Handwheels less than 152 mm (6 in.) in diameter shall be designed and located for one-handed operation. Handwheels greater than 152 mm (6 in.) shall be designed and located for two-handed operation. Handwheels designed for two-hand operation shall be used when the breakout or rotational forces are too high to be easily overcome with a one-handed control. Typical applications are steering, latch securing, valve opening/closing and direct-linkage adjustment.

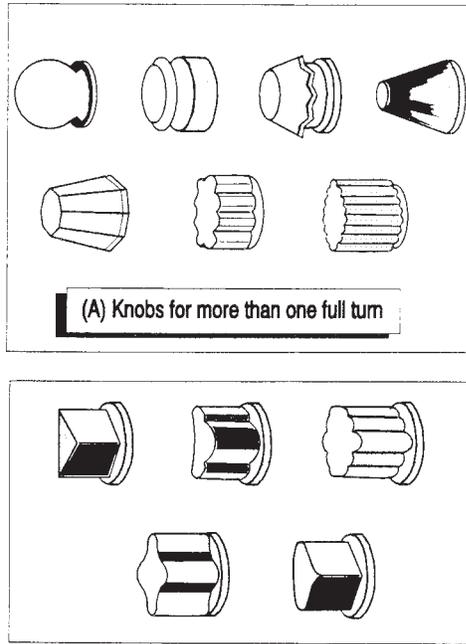


FIG. 31 Recommended Knob Shapes

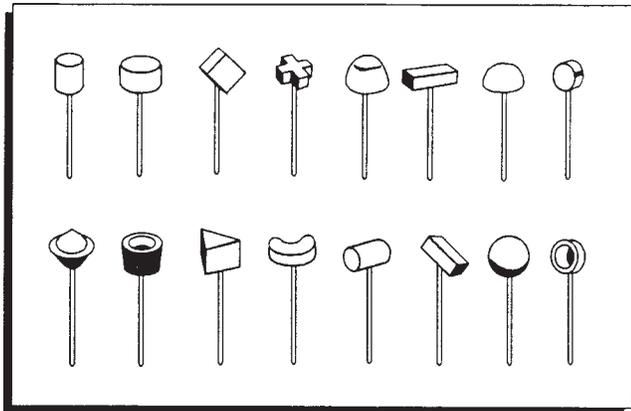


FIG. 32 Easily Recognizable Knob Shapes

24.6.2 *Turning Aids*—Knurling, indentation, high-friction covering, or a combination of these shall be built into the handwheel to facilitate operator grasp for applying maximum torque and to reduce the possibility of the wheel being jerked from the operator’s hands.

24.6.3 *Spinner Handles*—For applications in which the wheel may be rotated rapidly through several revolutions, a spinner handle may be added. Such handles shall not be used, however, if the projecting handle is vulnerable to inadvertent displacement of a critical wheel setting or if it creates a safety hazard.

24.6.4 *Direction of Movement*—Except for valves, handwheels shall rotate clockwise for ON or INCREASE and counterclockwise for OFF or DECREASE. The direction of motion shall be indicated on the handwheel, or immediately adjacent thereto, by means of arrow and appropriate legends. Valve handwheels shall turn counterclockwise to OPEN and clockwise to CLOSE. Direction of motion shall be indicated as stated above.

24.6.5 *Dimensions, Resistance, Displacement, and Separation*—Control dimensions, resistance, displacement, and separation between edges of adjacent handwheels shall conform to the criteria in Fig. 37.

24.6.6 *Location*—Where possible, valve handwheels shall be located as shown in Fig. 38 for valves mounted above the operators standing surface. Valve handwheels located below the standing surface (for example, below bilge deck grating), the handwheel shall be oriented parallel or perpendicular to the grating with the grasping surface of the handwheel no more than 300 mm (12 in.) below the standing surface. No valve handwheel larger than 510 mm (20 in.) in diameter shall be installed in the overhead above 1.93 m (77 in.) unless the operating force on the handwheel is less than 40 ft-lbf.

24.6.6.1 *Access*—Access to valve handwheels requiring one-handed operating from a bending, squatting, or standing ladder position shall not exceed the values shown in Fig. 39. Small valve handwheels installed on pipes wrapped with insulation shall be installed so there is a minimum of 50-mm (2-in.) clearance between the back of the handwheel and the insulation material. Handwheels associated with valves on strainers and filters shall be located so they are accessible with spray shields or enclosures in place. A minimum of 80-mm (3-in.) clearance on all sides of a handwheel shall be provided.

24.6.6.2 *Position Indicators*—Valves and handwheels equipped with mechanical position indicators shall be installed so the indicator is directly visible to the operator from the normal operating position.

24.6.6.3 *Steering Wheel Shape*—Except for established uses in applications in which maximum wheel deflection does not exceed $\pm 2/3$ (120°), all steering wheels shall be round.

25. Discrete Linear Controls

25.1 Push Buttons (Finger or Hand Operated):

25.1.1 *Use*—Push buttons shall be used when a control or an array of controls is needed for momentary contact or for activating a locking circuit, particularly in high-frequency-of-use situations.

25.1.2 *Shape*—The push-button surface shall normally be concave (indented) to fit the finger. When this is impractical, the surface shall provide a high degree of frictional resistance to prevent slipping.

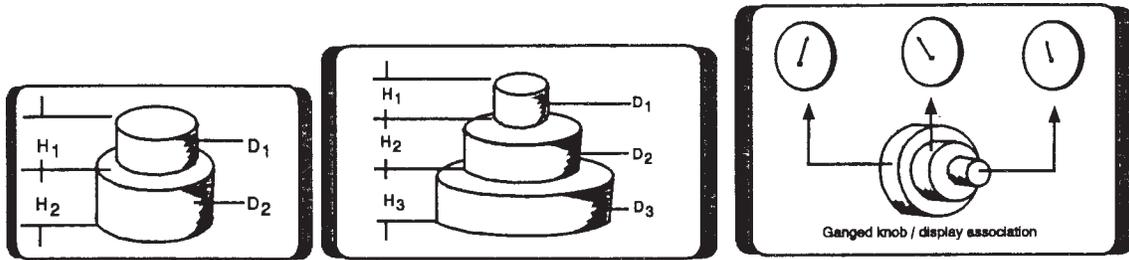
25.1.3 *Positive Indication*—A positive indication of control activation shall be provided (snap feel, audible click, or integral light).

25.1.4 *Channel or Cover Guard*—A channel or cover guard shall be provided when it is imperative to prevent accidental activation of the controls. When a cover guard is in the open position, it shall not interfere with operation of the protected device or adjacent controls.

25.1.5 *Dimensions, Resistance, Displacement, and Separation*—Except for use of push buttons in keyboards, the control dimensions, resistance, displacement, and separation between adjacent edges of finger- or hand-operated push buttons shall conform to the criteria in Fig. 40.

25.1.6 *Resistance*—Single-finger, 2.8 N (10 oz) to 11 N (40 oz). Thumb or palm, 2.8 N (10 oz) to 23 N (80 oz).

25.1.7 *Interlocks or Barriers*—Mechanical interlocks or barriers may be used instead of the spacing required by Fig. 40.



DIMENSIONS										
	TWO KNOB ASSEMBLY				THREE KNOB ASSEMBLY					
	N ₁	N ₂	D ₁	D ₂	N ₁	N ₂	N ₃	D ₁	D ₂	D ₃
MINIMUM	16 mm (5/8 in)	13 mm (1/2 in)	18 mm (1/2 in)	22 mm (7/8 in)	19 mm (3/4 in)	19 mm (3/4 in)	6 mm (1/4 in)	13 mm (1/2 in)	44 mm (1 3/4 in)	75 mm (3 in)
MAXIMUM				100mm (4 in)						100mm (4 in)

	TORQUE		SEPARATION			
	*	**	ONE HAND INDIVIDUALLY		TWO HANDS SIMULTANEOUSLY	
			BARE	GLOVED	BARE	GLOVED
MINIMUM			25 mm (1 in)	63 mm (2 1/2 in)	50 mm (2 in)	90 mm (3 1/2 in)
OPTIMUM			50 mm (2 in)	90 mm (3 1/2 in)	75 mm (3 in)	100 mm (4 in)
MAXIMUM	32 ml-l-m (4 1/2 in-oz)	42 ml-l-m (6 in-oz)				

* To and including 25mm (1 in) diameter knobs.
 ** Greater than 25 mm (1 in) diameter knobs.

FIG. 33 Ganged Knobs

25.1.8 *Identification/Legends*—Labels placed on the push-button face are preferred. Legends shall normally be legible with or without internal illumination. A lamp test capability or a dual lamp reliability, or both, shall be provided, except for switches using LEDs in place of incandescent lamps. Other considerations include:

25.1.8.1 No more than three lines of lettering shall normally be used on a legend plate.

25.1.8.2 Lamps shall be replaceable from the front of the panel, by hand, and the legend or cover plate shall be keyed to prevent possibility of interchanging covers.

25.2 *Keyboards:*

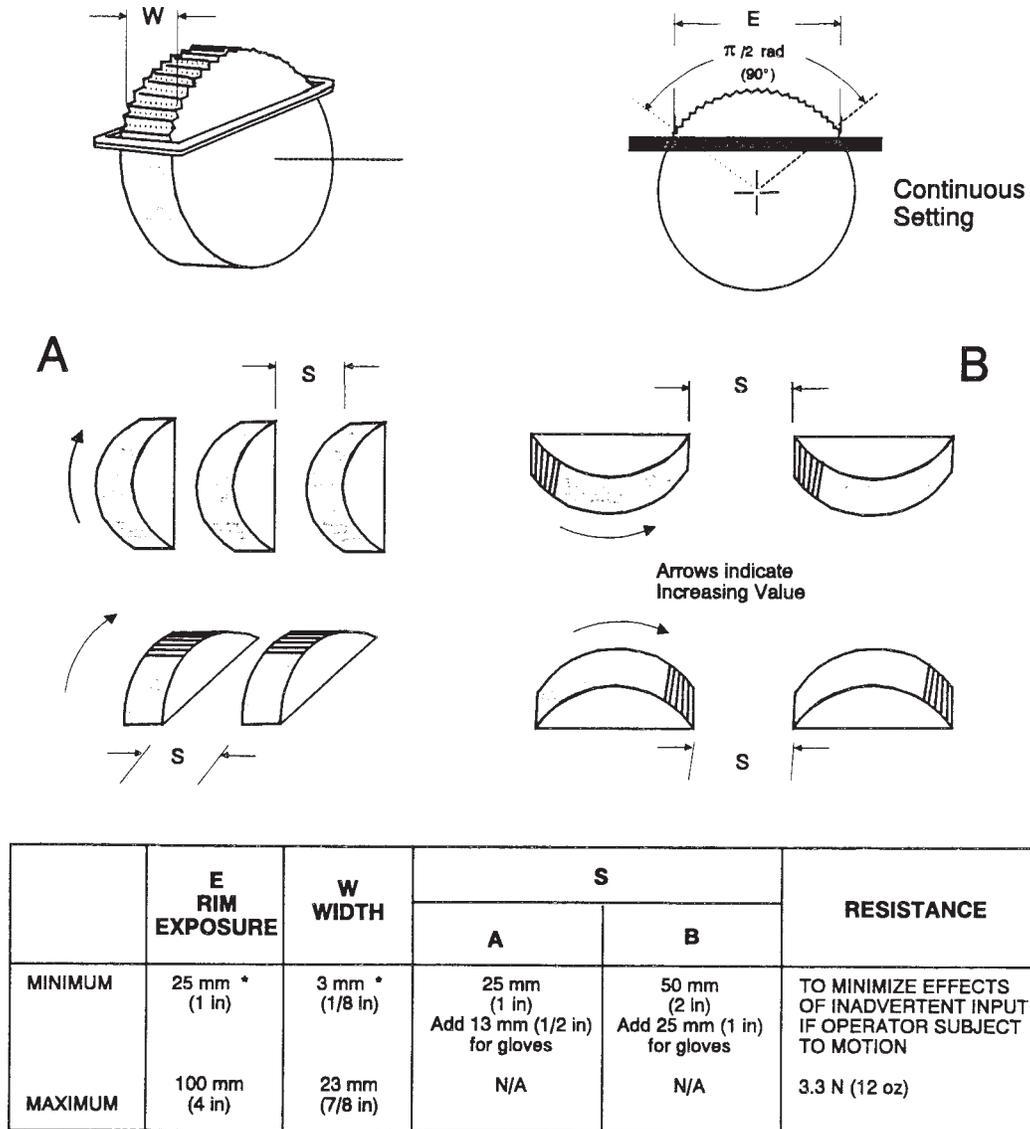
25.2.1 *Use*—Arrangements of push buttons in the form of keyboards shall be used when alphabetic, numeric, or special function information is to be entered into a system.

25.2.2 *Layout and Configuration*—The key configuration and the number of keys are dependent upon the predominant type of information to be entered into the system. The major forms that keyboards can take, which aid in the entry of such information, are given below:

25.2.2.1 *Numeric Keyboard*—The configuration of a keyboard used to enter solely numeric information shall be a 3 × 3 + 1 matrix with the zero digit entered on the bottom row and

TABLE 15 Knob Detentes Placement

Total Number of Settings	Recommended Starting Position, rad (degrees)			Recommended Angular Displacement, rad (degrees)	Recommended Radius for 13-mm Separation, mm (in.)
	Left-Hand Operation	Right-Hand Operation	Either Hand		
3	0.28 (16.00)	4.60 (264.00)	5.59 (320.00)	0.70 (40.00)	18.2 (0.72)
4	6.13 (351.00)	4.42 (253.29)	5.27 (302.14)	0.67 (38.57)	18.9 (0.74)
5	5.72 (327.73)	4.25 (243.31)	4.98 (285.52)	0.65 (37.24)	19.5 (0.77)
6	5.34 (306.00)	4.08 (234.00)	3.61 (207.00)	0.63 (36.00)	20.2 (0.80)
7	4.99 (285.67)	3.93 (225.29)	4.46 (255.48)	0.61 (34.84)	20.8 (0.82)
8	4.65 (266.62)	3.79 (217.13)	4.22 (241.87)	0.59 (33.75)	21.6 (0.85)
9	4.34 (248.71)	3.66 (209.45)	4.00 (229.08)	0.57 (32.73)	22.2 (0.87)
10	4.05 (231.85)	3.53 (202.22)	3.79 (217.03)	0.55 (31.77)	22.9 (0.90)
11	3.77 (215.98)	3.41 (195.42)	3.59 (205.70)	0.54 (30.86)	23.6 (0.93)
12	0, 1.57, or 3.14 (0, 90, or 180)	3, 14, 4.71, or 6.20 (180, 270, or 360)	0 or (0 or 3.14 180)	0.52 (30.00)	24.3 (0.96)



* Preferred. Some miniature applications may require less.

FIG. 34 Thumbwheel Adjustment Controls

arranged in either of the following ways:

123 456 789 0 or 789 456 123 0

25.2.2.2 *Alphanumeric Keyboard*—Keyboard configurations can vary with the entry of data changing from primarily alphabetic to primarily numeric. For these applications, two alternatives are preferred: provide a keyboard where there is no separation between alphabetic and numeric characters or provide a separation to emphasize the two separate functions, with the numeric keyboard located to the right of the standard keyboard.

25.2.2.3 *Dimensions, Resistance, Displacement, and Separation*—The control dimensions, resistance, displacement, and separation between adjacent edges of the push buttons which form keyboards shall conform to the criteria in Table 16 and Table 17. For a given keyboard, these criteria shall be uniform for all individual keys. For those applications in which operation while wearing (trigger finger) arctic mittens is required, the minimum key size shall be 19 mm (0.75 in.).

Other parameters are unchanged from those of bare-handed operation (see Table 16 and Table 17).

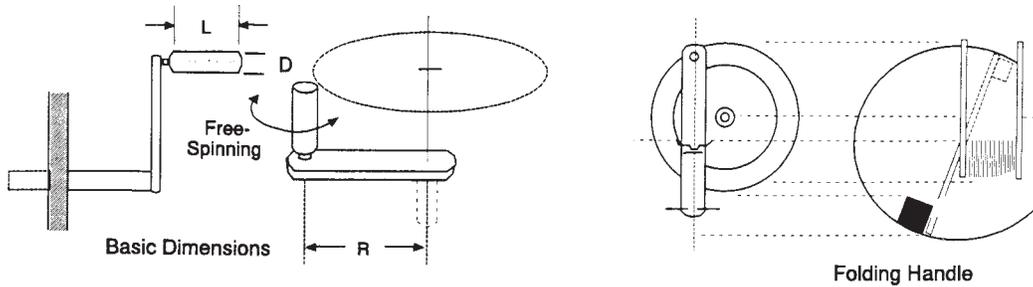
25.2.2.4 The slope of nonportable keyboards shall be 260 to 435 mrad (15 to 25°) from the horizontal. The preferred slope is 280 to 300 mrad (17 to 18°). The slope of a portable device can be varied according to the preference of the operator. The first row of keys shall be between 230 and 300 mm (9 and 12 in.) above the seat level.

25.2.2.5 *Multiple Keyboards*—Systems containing more than one keyboard shall maintain the same configuration for alphanumeric, numeric, and special function keys throughout the system.

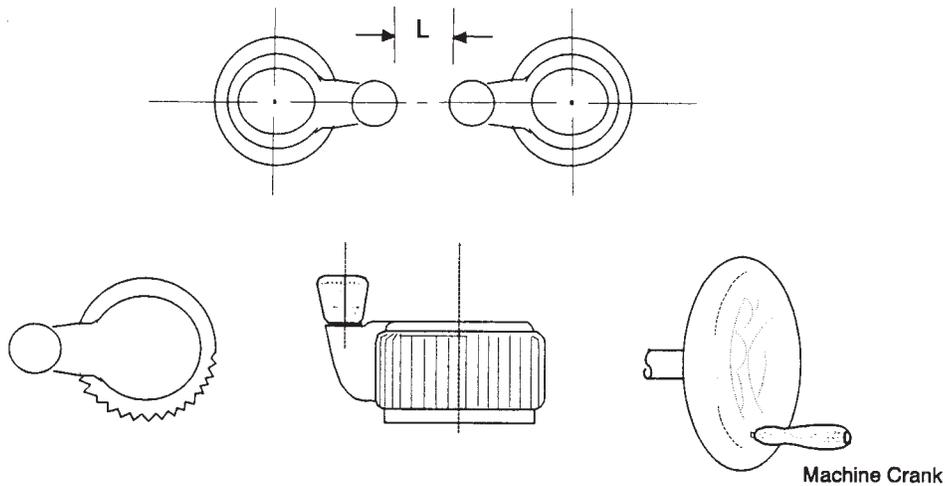
25.2.2.6 *Feedback*—Feedback shall be provided to inform the operator whether the key was pressed, the intended key was pressed, and whether the next operation may be initiated.

25.3 *Toggle Switch Controls:*

25.3.1 *Use*—Toggle switches shall be used for functions that require two discrete positions or where space limitations



Combined Finger/Spinner Styles (Consoles)



LOAD	SPECIFICATION	HANDLE				R, TURNING RADIUS			
		L, LENGTH		D, DIAMETER		RATE BELOW 100 RPM		RATE ABOVE 100 RPM	
		mm	in	mm	in	mm	in	in	in
LIGHT LOADS: Less than 22 N (5 lb). (Wrist and finger move- ment)	MINIMUM	25	1	10	3/8	38	1 1/2	13	1/2
	PREFERRED	38	1 1/2	13	1/2	75	3	65	2 1/2
	MAXIMUM	75	3	16	5/8	125	5	115	4 1/2
HEAVY LOADS: More than 22 N (5 lb). (Arm movement)	MINIMUM	75	3	25	1	190	7 1/2	125	5
	PREFERRED	95	3 3/4	25	1	—	—	—	—
	MAXIMUM	—	—	38	1 1/2	510	20	230	9

S = Separation between adjacent controls or any adjacent obstruction 75 mm (3 in) minimum

FIG. 35 Cranks

are severe. Toggle switches with three positions shall be used only where the use of a rotary control, legend switch control, and so forth, is not feasible or when the toggle switch is of the spring-loaded, center position-off type. Three position toggle switches that are spring loaded to center-off from only one other position shall not be used if release from the spring-loaded position results in switch handle travel beyond the off position. Toggle switches are considered herein to be discrete position controls. Small controls that are the same size and

shape as toggle switches and used for making continuous adjustments are described herein as levers.

25.3.2 *Accidental Activation*—When the prevention of accidental activation is of primary importance (critical, dangerous, or hazardous conditions would result), channel guards, lift-to-unlock switches, or other equivalent prevention mechanisms shall be provided. Safety or lock wire shall not be used. Resistance of lift-to-unlock mechanisms shall not exceed 13 N

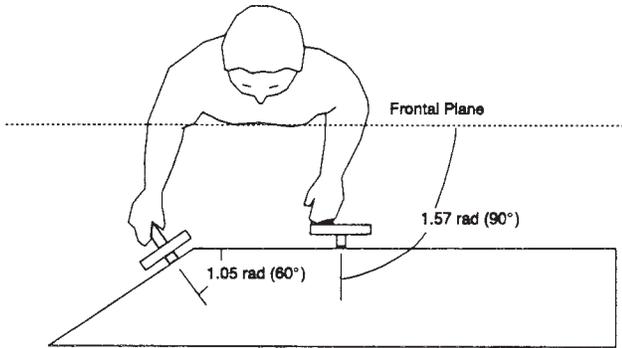


FIG. 36 Proper Mounting of Rapidly Operated Cranks

(3 lbs). If a cover guard is used, its location when open shall not interfere with the operation of the protected device or adjacent controls.

25.3.3 *Dimensions, Displacement, and Separation*—Dimensions, resistance, displacement, and separation between adjacent edges of toggle switches shall conform to the criteria in Fig. 41. Resistance shall gradually increase, then drop when the switch snaps into position. The switch shall not be capable of being stopped between positions. Resistance for a small switch ranges from 2.8 N (10 oz) minimum to 4.5 N (16 oz) maximum. For large switches, the forces are 2.8 N (10 oz) minimum to 11 N (40 oz) maximum.

25.3.4 *Positive Indication*—An indication of control activation shall be provided (snap feel, audible click, associated or integral light).

25.3.5 *Orientation*—Toggle switches shall be vertically oriented with OFF in the down position. Horizontal orientation and actuation of toggle switches shall be used only for compatibility with the controlled function or equipment location. Switch orientation and toggle switch movement for ON is shown in Fig. 42.

25.4 *Legend Switches:*

25.4.1 *Dimensions, Resistance, Displacement, and Separation*—Dimensions, resistance, displacement, and separation between adjacent edges of legend switches shall conform to the criteria in Fig. 43, except that maximum switch separation does not apply to nonmatrix applications.

25.4.2 *Barrier Height*—Barrier height from panel surface shall conform to the criteria in Fig. 43. Unless otherwise specified, barriers are required on critical switches and on switches likely to be inadvertently actuated. Barriers, when used, shall not obscure visual access to controls, labels, or displays.

25.4.3 *Other Requirements:*

25.4.3.1 For positive indication of switch activation, the legend switch shall be provided with a detente or click. When touch-sensitive switches are used, a positive indication of activation shall be provided, for example, an integral light within or above the switch being activated.

25.4.3.2 The legend shall be legible with or without internal illumination.

25.4.3.3 A lamp test or dual lamp/filament reliability shall be provided for switches if the mean time between failure (MTBF) is less than 100 000 h.

25.4.3.4 Lamps within the legend switch shall be replaceable from the front of the panel by hand and the legends or covers shall be keyed to prevent the possibility of interchanging the legend covers.

25.4.3.5 There shall be a maximum of three lines of lettering on the legend plate.

25.5 *Rocker Switches:*

25.5.1 *Use*—Rocker switches may be used in lieu of toggle switches for functions that require two discrete positions. They may be used for applications in which toggle switch handle protrusions might snag the operator's sleeve or phone cord or there is insufficient panel space for separate labeling of switch positions. Rocker switches with three positions shall be used only where the use of a rotary control, legend switch control, and so forth, is not feasible or when the rocker switch is of the spring-loaded center-off type.

25.5.2 *Accidental Actuation*—When the prevention of accidental actuation is of primary importance (critical, dangerous, or hazardous conditions would result), channel guards or equivalent protective measures shall be provided.

25.5.3 *Positive Indication*—An indication of control activation shall be provided (snap feel, audible click, associated or integral light).

25.5.4 *Dimensions, Resistance, Displacement, and Separation*—Dimensions, resistance, displacement, and separation between centers of rocker switches shall conform to the criteria in Fig. 44. Resistance shall gradually increase, then drop when the switch snaps into position. The switch shall not be capable of being stopped between positions.

25.5.5 *Orientation*—Where practicable, rocker switches shall be vertically oriented. Activation of the upper wing shall turn the equipment or component on, or cause the quantity to increase, or cause the equipment or component to move forward, clockwise, to the right, or up. Horizontal orientation of rocker switches shall be used only for compatibility with the controlled function or equipment location.

25.5.6 *Color and Illumination*—Alternate colors may be used to denote the ON and OFF portions of a rocker switch. Alternate illumination of either the ON or OFF switch position may be used to facilitate positive recognition of current switch position. For areas in which ambient illumination will provide display luminance below 3.5 cd/m² (1 ft-L), the rocker switch shall be internally illuminated. Digits and letters shall appear as light or white illuminated characters on an opaque background and their dimensions shall approximate the following:

- 25.5.6.1 Height, 4.8 mm (3/16 in.).
- 25.5.6.2 Height-to-width ratio, 3:2.
- 25.5.6.3 Height-to-stroke-width ratio, 10:1.

25.6 *Slide Switch Controls:*

25.6.1 *Use*—Slide switch controls may be used for functions that require two discrete positions. Slide switch controls may also be used for functions that require a higher number of discrete positions in which the switches are arranged in a matrix to permit easy recognition of relative switch settings (for example, audio settings across frequencies), but shall not be used where mispositioning is to be avoided.

25.6.2 *Accidental Actuation*—When the prevention of accidental actuation is of primary importance (critical, dangerous,

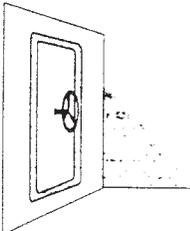
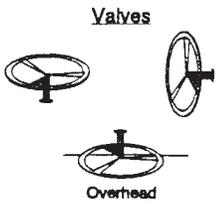
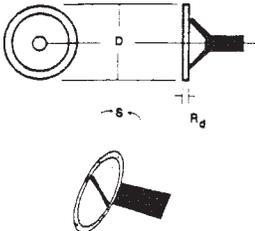
	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	CONTINUOUS ADJUSTMENT FOR ALTERNATE SLEWING/PRECISE POSITIONING, USING DISPLAY	200-510 mm (8 in - 20 in)	19 - 32 mm (3/4 in - 1 1/4 in)	75 mm (3 in) around rim	N/A	710 mm (28 in) elbow-elbow clearance
	CONTINUOUS LOCK-UNLOCK OPERATION	200 mm (8 in) for 22 N (5 lb) to 510 mm (22 in) for	19 - 32 mm (3/4 in - 1 1/4 in)	75 mm (3 in) around rim	N/A	710 mm (28 in) elbow-elbow clearance
	HIGH TORQUE VALVES	200-400 mm (8 in - 16 in) for overhead; 200-510 mm (8 in - 20 in) for other positions 300-1520 mm (12 in - 60 in) above standing surface	19 - 32 mm (3/4 in - 1 1/4 in)	75 mm (3 in) around rim	N/A	710 mm (28 in) elbow-elbow clearance
	VEHICLE STEERING (AUTOMOTIVE). MAX NON-POWER STEERING MAX NON-POWER = 220 N (50 lb)	355 - 400 mm (14 - 16 in) for pwr steering 400 - 510 mm (16 - 20 in) for non-pwr steering	19 - 32 mm (3/4 - 1 1/4 in)	525 mrad (30°) for light vehicle (preferred) 785 mrad (45°) for heavy vehicle (preferred)	Max of 2.09 rad (120°) when both hands must remain on wheel	N/A

FIG. 37 Handwheels

or hazardous conditions would result), channel guards or other equivalent means shall be provided.

25.6.3 *Dimensions, Resistance, and Separation*—Dimensions, resistance, and separation of slide switch handles shall conform to criteria in Fig. 45. Detentes shall be provided for each control setting. Resistance shall gradually increase, then drop when the switch snaps into position. The switch shall not be capable of stopping between positions.

25.6.4 *Orientation*—Where practicable, slide switches shall be vertically oriented with movement of the slide up or away from the operator turning the equipment or component on, causing a quantity to increase, or causing the equipment or component to move forward, clockwise, to the right or up. Horizontal orientation or actuation slide switches shall be used only for compatibility with the controlled function or equipment location.

25.6.5 *Positive Indication*—Slide switch controls involving more than two positions shall be designed to provide positive

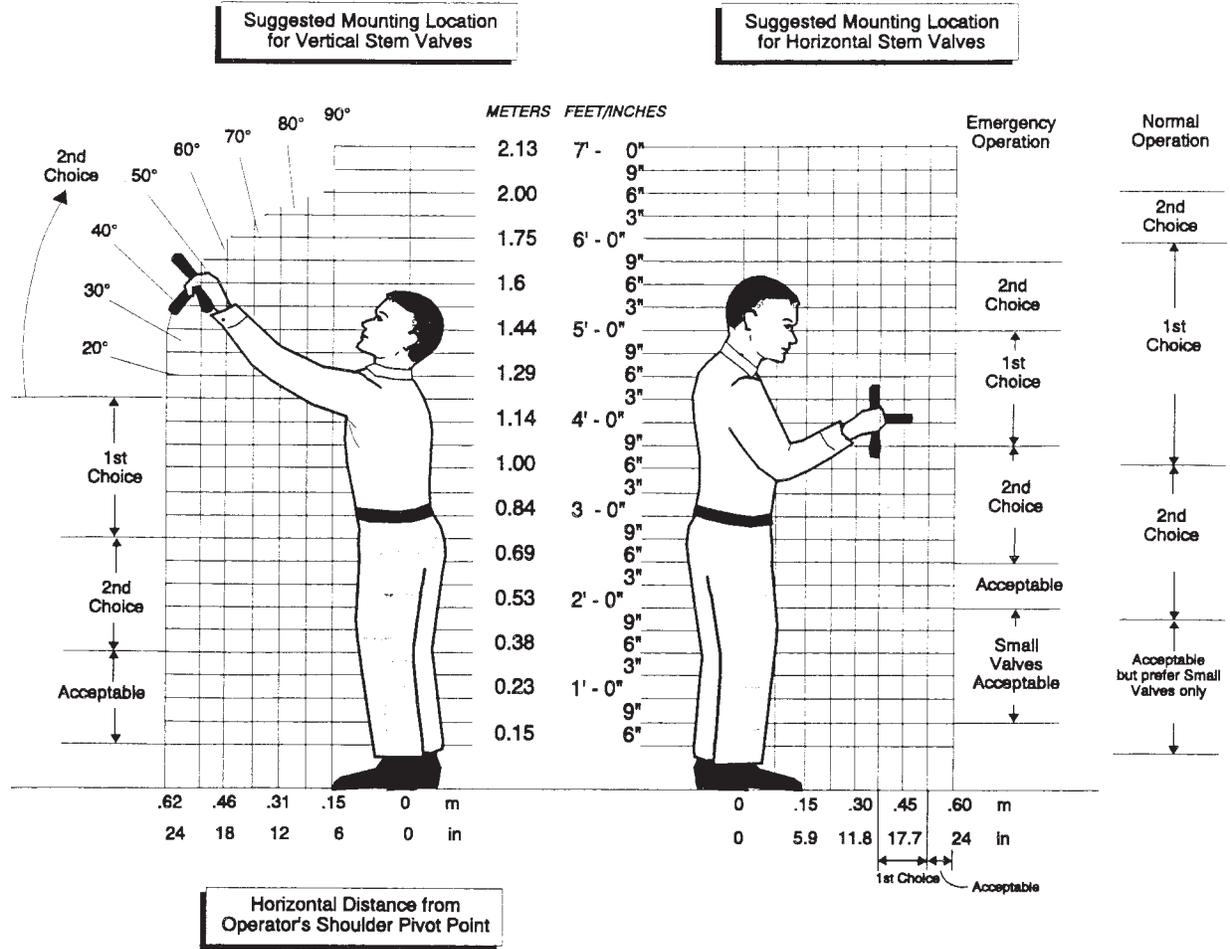
indication of control setting, preferably a pointer located on the left side of the slide handle.

25.7 *Discrete Push-Pull Controls:*

25.7.1 *Applications*—Push-pull controls may be used when two discrete functions are to be selected. However, such applications should be used sparingly. They may also be used in certain cases in which limited panel space suggests a miniaturized knob that may be used to serve two related, but distinct, functions (such as an ON-OFF/volume switch for a TV monitor). A three-position push-pull control is acceptable in isolated instances in which the criticality of inadvertent selection of the wrong position has no serious consequences.

25.7.2 *Handle Dimensions, Displacement, and Clearances*—Push-pull control handles shall conform to criteria in Fig. 46.

25.7.3 *Rotation*—Except for combination push-pull/rotate switch configurations, push-pull control handles shall be keyed to a nonrotating shaft, unless the control is to be used for a



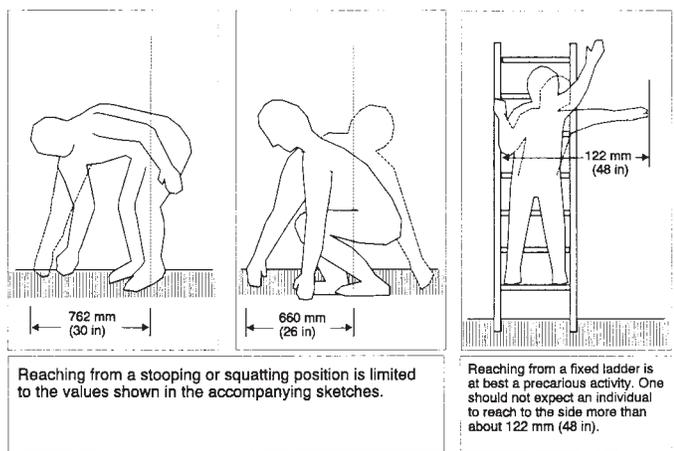
Horizontal Distance from Operator's Shoulder Pivot Point

Note: Heights measured to handwheel centerline.

Heights are to the maximum extension of valve stem for rising stem valves.

Note: For valves mounted higher than shown, clear access should be provided to reach via ladder or other means. Where chains are used to operate overhead handwheels, they shall end between 36 and 60 inches above the deck.

FIG. 38 Recommended Mounting Heights for Valve Handwheels



Reaching from a stooping or squatting position is limited to the values shown in the accompanying sketches.

Reaching from a fixed ladder is at best a precarious activity. One should not expect an individual to reach to the side more than about 122 mm (48 in).

FIG. 39 Reaching Limits for Bending, Squatting, or Standing on Ladders

special application (for example, the handle is rotated to disengage the brake setting). When the control system provides a combination push-pull/rotate functional operation, using a round style knob, the rim of the knob shall be serrated to

denote (visually and tactually) that the knob can be rotated and to facilitate a slip-free finger grip.

25.7.4 *Detentes*—Mechanical detentes shall be incorporated into push-pull controls to provide tactile indication of positions.

25.7.5 *Snagging and Inadvertent Contact*—Use, location, and operating axis of push-pull-type controls shall preclude the possibility of the operator(s):

25.7.5.1 Bumping a control while getting into or out of position.

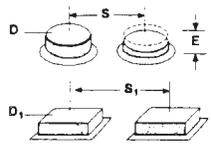
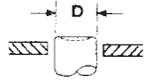
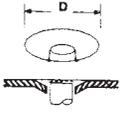
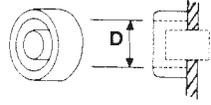
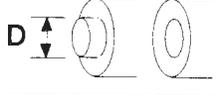
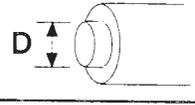
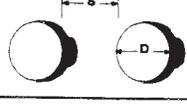
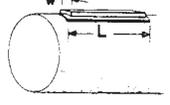
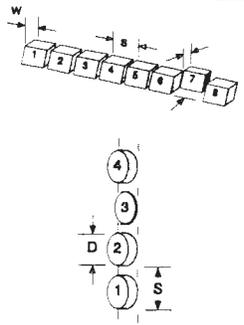
25.7.5.2 Snagging clothing, communication cables, or other equipment items on the control.

25.7.5.3 Inadvertently deactuating the control setting while reaching for another control.

25.7.6 *Direction of Control Motion*—Control direction shall be as follows:

25.7.6.1 Pull the operator for ON or actuation; push away for OFF or deactuation.

25.7.6.2 Clockwise for deactuation or increasing function of combination pull/rotary switches.

	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	<p>PANEL-MOUNTED PUSH BUTTONS: SINGLE FINGER, ONE BUTTON AT A TIME. NON-LEGEND OR BUTTONS THAT REQUIRE ONLY A SINGLE NUMBER ON THE FRONT SURFACE MAY BE ROUND, SQUARE OR RECTANGULAR</p>	<p>FINGERTIP D - MIN DIAM. OR DIMENSION (D₁) = 10 mm* (3/8 in) D-MAX = 25 mm (1 in)</p>	<p>THUMB OR PALM D - MIN = 19 mm (3/4 in)</p>	<p>— PREFERRED MIN</p>	<p>PREFERRED MIN S₁ - MIN = 13 mm (1/2 in) MIN = 3.2 mm (1/8 in) PREFERRED MAX = 6.5 mm (1/4 in) ADD FOR GLOVED OPN 13 mm (1/2 in)</p> <p>NOTES: (1) THE DEPRESSED BUTTON (E)</p>	<p>S₁ - MIN = 19 mm (3/4 in) WITH GLOVES 25 mm (1 in)</p>
	<p>A CONCAVE SURFACE MAY BE USED TO AID FINGER-CENTERING (NON-GLOVE OPN ONLY).</p>	<p>D-MAX = 19 mm (3/4 in) D-MIN = 13 mm (1/2 in)</p>	<p>—</p>	<p>—</p>	<p>SHALL REMAIN EXPOSED BY AT LEAST 2.5 mm (.1 in) (2) SWITCHES WITH MOTION (e.g. THERMAL)</p>	
	<p>RECESSED BUTTON TO MINIMIZE INADVERTENT END OPERATION. TAPERED "WELL" GUIDES FINGER.</p>	<p>OPENING = 19 mm (3/4 in)</p>	<p>D-MIN WELL 32 mm (1 1/4 in) WITH GLOVES</p>	<p>TO THE APPROVAL BY THE PROCURING ACTIVITY</p>	<p>MISIBLE SUBJECT</p>	
	<p>PREVENT INADVERTENT OPERATION OF CRITICAL SWITCH, EITHER WITH GUARD RING, OR PANEL WELL.</p>	<p>—</p>	<p>SAME AS ABOVE</p>	<p>—</p>		
	<p>HANDLE, END-MOUNTED, PUSH BUTTON SWITCH: INDEX FINGER-OPERATED. RECESS TO PRECLUDE INADVERTENT OPERATION.</p>	<p>D-MINIMUM DIAM 10 mm (3/8 in)</p>	<p>—</p>	<p>—</p>	<p>SAME AS ABOVE</p>	<p>N/A</p>
	<p>THUMB-OPERATED</p>	<p>D-MINIMUM- 13 mm (1/2 in)</p>	<p>—</p>	<p>—</p>	<p>SAME AS ABOVE</p>	<p>N/A</p>
	<p>ALTERNATE FINGER OR HEEL OF THE HAND OPERATION. CONVEX SURFACE DESIRABLE.</p>	<p>D - MIN = 25 mm (1 in)</p>	<p>—</p>	<p>—</p>	<p>SAME AS ABOVE</p>	<p>S - MIN FOR PALM OPN = 75 mm (3 in)</p>
	<p>GRIP HANDLE SWITCH ALTERNATE MULTI-FINGER OR PALM OPERATION</p>	<p>W-MIN = 6.5 mm (1/4 in)</p>	<p>L - PREFERRED MIN = 25 mm (1 in)</p>	<p>—</p>	<p>SAME AS ABOVE</p>	<p>N/A</p>
	<p>GANGED PUSH BUTTON ASSEMBLY SQUARE, RECTANGULAR OR ROUND SHAPES ARE ACCEPTABLE. DEPRESSEDION OF ANY BUTTON SHALL CAUSE ANY PREVIOUSLY DEPRESSED BUTTON TO RETURN TO DEACTIVATED POSITION. NUMBERED BUTTONS SHALL PROGRESS AS ILLUSTRATED.</p>	<p>W OR D MIN = 10 mm (3/8 in) FOR GLOVES 13 mm (1/2 in)</p>	<p>—</p>	<p>—</p>	<p>x.a - MIN EXPOSURE WHEN DEPRESSED = 3.2 mm (1/8 in) x.b - MIN DEPRESSION TO ACTIVATE (PREFERRED = 5 mm (1/5 in)) NOTE: MAX DISPLACEMENT SHALL NOT EXCEED 13 mm (1/2 in)</p>	<p>S - CTR-CTR SPACING MIN = 19 mm (3/4 in) FOR GLOVES 25 mm (1 in)</p>

* For miniaturized applications, diameters as small as 3.2 mm (1/8 in) may be used subject to approval by the procuring acitivity.

FIG. 40 Pushbutton Switches

TABLE 16 Keyboards, Inch-Pound Units

	Dimensions		Resistance		
	Diameter, D ^A		Numeric, oz	Alpha- numeric, oz	Dual Function, oz
	Bare- handed, in.	Arctic Mittens, in. ^B			
Minimum	0.385	0.75	3.5	0.0	0.9
Maximum	0.75		14.0	5.3	5.3
Preferred	0.5	0.75			

	Displacement			
	Numeric, in.	Alpha- numeric, in.	Dual Function, in.	
Maximum	0.19	0.25	0.19	
Preferred				0.25

^A See Fig. 12.

^B Trigger finger type.

TABLE 17 Keyboards, SI Units

	Dimensions		Resistance		
	Diameter, D ^A		Numeric, N	Alpha- numeric	Dual Function
	Bare- handed, mm	Arctic Mittens, mm ^B			
Minimum	10	19	1	250	250
Maximum	19		4	mN	mN
Preferred	13	19		1.5 N	1.5 N

	Displacement			
	Numeric, mm	Alpha- numeric, mm	Dual Function, mm	
Maximum	4.8	6.4	4.8	
Preferred				6.4

^A See Fig. 12.

^B Trigger finger type.

25.7.7 *Resistance*—Force for pulling a panel control with fingers shall be not more than 18 N (4 lbs), for pulling a T-bar with four fingers shall be not more than 45 N (10 lbs).

25.8 Printed Circuit (PC) Switch Controls:

25.8.1 *Use*—PC switches may be used when manual programming functions are required in systems using printed circuit boards.

25.8.2 *Dimensions, Resistance, Displacement, and Separation*—Dimensions, resistance, displacement, and separation between adjacent PC switch actuators shall conform to the following:

25.8.2.1 Dimensions of actuators shall be sufficiently high to permit error-free manipulation by the operator when using some commonly available stylus (for example, a pencil or a pen). The design of the actuators shall not require the use of a special tool for manipulation.

25.8.2.2 Actuator resistance shall be sufficiently high to avoid inadvertent actuation under expected use conditions. Resistance shall gradually increase, then drop when the actuator snaps into position. The actuator shall not be capable of stopping between positions.

25.8.2.3 When actuators are slide type, they shall have sufficient travel (displacement) to permit easy recognition of switch setting. At a minimum, the travel shall be twice the length of the actuator. When actuators are rocker type, the actuated wing shall be flush with the surface of the module.

25.8.2.4 Actuators shall have sufficient separation to permit error-free manipulation by the operator (the stylus cannot inadvertently contact adjacent actuators).

25.8.3 *Shape*—The surface of the actuator shall be indented to accept the point of the stylus. The indentation shall be sufficiently deep to avoid slippage of the stylus during manipulation.

26. Continuous Adjustment Linear Controls

26.1 Levers:

26.1.1 *Use*—Levers may be used when large amounts of force or displacement are involved or when multidimensional movements of controls are required.

26.1.2 *Coding*—When several levers are grouped in proximity to each other, the lever handles shall be coded.

26.1.3 *Labeling*—When practicable, all levers shall be labeled as to function and direction of motion.

26.1.4 *Limb Support*—When levers are used to make fine or continuous adjustments, support shall be provided for the appropriate limb segment as follows:

26.1.4.1 For large hand movements, elbow support.

26.1.4.2 For small hand movements, forearm support.

26.1.4.3 For finger movements, wrist support.

26.1.5 *Dimensions*—The length of levers shall be determined by the mechanical advantage needed. When the lever or grip handle is spherical, its diameter shall conform to the criteria in Fig. 47. When the levers are of the slide type, dimensions and separations shall comply with Fig. 48.

26.1.6 *Resistance*—The resistance incorporated in levers shall be within the limits indicated in Fig. 47 and Fig. 48 measured as linear force applied to a point on the handle.

NOTE 1—The right hand can supply slightly more force than the left, but the difference is not significant. The same amount of push-pull force can be applied when the control is along the median plane of the body as when it is directly in front of the arm, 180 mm (7 in.) from the median plane. When the control is placed in front of the opposite (unused) arm, only 75 % as much force can be applied. When the control is 250 to 480 mm (10 to 19 in.) forward of the neutral seat reference point, twice as much push-pull force can be applied with two hands as with one-hand operation. Outside this range, two-hand operation becomes less effective.

26.1.7 *Elastic Resistance*—For joystick controls, elastic resistance that increases with displacement may be used to improve stick feel.

26.1.8 *Displacement and Separation*—Control displacement (for the seated operator) and separation shall conform to the criteria in Fig. 47.

26.2 *Displacement Joysticks*—(also known as Isotonic Joysticks.) Displacement joysticks usually have a spring resistance to movement away from the center (null) position, although some have no spring. Joystick controls may be used when the task requires precise or continuous control in two or more related dimensions. (The term “joystick” is used here to refer primarily to controls used for cursor placement or precise adjustment.) When positioning accuracy is more critical than

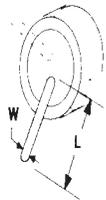
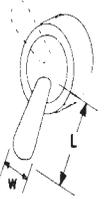
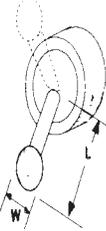
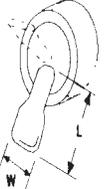
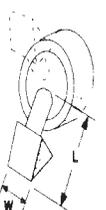
	APPLICATION CRITERIA	DESIGN CRITERIA		
		DIMENSIONS		
	MINIATURE TOGGLE SWITCH: LIMIT USE TO INDOOR APPLICATIONS WHERE LIMITED PANEL SPACE PRECLUDES STD SIZE COMPONENTS.	W - MIN DIAM = 3.3 mm (.13 in)	L - MIN LENGTH = 13 mm (1/2 in)	
	STANDARD CONFIGURATION: USE LARGER SIZES FOR APPLICATIONS WHERE GLOVED OPERATION IS LIKELY.	W - MIN DIAM = 4.5 mm (.18 in) MAX=7.8 mm (.31 in)	LENGTH MIN = 13 mm (1/2 in) MAX = 50 mm (2 in)	
	BALL CAP DESIGN APPLICABLE WHERE FIRM GRASP OF TOGGLE IS NEEDED DUE TO VEHICLE/OPERATION OSCILLATION.	W - MIN BAL DIAM = 4.5 mm (.18 in) MAX=7.8 mm (.31 in)	SAME AS ABOVE	
	FLAT OR APPLIED TAB HANDLES PROVIDE IMPROVED VISUAL POSITION REFERENCE WHEN OPERATIONALLY IMPORTANT.			W - MIN HANDLE WIDTH = 4.5 mm (.18 in)
	APPLIED TAB HANDLE PROVIDES MEANS FOR COLOR CODING.		L - 10 mm (.40 in) PREFERRED MAX = 25 mm (1 in)	W - 10 mm (.40 in) PREFERRED MIN = 4.8 mm (.19 in) MAX = 18 mm (1.5 in)
	ALTERNATE TO ANY STD SIZE CONFIGURATION ABOVE		SAME AS ABOVE	SAME AS ABOVE

FIG. 41 Toggle Switches

positioning speed, displacement joysticks shall be selected over isometric joysticks. Displacement joysticks may also be used for various display functions such as data pickoff from a CRT and generation of free-drawn graphics. In rate control applications, which allow the follower (cursor or tracking

symbol) to transit beyond the edge of the display, indicators shall be provided to aid the operator in bringing the follower back onto the display. Displacement joysticks that are used for rate control shall be spring loaded for return to the center when the hand is removed. Displacement joysticks that have a

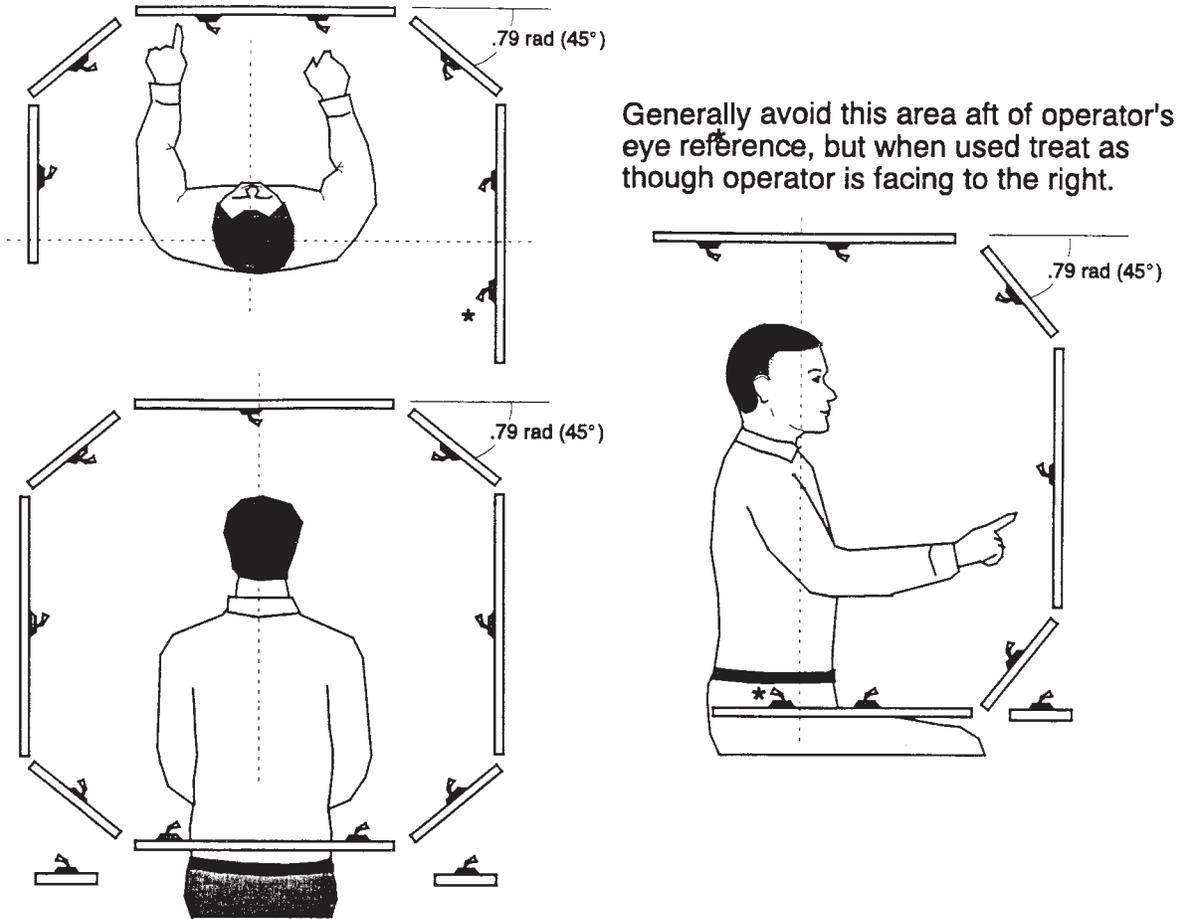
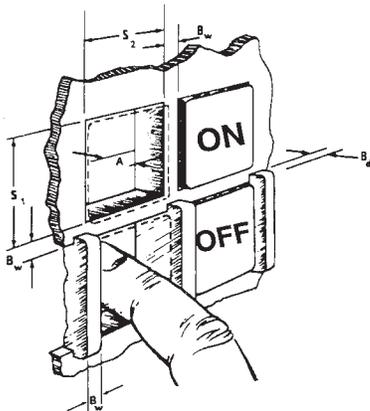


FIG. 42 Toggle Switch Orientation for "ON"



	S ₁ , S ₂ SIZE	A DISPLACEMENT	BARRIERS		RESISTANCE
			B _w	B _d	
MINIMUM	19 mm* (3/5 in.)	3 mm** (1/8 in.)	3 mm (1/8 in.)	5 mm (3/16 in.)	2.8 N*** (10 oz.)
MAXIMUM	36 mm (1 1/2 in.)	6 mm (1/4 in.)	6 mm (1/4 in.)	6 mm (1/4 in.)	16.7 N (60 oz.)

* 15 mm (5/8 in.) where switch is not depressed below the panel.
 ** 5 mm (3/16 in.) for positive position switches.
 *** 5.6 N (20 oz.) for use in moving vehicles. NOTE: B_w also refers to switch separation.

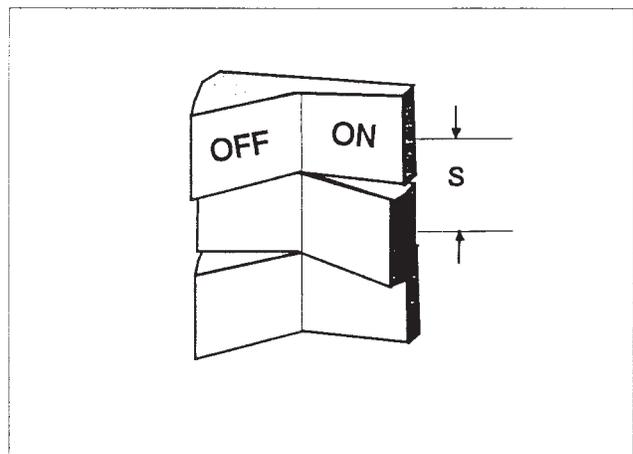
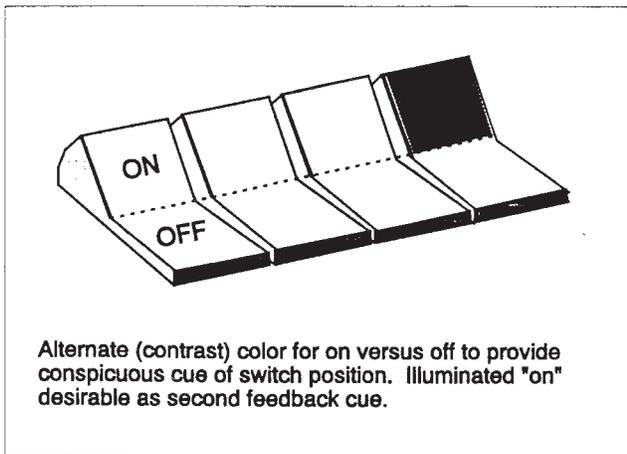
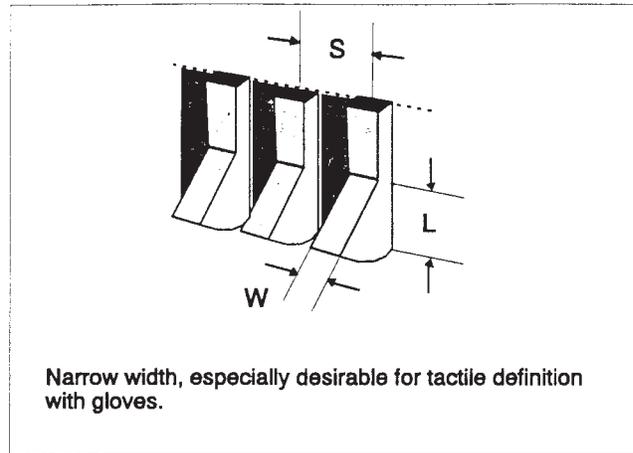
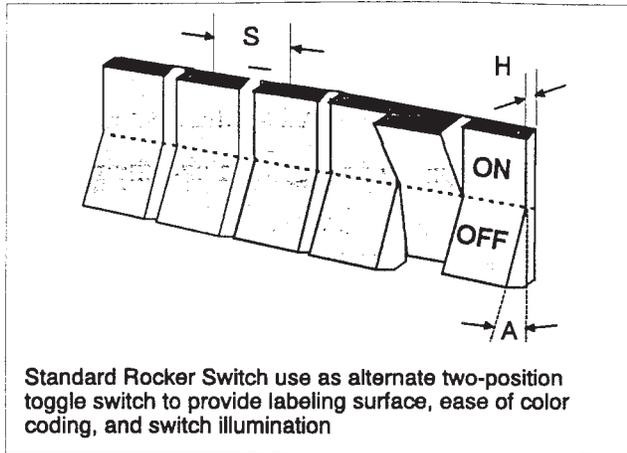
FIG. 43 Legend Switch

deadband near the center or hysteresis shall not be used with automatic sequencing of a CRT follower (cursor or tracking symbol) unless they are instrumented for null return or zero set to the instantaneous position of the stick at the time of sequencing. Upon termination of the automatic sequencing routine, joystick center shall again be registered to scope center. Displacement joysticks usually require less force than isometric joysticks and are less fatiguing for long operating periods.

26.2.1 Hand-Operated Displacement Joysticks:

26.2.1.1 Specific Use—In addition to the general use, hand-operated displacement joysticks may be used as vehicle controllers and aiming sensors. Hand-operated displacement joysticks may be used as mounting platforms for secondary controls, such as thumb- and finger-operated switches. Operation of secondary controls has less induced error on the displacement hand grip than does isometric handgrips.

26.2.1.2 Dynamic Characteristics—Movement shall not exceed 45° from the center position. Movement shall be smooth in all directions, and positioning of a follower shall be attainable without noticeable backlash, cross-coupling, or need for multiple corrective movements. Control ratios, friction, and inertia shall meet the dual requirements of rapid gross positioning and precise fine positioning. When used for generation of free-drawn graphics, the refresher rate for the follower on



	DIMENSIONS		RESISTANCE
	W - WIDTH	L - LENGTH	
MINIMUM	6 mm (1/4 in)	13 mm (1/2 in)	2.8 N (10 oz)
MAXIMUM	N/A	N/A	11 N (40 oz)

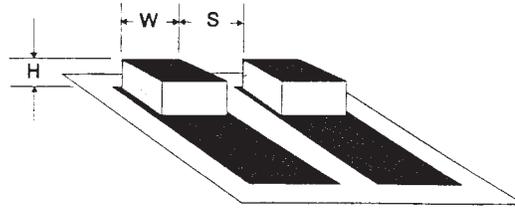
	DISPLACEMENT		SEPARATION (Center-to-Center)	
	H, HT, DEPRESSED	A, ANGLE	S (Bare Hand)	S (Gloved Hand)
MINIMUM	3 mm (1/8 in)	.52 rad (30°)	6 mm (1/4 in)	6 mm (1/4 in)

FIG. 44 Rocker Switches

the CRT shall be sufficiently high to give the appearance of a continuous track. Delay between control movement and confirming display response shall be minimized and shall not exceed 0.1 s.

26.2.1.3 *Dimensions, Resistance, and Clearance*—The hand grip length shall be in the range of 110 to 180 mm (4.3 to

7.1 in.). The grip diameter shall not exceed 50 mm (2 in.). Clearances of 100 mm (4 in.) to the side and 50 mm (2 in.) to the rear shall be provided to allow for hand movement. Joysticks shall be mounted to provide forearm support. Modular devices shall be mounted to allow actuation of the joystick without slippage, movement, or tilting of the mounting base.



	DIMENSIONS		RESISTANCE	
	H ACTUATOR HEIGHT * **	W ACTUATOR WIDTH	SMALL SWITCH	LARGE SWITCH
MINIMUM	6 mm (1/4 in)	13 mm (1/2 in)	2.8 N (10 oz)	2.8 N (10 oz)
MAXIMUM	N/A	N/A	4.5 N (16 oz)	11 N (40 oz)

* Use by bare finger.
** Use with heavy handwear.

	S, SEPARATION		
	SINGLE FINGER OPERATION	SINGLE FINGER SEQUENTIAL OPERATION	SIMULTANEOUS OPERATION BY DIFFERENT FINGERS
MINIMUM	19 mm (3/4 in)	13 mm (1/2 in)	16 mm (5/8 in)
MAXIMUM	50 mm (2 in)	25 mm (1 in)	19 mm (3/4 in)

FIG. 45 Slide Switches

26.2.2 *Finger-Operated Displacement Joysticks:*

26.2.2.1 *Specific Use*—In addition to the general uses, finger-operated displacement joysticks are useful for free-drawn graphics. In this application, there is usually no spring return to center, and the resistance shall be sufficient to maintain the handle position when the hand is removed.

26.2.2.2 *Dynamic Characteristics*—Movement shall not exceed 45° from the center position. Movement shall be smooth in all directions, and positioning of a follower shall be attainable without noticeable backlash, cross-coupling, or need for multiple corrective movements. Control ratios, friction, and inertia shall meet the dual requirements of rapid gross positioning and precise fine positioning. Recessed mounting or pencil attachments may be used as indicated in Fig. 49 to provide greater precision of control. When used for generation of free-drawn graphics, the refresher rate for the follower on the CRT shall be sufficiently high to give the appearance of a continuous track. Delay between control movement and the confirming display response shall be minimized and shall not exceed 0.1 s.

26.2.2.3 *Dimensions, Resistance, and Clearance*—The joystick shall be mounted on a desk or shelf surface as shown in Fig. 49. Joysticks shall be mounted to provide forearm or wrist support. Modular devices shall be mounted to allow actuation of the joystick without slippage, movement, or tilting of the mounting base.

26.2.3 *Thumbtip/Fingertip-Operated Displacement Joysticks:*

26.2.3.1 *Specific Use*—Thumbtip/fingertip-operated joysticks may be mounted on a handgrip, which serves as a steady

rest to damp vibrations and increase precision. If so mounted, the handgrip shall not simultaneously function as a joystick controller.

26.2.3.2 *Dynamic Characteristics*—Movement shall not exceed 785 rad (45°) from the center position.

26.2.3.3 *Dimensions, Resistance, and Clearance*—Joysticks shall be mounted to provide wrist or hand support. Console mounted devices shall be mounted as shown in Fig. 49. Modular devices shall be mounted to allow actuation of the joystick without slippage, movement, or tilting of the mounting base.

26.2.4 *Isometric Joystick (Two-Axis Controllers)*—Also known as stiff stick, force stick, or pressure stick. The controller has no perceptible movement, but its output is a function of force applied. Joystick controls may be used when the task requires precise or continuous control in two or more related dimensions. Isometric joysticks are particularly appropriate for applications: (1) which require precise return to center after each use; (2) in which operator feedback is primarily visual rather than tactile feedback from the control itself; and (3) where there is minimal delay and tight coupling between control and input and system reaction. Isometric sticks shall ordinarily not be used in applications in which it would be necessary for the operator to maintain a constant force on the control for a long period of time or in which there is no definitive feedback when maximum control inputs have been exceeded. Joystick controls may be used when the task requires precise or continuous control in two or more related dimensions. When positioning speed is more critical than positioning

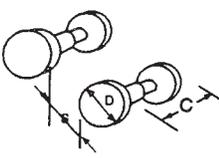
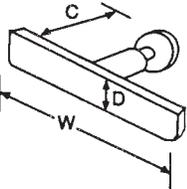
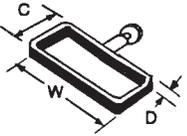
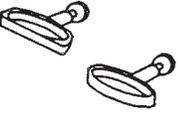
APPLICATION CRITERIA	DESIGN CRITERIA				
	DIMENSIONS			DISPLACEMENT	SEPARATION
 <p>PUSH-PULL CONTROL, LOW RESISTANCE FOR TWO-POSITIONS, MECHANICAL AND/OR ELECTRICAL SYSTEMS</p> <p>ALTERNATE THREE-POSITION PLUS ROTARY FUNCTION ACCEPTABLE FOR APPLICATION SUCH AS VEHICLE HEADLIGHT PLUS PARKING LIGHTS. PANEL AND DOME LIGHTS PROVIDE SERRATED RIM.</p>	D, MIN DIAM: 19 mm (3/4 in)	C, MIN CLEARANCE 25 mm (1 in) Add 13 mm (1/2 in) for gloved hand.		25 ± 13 mm (1 1/2 in) MIN BETWEEN PULL POSNS: 13 mm (1/2 in)	S - MIN SPACE BETWEEN 38 mm (1 1/2 in) Add 13 mm (1/2 in) for gloved hand
 <p>ALTERNATE HANDLE: MINIATURE ELECTRICAL PANEL SWITCH ONLY. AVOID GLOVE USE APPLICATION.</p>	D, MIN DIAM: 6 mm (1/4 in)	N/A	L, MIN LGTH 19 mm (3/4 in)	MINIMUM 13 mm (1/2 in)	S, MIN SPACE BETWEEN: 25 mm (1 in)
 <p>HIGH-FORCE PUSH-PULL FOR TWO-POSITION MECHANICAL SYSTEM ONLY.</p>	W, MIN WIDTH 100 mm (4 in)	D, DEPTH: 16 - 18 mm (5/8 - 1 1/2 in)	C, MIN CLEARANCE: 36 mm (1 1/2 in) Add 38 mm (1 1/4 in) for gloved hand	MINIMUM: 25 mm (1 in) PREFERRED: 50 mm (2 in)	
 <p>SAME AS ABOVE. PREFERRED WHERE POSSIBLE GARMENT OR CABLE-SNAG POSSIBILITY EXISTS.</p> <p>NOTE: 1 & 2 FINGER PULLS ALSO ACCEPTABLE FOR LESS THAN 18 N (4 lb) APPLICATIONS.</p> 	W, MIN WIDTH 100 mm (4 in) Add 25 mm (1 in) for gloved hand	D, DEPTH 16 - 38 mm (5/8 - 1 1/2 in)	C, MIN CLEARANCE: 32 mm (1 1/2 in)	MINIMUM: 25 mm (1 in) PREFERRED: 50 mm (2 in)	S, MIN SPACE BETWEEN: 13 mm (1/2 in)

FIG. 46 Push-Pull Controls

accuracy, isometric joysticks shall be selected over displacement joysticks. Isometric joysticks may also be used for various display functions such as data pickoff from a CRT. In rate control applications, which may allow the follower (cursor or tracking symbol) to transit beyond the edge of the display, indicators shall be provided to aid the operator in bringing the follower back onto the display.

26.2.4.1 Hand Operated:

(a) Specific Use—In addition to the general use, hand-operated isometric joysticks may be used as vehicle controllers and aiming sensors. Hand-operated isometric joysticks may be used as mounting platforms for secondary controls, such as thumb- and finger-operated switches. Operation of secondary controls has greater induced error on the isometric hand grip than does displacement handgrip joysticks.

(b) Dynamic Characteristics—Maximum force for full output shall not exceed 118 N (26.7 lbs).

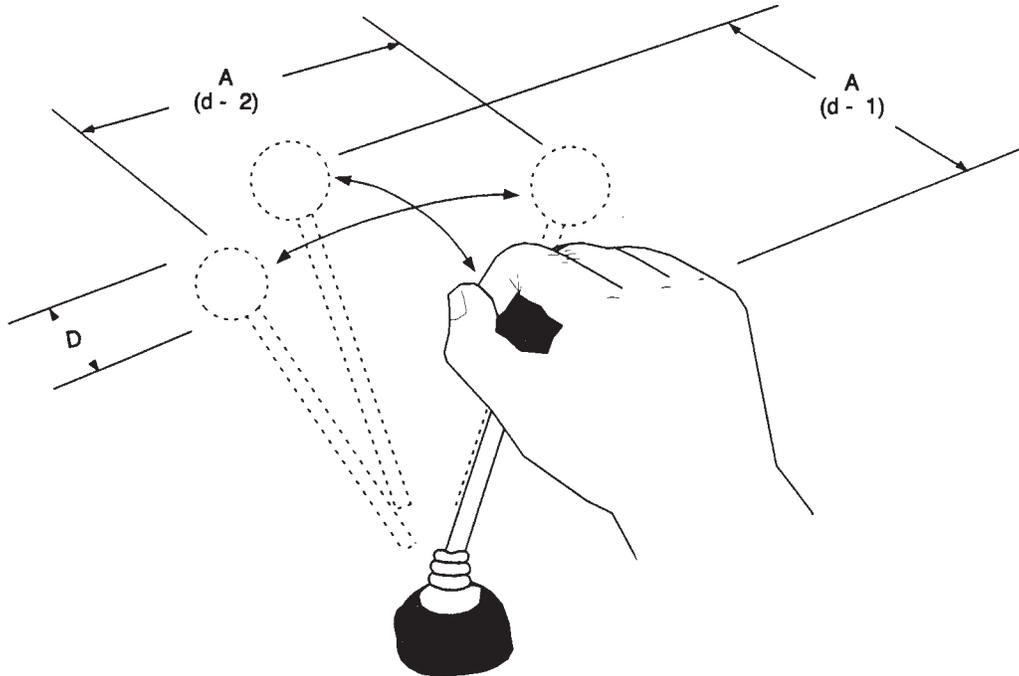
(c) Dimensions, Resistance, and Clearance—The hand grip length shall be in the range of 110 to 180 mm (4.3 to 7.1 in.). The grip diameter shall not exceed 50 mm (2 in.). Clearances

of 100 mm (4 in.) to the side and 50 mm (2 in.) to the rear shall be provided to allow for hand movement. Joysticks shall be mounted to provide forearm support. Modular devices shall be mounted to allow actuation of the joystick without slippage, movement, or tilting of the mounting base.

26.2.4.2 Finger-Operated Displacement Joysticks:

(a) Specific Use—In addition to the general uses, finger-operated displacement joysticks are useful for free-drawn graphics. In this application, there is usually no spring return to center, and the resistance shall be sufficient to maintain the handle position when the hand is removed.

(b) Dynamic Characteristics—Movement shall not exceed 785 mrad (45°) from the center position. Movement shall be smooth in all directions, and positioning of a follower shall be attainable without noticeable backlash, cross-coupling, or need for multiple corrective movements. Control ratios, friction, and inertia shall meet the dual requirements of rapid gross positioning and precise fine positioning. Recessed mounting or pencil attachments may be used to provide more precise control. When used for generation of free-drawn graphics, the



	DIAMETER		RESISTANCE			
	D		(d-1)		(d-2)	
	Finger Grasp	Hand Grasp	One Hand	Two Hands	One Hand	Two Hands
Maximum	13 mm (1/2 in)	38 mm (1 1/2 in)	9 N (2 lb)	9 N (2 lb)	9 N (2 lb)	9 N (2 lb)
Minimum	38 mm (1 1/2 in)	75 mm (3 in)	135 N (30 lb)	220 N (50 lb)	90 N (20 lb)	135 N (30 lb)
	DISPLACEMENT		SEPARATION			
	A		One Hand Random		Two Hands Simultaneously	
	Forward (d-1)	Lateral (d-2)				
Minimum	—	—	50 mm (2 in)		55 mm (3 in)	
Preferred			100 mm (4 in)		125 mm (5 in)	
Maximum	380 mm (14 in)	970 mm (38 in)				

FIG. 47 Lever

refresher rate for the follower on the CRT shall be sufficiently high to give the appearance of a continuous track. Delay between control movement and the confirming display response shall be minimized and shall not exceed 0.1 s.

(c) Dimensions, Resistance, and Clearance—The joystick shall be mounted on a desk or shelf surface as shown in Fig. 49. Joysticks shall be mounted to provide forearm or wrist support. Modular devices shall be mounted to allow actuation of the joystick without slippage, movement, or tilting of the mounting base.

26.2.4.3 Thumbtip/Fingertip-Operated:

(a) Specific Use—Thumbtip/fingertip-operated joysticks may be mounted on a handgrip, which serves as a steady rest to damp vibrations or increase precision. If so mounted, the handgrip shall not simultaneously function as a joystick controller.

(b) Dynamic Characteristics:

(c) Dimensions, Resistance, and Clearance—Joysticks shall be mounted to provide wrist or hand support. Console mounted devices shall be mounted as shown in Fig. 49. Modular devices shall be mounted to allow actuation of the joystick without slippage, movement, or tilting of the mounting base.



	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	<p>SLIDE-LEVERS MAY BE USED FOR LOW-FORCE, CONTINUOUS ADJUSTMENT OR GROSS MODE SELECTION (DO NOT USE FOR PRECISE-SETTING).</p> <p>HANDLES SHOULD BE "TAB-SHAPED, WITH LONG DIMENSION PERPENDICULAR TO MOTION AXIS (e.g., TO SERVE AS A POINTER)</p> <p>MOVEMENT AXIS MAY BE UP-DOWN, LATERAL OR FORE-AFT. FUNCTIONAL INCREASE SHALL BE:</p> <ul style="list-style-type: none"> • UP • RIGHT • FORWARD <p>BANKED, SLIDE-LEVER ASSEMBLIES MAY BE USED FOR ELECTRICALLY AND OR MECHANICALLY-CONNECTED SELECTORS OR ADJUSTMENT FUNCTIONS, TO PROVIDE RAPID VISUAL CHECK OF RELATED SETTINGS.</p> <p>NOTE: RESISTANCE FOR ABOVE CONTROL TYPES SHOULD BE:</p> <p>MIN - 2.8 N (10 oz) MAX - 110 N (398 oz)</p> <p>THROTTLE LEVERS: HANDGRIP MAY BE EITHER CYLINDRICAL OR SPHERICAL</p> <p>MULTI-ENGINE THROTTLE ASSY: NOTE: WHEN THRUST REVERSE IS INCORPORATED, THE DESIGN SHALL REQUIRE A SEPARATE MANIPULATIVE MOTION, I.e., "LIFT" + AFT LEVER MOVEMENT.</p>	<p>D - MIN = 13 mm (1/2 in) or WITH GLOVES 19 mm (3/4 in)</p>	<p>W - MIN = 6.5 mm (1/4 in)</p>	<p>H - MIN = 16 mm (5/8 in)</p>		<p>S - MIN = 19 mm (3/4 in) or WITH GLOVES 25 mm (1 in)</p>
	<p>SAME AS ABOVE</p>	<p>SAME AS ABOVE</p>	<p>SAME AS ABOVE</p>		<p>SAME AS ABOVE</p>	
	<p>D - MIN = 19 (3/4 in) MAX = 28 mm (1 1/8 in)</p> <p>D - MIN = 25 mm (1 1/4)</p>	<p>L - MIN = 65 mm (1/4 in)</p>			<p>MIN FINGER CLEARANCE ALL SIDES - 50 mm (2 in)</p>	
						<p>S - TYPICAL = 100 mm (4 in) NOT TO EXCEED 125 mm (5 in)</p>

FIG. 48 Slide Levers

26.3 Ball Control (Also Known as Track Ball, Ball Tracker, Joyball, and Rolling Ball):

26.3.1 *Use*—A ball control suspended on low-friction bearings may be used for various control functions such as data pickoff on a display. The ball control cannot provide an automatic return to point of origin, hence if used in applications requiring automatic return to origin following an entry or readout, the interfacing system must provide this. Because the ball can be rotated within limit in any direction, it is well suited for applications in which there may be accumulative travel in a given direction. In any application that would allow the ball to drive the follower on the display off the edge of the display, indicators shall be provided to advise the operator how to bring the follower back onto the display. Ball controls shall be used only as position controls (that is, a given movement of a ball makes a proportional movement of the follower on the display).

26.3.2 *Dynamic Characteristics*—The ball control shall be capable of rotation in any direction so as to generate any combination of x and y output values. When moved in either the x or y directions alone, there shall be no apparent cross

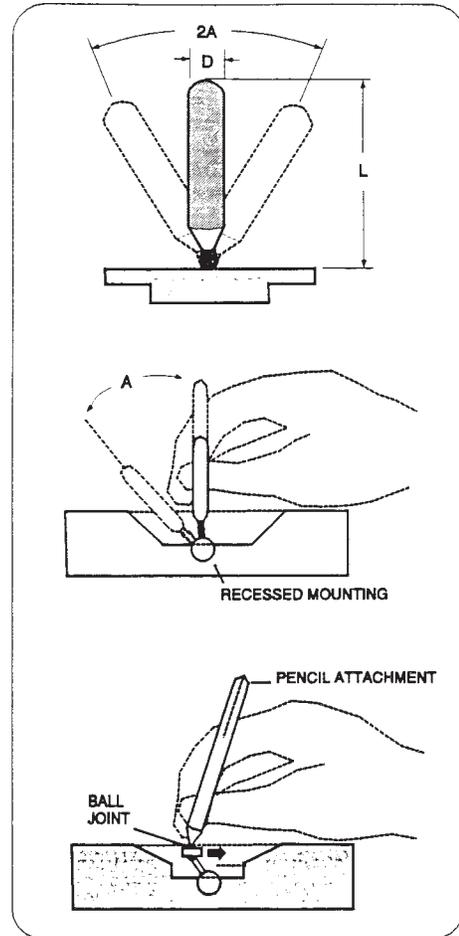
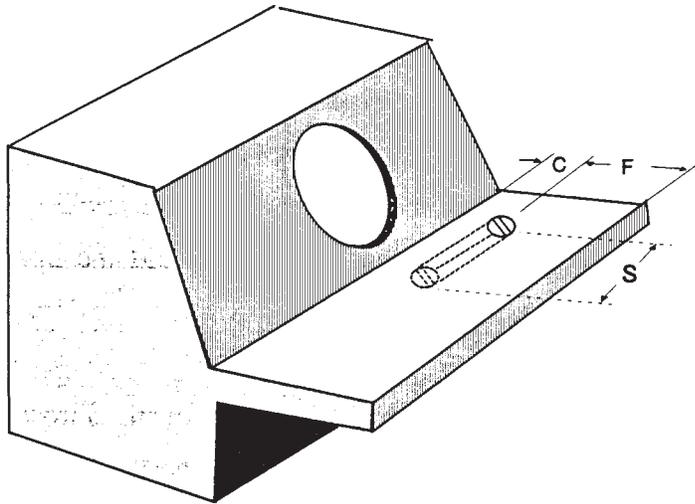
coupling (follower movement in the orthogonal direction). While manipulating the control, neither backlash nor cross coupling shall be apparent to the operator. Control ratios and dynamic features shall meet the dual requirement of rapid gross positioning and smooth, precise fine positioning.

26.3.3 *Limb Support*—When trackball controls are used to make precise or continuous adjustments, wrist support or arm support or both shall be provided.

26.3.4 *Dimensions, Resistance, and Clearance*—Dimensions, resistance, and clearances shall conform to the criteria in Fig. 50. The smaller diameter ball controls shall be used only where space availability is very limited and when there is no need for precision. Preferred mounting is on a shelf or desk top.

26.4 *Grid-and-Stylus Devices*—These provisions cover various techniques that use some means of establishing an x and y grid and a stylus for designating specific points on that grid for control purposes (time-shared x and y potential grids and a voltage-sensitive stylus).

26.4.1 *Application*—Grid and stylus devices may be used for data pickoff from a CRT, entry of points on a display,



	DIMENSIONS		RESISTANCE	DISPLACEMENT	CLEARANCE		
	D DIAM	L LENGTH			S DISPLAY CENTERLINE TO STICK CENTERLINE	C AROUND STICK	F STICK TO SHELF FRONT
	A ANGLE						
MINIMUM	6.5 mm (1/4 in)	75 mm (3 in)	3.3 N (12 oz)		0	*	120 mm (4 3/4 in)
MAXIMUM	16 mm (5/8 in)	150 mm (6 in)	8.9 N (32 oz)	$\frac{\pi}{4}$ rad (45°)	400 mm (15 3/4 in)		250 mm (9 7/8 in)

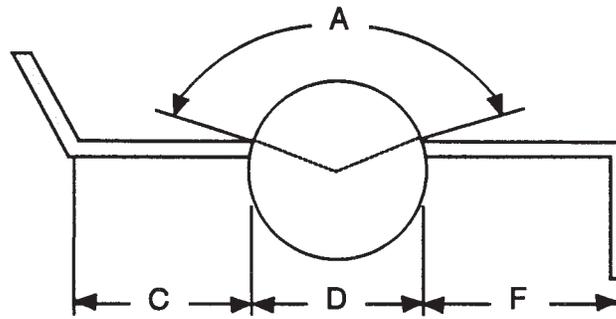
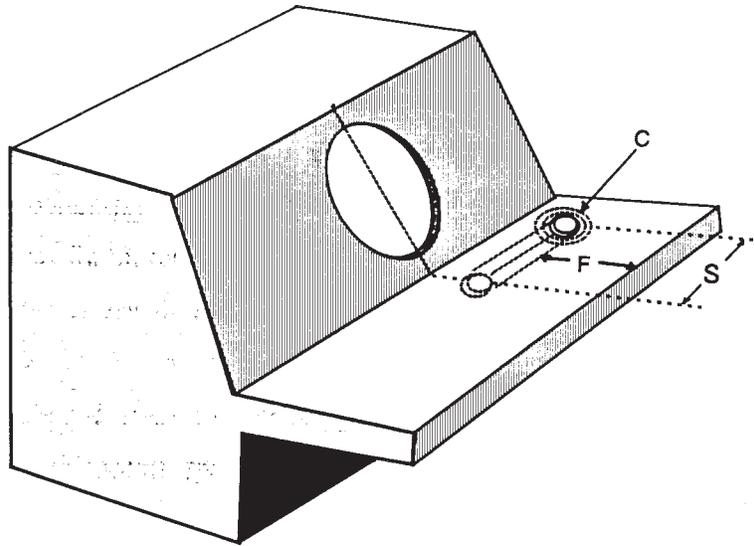
FIG. 49 Isotonic Joysticks

generation of free-drawn graphics, and smaller control applications. The grid may be on a transparent medium allowing stylus placement directly over corresponding points on the display or it may be displaced from the display in a convenient position for stylus manipulation. In either case, a follower (bug, mark, hook, and so forth) shall be presented on the display at the coordinate values selected by the stylus. Devices of this type shall be used only for zero order control functions (that is, displacement of the stylus from the reference position causes a proportional displacement of the follower).

26.4.2 *Dynamic Characteristics*—Movement of the stylus in any direction on the grid surface shall result in smooth

movement of the follower in the same direction. Discrete placement of the stylus at any point on the grid shall cause the follower to appear at the corresponding coordinates and to remain steady in position so long as the stylus is not moved. Refresh rate for the follower shall be sufficiently high to ensure the appearance of a continuous track whenever the stylus is used for generation of free-drawn graphics.

26.4.3 *Dimensions and Mounting*—Transparent grids that are used as display overlays shall conform to the size of the display. Grids that are displaced from the display shall approximate the display size and shall be mounted below the display in an orientation to preserve directional relationships to the



	DIMENSIONS		RESISTANCE		CLEARANCE		
	D DIAM	A SURFACE EXPOSURE	PRECISION REQUIRED	VIBRATION OR ACCEL CONDITIONS	S DISPLAY CENTERLINE TO BALL CENTERLINE	C AROUND BALL	F FALL TO SHELF FRONT
MINIMUM	50 mm (2 in)	1745 mrad (100°)			0	50mm (2 in)	120 mm (4 3/4 in)
MAXIMUM	150 mm (6 in)	2445 mrad (140°)	1.0 N (3.6 oz)	1.7 N (6 oz)	320 mm (12 5/8 in)		250 mm (9 3/4 in)
PREFERRED	100 mm (4 in)	2095 mrad (120°)	0.3 N (1.1 oz)				

FIG. 50 Ball Controls

maximum extent (a vertical plane passing through the north/south axis on the grid shall pass through or be parallel to the north/south axis on the display).

26.5 Free-Moving X-Y Controller (Mouse):

26.5.1 Application—This type of controller may be used on any flat surface to generate x and y coordinate values that control the position of the follower on the associated display. It may be used for data pickoff or for entry of coordinate values.

It shall be used for zero order control only (generation of x and y outputs by the controller results in proportional displacement of the follower). It shall not be used for generation of free-drawn graphics.

26.5.2 Dynamic Characteristics—The design of the controller and placement of the maneuvering surface shall be such as to allow the operator to consistently orient the controller to within ± 175 mrad (10°) of the correct orientation without

visual reference to the controller. (That is, for example, when the operator grasps the controller in what seems to be the correct orientation and moves it rectilinearly along what is assumed to be straight up the *y* axis, then the direction of movement of the follower on the CRT shall be between 175 and 6110 mrad (10 and 350°.) The controller shall be easily movable in any direction without a change of hand grasp and shall result in smooth movement of the follower in the same direction ± 175 mrad (10°). The controller shall be cordless and shall be operable with either the left or right hand. A complete excursion of the controller from side to side of the maneuvering area shall move the follower from side to side on the display regardless of scale setting or offset unless expanded movement is selected for an automatic sequencing mode of operation. In any application that would allow the controller to drive the follower off the edge of the display, indicators shall be provided to assist the operator in bringing the follower back onto the display.

26.5.3 Dimensions and Shape—The free-moving *x-y* controller shall have no sharp edges but shall be shaped roughly as a rectangular solid, with limiting dimensions as given in Table 18.

26.6 Light Pen:

26.6.1 Use—A simple light pen may be used as a track-oriented readout device. That is, it may be positioned on the display screen to detect the presence of a computer-generated track by sensing its refresh pattern; the display system will then present a follower (hook) on the designed track. With suitable additional circuitry, a follower can be made to track the movement of the light pen across the surface, thus allowing it to function as a two-axis controller capable of serving the same purposes as the grid and stylus devices (see 26.4, Grid and Stylus Devices).

26.6.2 Dynamic Characteristics—When used as a two-axis controller, light pen dynamic characteristics shall conform to 26.5.2.

26.6.3 Dimensions and Mounting—The light pen shall be 120 to 180 mm (4.7 to 7.1 in.) long with a diameter of 7 to 20 mm (0.3 to 0.8 in.). A convenient clip shall be provided at the lower right side of the CRT to hold the light pen when it is not in use.

26.7 High-Force Controls:

26.7.1 Use—In general, controls requiring operator forces exceeding the strength limits of the lowest segment of the expected user population shall not be used. In addition, high-force controls shall not be used except when the operator’s nominal working position provides proper body support

or limb support or both, such as, seat backrests, foot supports. Sustained (durations longer than 3 s) high-force requirements shall be avoided.

26.7.2 Arm-, Hand-, and Thumb-Finger Controls—Where arm-, hand-, and thumb-finger controls requiring high-control forces are to be used, the maximum force requirements shall not exceed those specified in Table 19 and Table 20, which shall be corrected, where applicable, for females. (Two thirds of each value shown is considered to be a reasonable adjustment.)

26.7.3 Foot Controls—Where foot controls requiring high-control forces are to be used, the force push exerted by the leg depends on the thigh angle and knee angle. Fig. 21 specifies the mean maximum push at various knee and thigh angles. The maximum push is about the 160° angle, referred to as the limiting angle. The values of Fig. 21 apply to males only and shall be corrected for females. (Two thirds of each value is considered to be a reasonable adjustment.)

26.8 Touch-Screen Controls for Displays:

26.8.1 Use—Touch-screen control may be used to provide an overlaying control function to a data display device such as CRTs, dot matrix/segmented plays, electroluminescent displays, programmable indicators, or other display devices in which direct visual reference access and optimum direct control access are desired.

26.8.2 Luminance Transmission—When used, touch-screen displays shall have sufficient luminance transmission to allow the display with touch screen installed to be clearly readable in the intended environment and meet the display luminance requirements herein.

26.8.3 Positive Indication—A positive indication of touch-screen activation shall be provided to acknowledge the system response to the control action.

26.8.4 Dimensions and Separation—The dimensions and separation of responsible areas of the touch screen shall conform to S1, S2, and Bw of Fig. 43.

26.8.5 Pressure—The actuation pressure of the touch screen shall conform to the alphanumeric resistance limits of Table 15.

26.8.6 Resistance—Force required to operate force-actuated touch screens shall conform to the alphanumeric resistance limits of Table 15.

26.9 Miniature Controls:

26.9.1 Use—Miniature controls may be used only when severe space limitations exist. Miniature controls shall not be used when available space is adequate for standard-sized controls or when heavy gloves or mittens will be worn.

26.9.2 Dimensions, Resistance, Displacement, and Separation—When design constraints dictate the use of miniature controls, the dimensions and separation of the controls shall be the maximum permitted by the available space up to the maxima prescribed herein for standard-sized controls. Resistance and displacement of miniature controls shall conform to the criteria specified for the standard size of that type of control.

TABLE 18 Limiting Dimensions for Free-Moving X-Y Controller

Dimension	Minimum		Maximum	
	mm	(in.)	mm	(in.)
Width (spanned by thumb to finger grasp)	40	(1.6)	70	(2.8)
Length	70	(2.8)	120	(4.7)
Thickness	25	(1.0)	40	(1.6)

TABLE 19 Arm Strength

Elbow Flexion rad (°)	N (lb) (Fifth Percentile Male Data)											
	Pull		Push		Up		Down		In		Out	
	L	R	L	R	L	R	L	R	L	R	L	R
3.14 (180)	222 (50)	231 (52)	187 (42)	222 (50)	40 (9)	62 (14)	58 (13)	76 (17)	58 (13)	89 (20)	36 (8)	62 (14)
2.18 (150)	187 (42)	258 (58)	133 (30)	187 (42)	67 (15)	80 (18)	89 (20)	67 (15)	89 (20)	36 (8)	67 (15)	67 (15)
2.09 (120)	151 (34)	187 (42)	116 (26)	160 (36)	76 (17)	107 (24)	93 (21)	116 (26)	89 (20)	98 (22)	44 (10)	67 (15)
1.57 (90)	142 (32)	165 (37)	98 (22)	160 (36)	76 (17)	89 (20)	93 (21)	116 (26)	71 (16)	80 (18)	44 (10)	71 (16)
1.05 (60)	116 (26)	107 (24)	98 (22)	151 (34)	67 (15)	89 (20)	80 (18)	89 (20)	76 (17)	89 (20)	53 (12)	76 (17)

TABLE 20 Hand and Thumb-Finger Strength

	N (lb) (Fifth Percentile Male Data)			
	Hand Grip		Thumb-Finger Grip (Palmer)	Thumb-Finger Grips (Tips)
	L	R		
πMomentary Hold	249.1 (56)	222.4 (50)	57.8 (13)	57.8 (13)
πSustained Hold	146.7 (33)	155.7 (35)	35.6 (8)	35.6 (8)

26.9.3 *Other Requirements*—Other design considerations (labeling, orientation, and so forth) shall conform to the requirements specified for the standard size of the control.

27. General Requirements for Labeling

27.1 *Application*—Labels shall be provided whenever it is necessary for personnel to identify equipment, follow procedures, or avoid hazards, except where it is obvious to the observer what an item is and how it may be used.

27.2 *Characteristics*—Label characteristics shall be consistent with such factors as:

- 27.2.1 Accuracy of identification required.
- 27.2.2 Time available for recognition or other responses.
- 27.2.3 Distance at which the labels must be read.
- 27.2.4 Illuminant level and color.
- 27.2.5 Criticality of the function labeled.
- 27.2.6 Consistency of label design within and between systems.

27.3 Types:

27.3.1 *Label*—The term label, when used alone, shall mean any type of plate, sign, placard, inscription, legend, marking, or combination of these, that is used for purposes of identification, or to impart information or instructions to the reader. This term is used generically herein to describe all the specific types of labels described below.

27.3.2 *Identification Label*—An identification label is a specific type of label used for identification purposes only. Identification labels are used to identify such things as spaces, locations, equipment, systems, controls and displays, classifications (for example, damage control and closure), and so forth.

27.3.3 *Hazard Label*—The term hazard plate is used to describe a specific category of labels that are used to identify and provide information about existing or potential situations that may be hazardous to ship personnel or equipment. There are only two required types of hazard labels: the danger label, and the caution label. For U.S. Navy ships, a third type is required, warning labels. The difference between a danger label, warning label, and a caution label is the degree of seriousness of the potential hazard, as defined below.

27.3.3.1 *Danger Label*—A danger label is a type of hazard label and is used to identify and provide information about a situation in which an action or omission of one on the part of the crew member could result in serious injury or death, serious damage to vital equipment, or a major reduction in the ship's capability to perform its mission.

27.3.3.2 *Warning Label*—A warning label is used to indicate a location, equipment, or system in which a potential hazard exists, capable of producing injury or death to personnel, if approved procedures are not followed.

27.3.3.3 *Caution Label*—A caution label is a type of hazard label and is used to identify and provide information about a situation in which an action or omission of one on the part of the crew member could result in a minor injury, minor damage to equipment, or a minor reduction in the ship's capability to perform its mission.

27.3.4 *Instruction Label*—An instruction label is a specific type of label used to present step-by-step instructions for accomplishing a specific task (operation or maintenance related) and to provide hazard and safety information related to performing the task.

27.3.5 *Information Label*—An information label is a specific type of label used to present nonprocedural, information of a general nature, related to health, first aid, sanitation, rules, housekeeping, general conduct, and so forth.

28. Label Content

28.1 Abbreviations:

28.1.1 *Criteria for Use*—Abbreviating a word or word group shall be used only if one of two conditions exists:

28.1.1.1 There is insufficient space available at the location where the label is to be affixed for the design of a label that would allow the entire inscription to be spelled out.

28.1.1.2 The abbreviation is more commonly known and understood by the user population than the spelled out word or word group.

28.1.2 *Criteria for Development*—If the need for an abbreviation has been justified, and a standard abbreviation does not exist in MIL-STD-12, nor does a standard abbreviation exist that is commonly understood and recognized by the intended user population, then, the following rules shall be applied to develop the abbreviation.

28.1.3 *Case*—Capital letters shall be used for abbreviations.

28.1.4 *Single Words*—When abbreviating single words:

28.1.4.1 Determine the number of characters required in the abbreviated term.

28.1.4.2 The same abbreviation shall be used for all tenses and for both singular and plural forms of a word. Remove

suffixes such as -ed, -es, -er, and -ing from the word to be abbreviated. (Make sure they are suffixes, as in “waxing,” and not an integral part of the word, as in “spring.”)

28.1.4.3 Choose the first letter and last consonant of the word to be abbreviated as the first and last letter of the abbreviation. For example, Multiplexor would be M--R.

28.1.4.4 Fill the remaining spaces with the consonants in the order in which they appear in the word. Avoid the use of a double consonants in the abbreviation. For example, a five-character abbreviation for Multiplexor would be MLTPR, a four-character abbreviation would be MLTR, and a three-character abbreviation would be MLR.

28.1.4.5 If there are insufficient consonants, use the first vowel in the order in which it appears in the word. For example, an eight-character abbreviation for Multiplexor would be MULTPLXR.

28.1.5 *Two-Word Groups*—When abbreviating two-word groups:

28.1.5.1 Determine the number of characters required in the abbreviated term.

28.1.5.2 Take half of the characters from the first word and the other half from the second word, using the above abbreviation methodology for single words. If an odd number of total characters is needed, take the odd character from the longer word. For example, a five-character abbreviation for Area Multiplexor would be AR MLR.

28.1.6 *Three or More Word Groups*—When abbreviating groups of three or more words, form an acronym by using the first letter of each word. For example, Aqueous Film Forming Foam would be abbreviated AFFF.

28.1.7 *Standardization*—Abbreviations shall be standardized and used consistently on the labels. All abbreviations which are not found in MIL-STD-12 shall be approved by the procuring activity before being used.

28.1.8 *Punctuation*—Periods or other punctuation shall not be used after abbreviations.

28.2 *Brevity*—Labels shall be as concise as possible without distorting the intended meaning or information and shall not be ambiguous. The amount of information provided shall be only that required to convey a clear message to the intended user; however, brevity shall not be stressed if the results will be unfamiliar to the user. Excessive detail, redundant words, phrases, and information shall be avoided.

28.3 *Familiarity*—Words and abbreviations shall be chosen on the basis of familiarity by the intended user population. For particular users (for example, maintenance technicians), common technical terms may be used even though they may be unfamiliar to crew members who are not expected to be part of the user population.

28.4 *Irrelevant Information*—Trade names, company logos, or other information not directly required by the user shall not appear on any labels, or be the subject of a label.

28.5 *Symbols*:

28.5.1 *Dependent Symbols*—Symbols that alone do not impart any specific information to the user (for example, %, +, -), but require the existence of supporting data to provide meaningful information (for example, 10 %, +5 psi, 3 lbs).

28.5.2 *Independent Symbols*—Symbols that alone provide information to the user and normally are associated with hazard or emergency situations. Examples of independent symbols suitable for shipboard use are shown in Fig. 51.

28.5.3 *Use*—Dependent symbols shall be used only when they have an accepted meaning to all intended users. Independent symbols may be integrated with any label that addresses the subject of the symbol (for example, a hazard label that identifies a potential shock hazard may contain the lightning bolt symbol). An independent symbol shall not be used alone to identify a hazardous situation; it shall always be accompanied by appropriate text as specified herein. An independent symbol may be used alone for nonhazardous identification purposes (for example, the first aid cross symbol may be used alone to identify a first aid kit).

28.6 *Format*:

28.6.1 *Consistent*—All labels of the same type shall be consistent in format and presentation of information.

28.6.2 *Heading*—Headings and subheadings shall be used to identify groups of related information. Headings and subheadings shall be of larger character size than the text of the label, with the major heading or label title the largest and subheadings of subsequently smaller size.

28.6.3 *Integrated Safety and Hazard*—Safety and hazard information that is integrated with other information (such as instructions) on labels other than hazard label shall be designed such that the safety and hazard information is clearly and distinctly different, visually, from the other information and is easily identified by the user.

28.7 *References*—References directing the user to other documents or sources of information shall not be made in a label if the referenced material is required to complete a task, recognize or avoid a hazardous situation, or clearly or completely understand the message of the label. References to other documents or sources of information may be used only to direct the user to supplemental information.

28.8 *Character/Background Color*:

28.8.1 *Background and Character Color*—Label background color shall contrast with the color of the surface to which it will be affixed. Any special background color shall be approved by the procuring activity before its use.

28.8.2 *Other Labels*—Where the ambient illuminance will be above 0.9 ft-c (10 lux), identification labels, instruction labels, information labels, and graphic labels (all labels other than hazard labels) shall be provided with black characters on a light background. Where dark adaptation lighting (low level

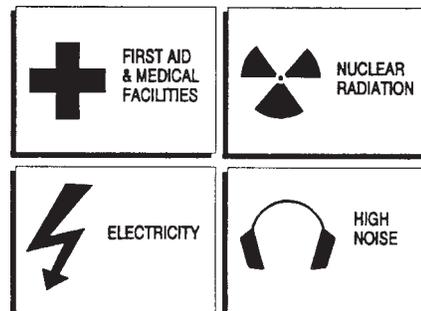


FIG. 51 Independent Symbols

white or red) is required, the displayed letters or numerals shall be visible without interfering with night vision requirements. Where possible, markings shall be white on a dark background.

28.9 *Reflection*—The use of glossy or highly reflective metallic materials for either the lettering or background shall be avoided.

28.10 *Characters and Numerals:*

28.10.1 *Style*—Characters shall be a simple block-type font, such as alternate gothic #2, news or trade gothic, or futura or spartan medium. All numerals shall be arabic.

28.10.2 *Capital and Lowercase*—All capital letters shall be used for identification labels, headings and subheadings, signal words such as danger, caution, attention, notice, legends, and short message labels. Capital and lowercase letters shall be used for extended sentence messages in which it is necessary to use punctuation.

28.10.3 *Letter Width*—The width of letters shall be 3/5 of the height, except for “M” and “W,” which shall be 4/5 of the height, and “I” which shall be one stroke wide.

28.10.4 *Numerical Width*—The width of numerals shall preferably be 3/5 of the height, except for the “4,” which shall be one stroke width wider, and the “1” which shall be one stroke wide.

28.10.5 *Wide Characters*—Where conditions indicate the use of wider characters, as on a curved surface, the basic height-to-width ratio may be increased to 1:1.

28.10.6 *Stroke Width Normal*—For black characters on a white (or light) background, the stroke width shall be 1/6 to 1/8 of the height.

28.10.7 *Stroke, Width, Dark Adaptation*—Where the dark adaptation is required or legibility at night is a critical factor, and white characters are specified on a black background, the stroke width of the characters shall be from 1/7 to 1/8 of the height (narrower than specified for normal daytime vision). The stroke width shall be the same for all letters and numerals of equal height.

28.10.8 *Stroke Width, Transilluminate Characters*—For transilluminate characters, the stroke width shall be 1/10 of the height.

28.10.9 *Character Spacing*—The minimum space between characters shall be one stroke width.

28.10.10 *Word Spacing*—Separation between words shall be the width of three characters ($\pm 1/2$ width). The minimum space between words shall be the width of one character.

28.10.11 *Line Spacing*—The minimum space between lines shall be 1/2-character height, but in no case shall the separation between the tallest character on a lower line be less than one stroke width from a character above that projects below the line.

28.10.12 *Character Height and Viewing Distance*—For general and panel design, with the luminance normally above 3.5 cd/m² (1 ft-L), for labels of all types, minimum character height shall conform to the following values for various expected viewing distances:

Viewing distance mm (in.)	Minimum height mm (in.)[pt]
Less than 500 (19.7)	2.3 (0.09) [6]
500–1000 (19.7–39.4)	4.7 (0.18) [12]
1000–2000 (39.4–78.7)	9.4 (0.37) [26]

2000–4000 (78.7–157.5)
4000–8000 (157.4–315.5)

19 (0.75) [54]
38 (1.50) [108]

28.10.13 *Letter and Numbers to Avoid*—Avoid using the number “1” in combination with letter “L” or “I” and the number zero together with the letters “O” or “Q.”

28.11 *Graphics:*

28.11.1 *Lines*—The minimum stroke width for lines shall be equal to the minimum stroke width for characters.

28.11.2 *Location*—Label location throughout the ship shall be as consistent and uniform from space to space, system to system, as possible.

28.11.3 *Label Groups*—Placement of several (more than three) labels in a group shall be avoided. However, if more than one label is required to be mounted in the same location, the labels shall be grouped by label type and organized as follows:

28.11.3.1 *Hazard labels* shall be grouped together and be mounted in the most prominent location.

28.11.3.2 *Instruction labels* shall be mounted in the next most prominent location.

28.11.3.3 *Information labels* and graphic plates shall be mounted in the next most prominent location.

28.11.3.4 *Graphic labels* that are referenced by other types of labels shall be mounted adjacent to the referencing label.

28.11.3.5 *Identification labels* shall be mounted to ensure maximum visibility and shall be placed on or immediately adjacent to the items they identify. Mounting labels on bulkheads or other ship structures for identification of valves, machinery, or other equipment shall be avoided.

28.11.4 *Preinstalled Labels*—Items that have labels installed before the item is located in the ship shall be placed so the labels are visible and legible after the item is in place.

28.11.5 *Visibility and Legibility*—Labels shall be designed for easy and accurate reading based on the anticipated reader’s viewpoint and reading distance, ship vibration, ship motion, and ambient illumination levels. Labels shall not be covered or obscured by other equipment.

28.11.6 *Label Surface*—Labels shall be placed on flat surfaces. If a label must be located on a curved surface, it must be completely visible to the observer. If the curvature is such that the characters become too small to read, another mode of labeling shall be used (for example, on attached tag).

28.11.7 *Label Life*—Labels shall be constructed and mounted so as to remain legible for the lifetime of the label.

29. Specific Requirements by Label Type

29.1 *Identification Label*—There are no specific requirements for the use and format of identification label. Identification labels shall comply with all requirements for labels in general, as specified herein.

29.2 *Hazard Labels:*

29.2.1 *Criteria for Use*—Depending on the severity of the potential hazard, an appropriate danger or caution label shall be provided wherever it is necessary to minimize the possibility of injury to personnel, damage to equipment or systems or where special precautions must be exercised. Examples of the need for danger or caution labels include the following:

29.2.1.1 Fixed physical obstructions,

29.2.1.2 Moving or rotating equipment,



29.2.1.3 Equipment contact hazards (high voltage, high or low temperature, and so forth),

29.2.1.4 Radiation hazards (electromagnetic or nuclear),

29.2.1.5 Laser beam,

29.2.1.6 Toxic fumes exposure or toxic chemical contact,

29.2.1.7 Flash or high intensity light (welders, strobe lights), and

29.2.1.8 Requirements for safety equipment or clothing.

29.2.2 *Danger/Warning/Caution Selection Criteria*—Selection of a danger, warning, or caution label shall be based on the descriptions given in Section 27.

29.2.3 *Format*:

29.2.3.1 *General*—Hazard labels shall be designed with an upper and lower component. The upper component shall contain the appropriate signal word, (DANGER, WARNING or CAUTION) and the lower component shall contain the necessary hazard inscription, as specified herein.

29.2.3.2 *Signal Word*—Danger labels shall contain only the signal word DANGER in the upper part of the label. Warning or caution labels shall contain only the signal word WARNING or CAUTION in the upper part of the label.

29.2.4 *Inscription*—All hazard labels shall contain, in the lower component, the following pieces of information presented in the order in which they are described below;

29.2.4.1 A brief statement of the hazard. If more than a single hazard is being identified, they shall be provided in a list rather than in paragraph format.

29.2.4.2 A brief statement instructing the reader how to avoid the stated hazard(s). If more than a single instruction is required, they shall be provided in step-by-step format rather than in paragraph format.

29.2.4.3 A brief statement of the potential consequences if the instructions for avoiding the hazard are not followed. If more than a single consequence is likely, they shall be provided in a list rather than paragraph format.

29.2.5 *Lettering*—The signal word shall be at least 50 % larger than the inscription text.

29.3 *Character/Background Color*:

29.3.1 *General*—Hazards labels shall be designed with an upper and lower component. The upper component shall contain the appropriate signal word (DANGER, WARNING, or CAUTION), and the lower component shall contain the necessary hazard inscription. See ANSI Z535.2 for label formats.

29.3.1.1 The signal word DANGER shall be in white letters on a red oval background with a white border on a black rectangular field. The inscription text shall be black characters on a white background.

29.3.1.2 The signal word DANGER and the text inscription shall be in white characters on a red background.

29.3.2 *Warning or Caution Labels*—Warning or caution labels shall comply with one of the two following character/background color schemes:

29.3.2.1 The signal word WARNING or CAUTION shall be yellow characters on a black rectangular background. The inscription text shall be black characters on a yellow background.

29.3.2.2 The signal word WARNING shall be black characters within a yellow truncated diamond on a black rectangular background. The inscription shall be black letters on a yellow background.

29.3.3 *CAUTION Labels*—The signal word CAUTION shall be yellow characters on a black rectangular background. The inscription shall be black letters on a yellow background.

29.4 *Instruction Labels*—An instruction label shall only be provided when:

29.4.1 It is likely that an item of equipment or system will be operated or maintained by personnel not trained for the task and the item of equipment or system is critical to the survivability or mission of the ship.

29.4.2 An item of equipment is authorized for use by all ship personnel and little or no training in its operation is provided.

29.4.3 The operation or maintenance of an item of equipment or system is lengthy and complex and it is likely that the task will have to be performed without the benefit of standard operating or maintenance procedure manuals or documents.

29.4.4 *Format*:

29.4.4.1 *Title*—All instruction labels shall be titled at the top of the label. The title shall identify the instructions as operating or maintenance, or both, and shall identify the equipment or system being addressed.

29.4.4.2 *Hazard and Safety*—Hazard and safety information that pertains to the task in general shall be provided on the label preceding the instructions. This information shall be labeled with a heading that identifies it as general hazard and safety information. Each statement identifying a potential hazard shall begin with the appropriate signal word DANGER, WARNING, or CAUTION.

29.4.4.3 *Inscription*—Instructions for completing the task shall be provided in numbered step-by-step format. Each step shall be stated as briefly and generically as possible. The instructions shall avoid the use of specific equipment model names or numbers or other aspects of the equipment or system that may change at some future time. Hazard and safety information that pertains to a particular step or steps in the procedure shall be provided immediately preceding the step or steps in the instructions. Each statement identifying a potential hazard shall begin with the appropriate signal word DANGER, WARNING, or CAUTION. Instructions shall be provided on a separate label from diagrams, schematics, charts, or other types of graphic labels, which may be referenced in the instructions. If operating instructions and maintenance instructions are provided on the same label, the operating instructions shall appear first, and the two groups of information shall be labeled with appropriate headings.

29.4.4.4 *Lettering*—The label title shall be at least 50 % larger than headings. Headings shall be at least 25 % larger than the inscription text.

29.5 *Information Labels*:

29.5.1 *Criteria for Use*—An information label shall only be provided when the information presented the reader will significantly contribute to the general safety, health, or readiness of the ship. Information labels shall not be used in place

of hazard labels to identify potential hazards or in place of instruction labels to identify procedures for performing a task.

29.5.2 Format:

29.5.2.1 General—Information labels shall be designed with an upper and lower component. The upper component shall contain an appropriate signal word, and the lower portion shall contain the necessary information inscription, as specified below.

29.5.2.2 Signal Word—Information labels shall contain the signal word ATTENTION in the upper panel.

29.5.2.3 Inscription—The inscription may be presented in paragraph format; however, if the information or a portion of it is a list, that information shall be presented in a list format. Excessive amounts of detail shall be avoided. Headings shall be used, as appropriate, to organize and identify related information.

29.5.2.4 Lettering—The signal word shall be at least 50 % larger than headings. Headings shall be at least 25 % larger than the inscription text.

29.6 Graphic Labels:

29.6.1 Criteria for Use—A graphic label, which may take the form of a diagram, schematic, chart, and so forth, should be used only when such information is absolutely necessary or required.

29.6.2 Format:

29.6.2.1 Title—All graphic labels shall be titled at the top of the label. The title shall identify the equipment, system, or information being presented. If more than one schematic or diagram is presented on a single label, each shall be labeled with a heading.

29.6.2.2 Schematics and Diagrams—All graphic symbols and special nomenclature used on a graphic label shall be defined in a legend. Descriptive text shall be as brief as possible and shall not obscure or congest the diagram or schematic. Information shall be provided on the label that indicates location and orientation of the equipment or system in the ship, as appropriate.

29.6.2.3 Charts—All charts of the same type, or used for the same purpose, such as lubrication charts, shall be of the same format, including the use of the same headings, units of measure, and organization and presentation of information.

29.6.2.4 Lettering—The label title shall be at least 50 % larger than headings. Headings shall be at least 25 % larger than the smallest text.

29.7 Control and Displays Labels:

29.7.1 General—Controls and displays shall be appropriately and clearly labeled with the basic information needed for proper identification, utilization, actuation, or manipulation of the element.

29.7.2 Simplicity—Control and display labels shall convey verbal meaning in the most direct manner, by using simple words and phrases.

29.7.3 Functional Labeling—Each control and display shall be labeled according to function, and the following criteria shall apply:

29.7.3.1 Similar names for different controls and displays shall be avoided.

29.7.3.2 Instruments shall be labeled in terms of what is being measured or controlled, taking into account the user and purpose.

29.7.3.3 Control labeling shall indicate the functional result or control movement (for example, increase, ON, OFF) and may include calibration data where applicable. Such information shall be visible during normal operation of the control.

29.7.3.4 When controls and displays must be used together (in certain adjustment tasks), appropriate labels shall indicate their functional relationship. The selection and use of terminology shall be consistent.

29.7.3.5 The units of measurement (volts, psi, inches, and so forth) shall be labeled on the panel.

29.7.4 Location—Label location throughout a system and within panel groupings shall be uniform. The following criteria shall apply to the location of control and display labels:

29.7.4.1 Ease of control operation shall be given priority over visibility of control position labels.

29.7.4.2 Labels shall normally be placed above the controls and displays they describe. When the panel is above eye level, labels may be located below if label visibility will be enhanced. Controls shall not obscure labels.

29.7.4.3 Labels shall be used to identify functionally grouped controls and displays. The labels shall be located above the functional groups they identify. When a line is used to enclose a function group and define its boundaries, the label shall be centered at the top of the group either in a break in the line or just below the line. When colored pads are used, the label shall be centered at the top within the pad area.

29.7.5 Character Size Versus Luminance—The height of letters and numerals shall be determined by the required reading distance and luminance. With a 28 in viewing distance, the height of numerals and letters shall be within the range of values, specified in points, provided in Table 21 for “low” and “high” control-display luminance conditions.

29.7.6 Size Graduation—Labels shall be graduated in size beginning with the smallest (control position labels) being determined by viewing conditions. Each increase in size shall be approximately 25 % larger. Guidelines for control-display label size gradations are shown in Fig. 52.

29.8 Units, Assemblies, Subassemblies, and Parts:

TABLE 21 Character Size Versus Luminance

Markings	Character Height ^A	
	Low Light (Below 1 ft-L), mm (in.) [pt]	Normal Light (Below 1 ft-L), mm (in.) [pt]
For critical markings, with positions variable (numerals on counters, settable or moving scales, and so forth)	5.5–8.6 (0.21–0.33) [14–22]	3.9–5.5 (0.15–0.21) [10–14]
For critical markings, with position fixed (numerals on fixed scales, controls, switch markings, emergency instructions, and so forth)	4.7–8.6 (0.18–0.33) [12–22]	3.1–5.5 (0.12–0.21) [8–14]
For noncritical markings (identification labels, routine instructions, markings required only for familiarization)	1.6–5.5 (0.07–0.21) [4–14]	1.6–5.5 (0.07–0.21) [4–14]

^AValues assume a 711-mm (28-in.) viewing distance. For Distance D, other than 28 in., multiply the character height by D/28 and round to the next higher point.

LABEL SPECIFICATIONS

Start with the smallest lettering size that will be compatible with the typical average viewing distance, establish specifications for each of the labeling categories illustrated by the accompanying sketch.

Typical Panel Labeling Standards

Label Designation	Letter Size	Location
1. Panel title	7.1 mm (.27 in) [18 pt]	Centered; 6.35 mm (1/4 in) from top edge of panel
2. Panel subsection	5.5 mm (.21 in) [14 pt]	Centered at top of subsection; 19.1 mm (3/4 in) from top edge of panel
3. Subtitle	4.7 mm (.18 in) [12 pt]	6.35 mm (1/4 in) above components or 13 mm (1/2 in) above labels of individual components
4. Toggle switch/Display Label	3.9 mm (.15 in) [10 pt]	6.35 mm (1/4 in) above and below standard switch
5. Single component	4.7 mm (.18 in) [12 pt]	6.35 mm (1/4 in) above component
6. Rotary switch positions	3.9 mm (.15 in) [10 pt]	6.35 mm (1/4 in) from apex of pointer, line from pointer to label

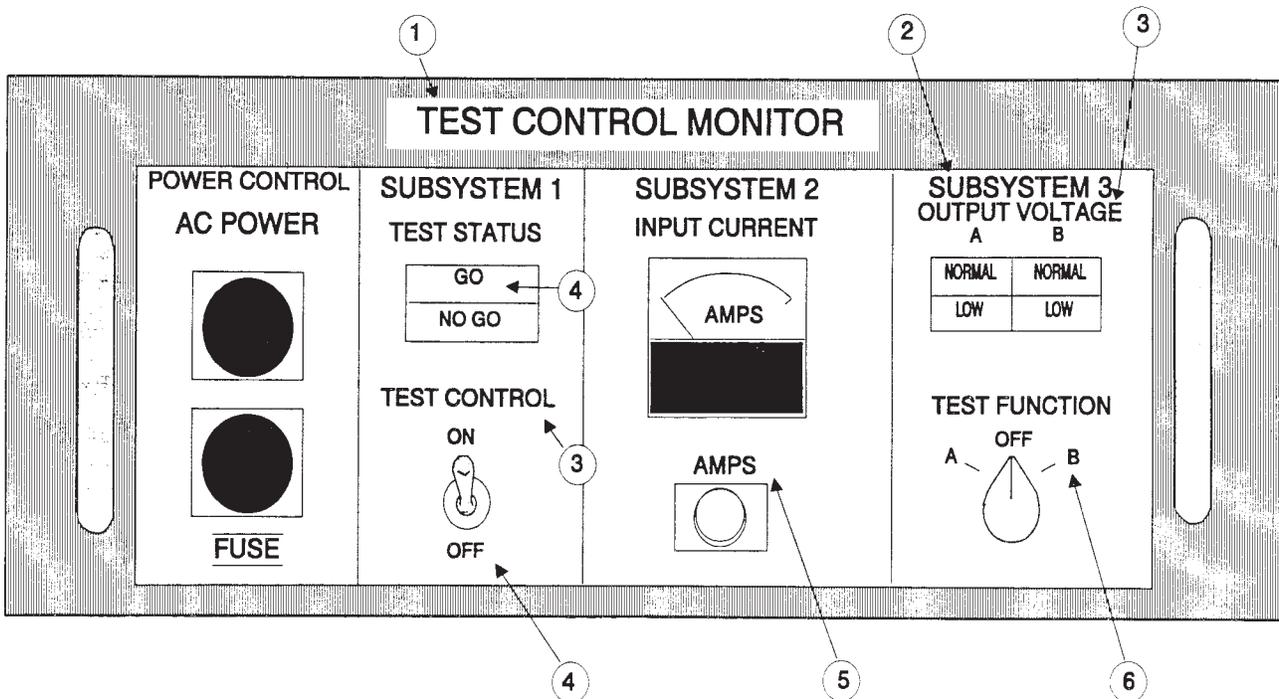


FIG. 52 Label Specifications

29.8.1 *General*—Each unit, assembly, subassembly, and part shall be labeled with a clearly visible, legible, and meaningful name, number, code, mark, or symbol as applicable.

29.8.2 *Simplicity*—Equipment shall be labeled with terms descriptive of the test or measurement applicable to their test points (for example, demodulator rather than crystal detector and power amplifier rather than bootstrap amplifier).



29.8.3 *Location*—The gross identifying label on a unit, assembly, or major subassembly shall be located:

29.8.3.1 Externally in such a position it is not obscured by adjacent items.

29.8.3.2 On the flattest, most uncluttered surface available.

29.8.3.3 On a main chassis of the equipment.

29.8.3.4 In a way to minimize wear or obscurement by grease, grime, or dirt.

29.8.3.5 In a way to preclude accidental removal, obstruction, or handling damage.

29.9 *Prototype and Production Equipment Labels*—Labels for both prototype and production equipment shall meet the criteria specified herein. Labels for production equipment shall meet the criteria specified for the duration of equipment use. Since frequent design changes may be anticipated in prototype equipment, labels for such equipment shall be simply and easily affixed, altered, and removed.

29.10 *Installation*:

29.10.1 *Orientation*—Labels shall be horizontal and read from left to right. Where space is limited and the label is not critical for personnel or equipment safety, a vertical label may be used that shall read from top to bottom. Labels shall not be placed on controls that turn (except value handwheels) which could place the label in an upside down position.

30. Anthropometry

30.1 *General*—The design of any system, individual piece of equipment, or total vessel is most efficient and cost effective if it is laid out from the beginning, around the human. One important aspect of designing to accommodate the human is to ensure that the design is compatible with the physical dimensions of the human body. Consequently, design limits shall be based on a range from the fifth to the ninety-fifth percentile for critical body dimensions. If females are expected users, then the fifth percentile dimensions used shall be those for women. If males only will be the users, then the lower design limit shall be fifth percentile dimensions for men. The upper design limit is always for the ninety-fifth percentile male. For any body dimension, the fifth percentile value indicates that 5 % of the population will be equal to or smaller than that value, and 95 % will be larger; conversely, the ninety-fifth percentile values indicate that 95 % of the population will be equal to or smaller than that value and 5 % will be larger. Therefore, use of a design range from the fifth to the ninety-fifth percentile values will theoretically provide coverage for 90 % of the user population for that dimension. The limited anthropometric data presented in this section is intended to provide general design guidance. Use of these data shall take the following into consideration:

30.1.1 The nature, frequency, safety, and difficulty of the related tasks to be performed by the operator or wearer of the equipment.

30.1.2 The position of the body during performance of these tasks.

30.1.3 Mobility or flexibility requirements imposed by these tasks.

30.1.4 Increments in the design-critical dimensions imposed by the need to compensate for obstacles, projections, and so forth.

30.1.5 Increments in the design-critical dimensions imposed by protective clothing or equipment, packages, lines, padding, and so forth.

30.2 *Anthropometric Data*—The anthropometric data presented in Figs. 53-58 and Table 22 represent various body measurements, that is, anthropometric data. The open numbers are for the nude body, and are given for the fifth and ninety-fifth percentile male and female in both inches and centimetres. Fig. 59 presents anthropometric data for several dynamic body positions often involved in work activities. Figs. 60-62 provide dimensions for head and hand protectors frequently worn by personnel on a ship.

30.3 *Use of Data*:

30.3.1 *Data Limitations*—Because some of the anthropometric data presented here represent only nude body measurements, suitable allowances shall be made for light or heavy clothing, helmets, boots, body armor, load-carrying equipment, protective equipment, and other worn or carried items, when using these data for design criteria.

30.3.2 *Clearance Dimensions*—Clearance dimensions (for example, for passageways and accesses) that must accommodate or allow passage of the body or parts of the body shall be based upon the ninety-fifth percentile values for applicable body dimensions.

30.3.3 *Limiting Dimensions*—Limiting dimensions (reaching distance, control movement, displays, test points, handrails, and so forth) that restrict or are limited by extensions of the body shall be based upon the fifth percentile values for applicable body dimensions.

30.3.4 *Adjustment Dimensions*—Seats, restraint systems, safety harnesses, belts, controls, or any equipment that must be adjusted for the comfort or performance of the individual user shall be adjustable over the range of the fifth to ninety-fifth percentile values for the applicable body member(s).

30.3.5 *Clothing and Personal Equipment*—Clothing and personal equipment (including protective or specialized equipment worn or carried by the individual) shall be designed and sized to accommodate at least the fifth through the ninety-fifth percentile values of body dimensions. Pertinent dimensions of essential or critical equipment (for example, aviators' helmets) shall be based on the first and ninety-ninth percentile values. Where two or more dimensions are used simultaneously as design parameters, appropriate multivariate data and techniques shall be used. (See appendix for representative references.)

30.4 *Special Populations*—Where equipment will be used, inclusively or exclusively, by selected or specialized segments of the user population or population ranges other than the fifth to ninety-fifth percentiles, appropriate available anthropometric data on these specialized populations shall be used for design and sizing criteria. Where equipment is intended for use by foreign personnel, appropriate anthropometric data on such populations shall be used for design and sizing criteria.

30.5 *Range of Human Motion*—The range of body movement for the arms, legs, and head are shown in Fig. 63 and Table 23. These values are based on the nude body and would have to be reduced for the clothed personnel.

TABLE 22 Anthropometric Data

	5th Percentile, cm (in.)			95th Percentile, cm (in.)		
	Male	Arctic ^A 61.6 kg (135.8 lbs)	Female 46.4 kg (102.3 lbs)	Male	Arctic ^A 98.1 kg (216.3 lbs)	Female 77.0 kg (169.8 lbs)
Standing Body Dimensions						
1 STATURE	164.5 (64.8)	173.2 (68.2)	152.4 (60.0)	187.1 (73.7)	194.1 (76.4)	173.7 (68.4)
2 EYE HEIGHT (STANDING)	152.8 (60.2)	157.7 (62.1)	141.5 (55.7)	174.3 (68.6)	176.8 (69.6)	162.1 (63.8)
3 SHOULDER (ACROMIALE) HEIGHT	134.2 (52.8)	138.4 (54.5)	123.0 (48.4)	154.6 (60.9)	158.5 (62.4)	143.2 (56.4)
4 CHEST (NIPPLE) HEIGHT	118.6 (46.7)		108.9 (42.9)	137.3 (54.1)		127.3 (50.1)
5 ELBOW (RADIALE) HEIGHT	102.3 (40.3)		96.1 (37.8)	119.9 (47.2)		111.0 (43.7)
6 FINGERTIP (DACTYLION) HEIGHT	59.1 (23.3)		55.1 (21.7)	72.4 (28.5)		67.0 (26.5)
7a WAIST (ILIOCRISTALE) HEIGHT	95.3 (37.5)		91.1 (35.9)	115.9 (45.6)		107.1 (42.2)
7b WAIST (OMPHALION) HEIGHT	97.7 (38.5)		90.3 (35.6)	114.3 (45.0)		106.5 (41.9)
7c WAIST (NATURAL INDENTATION) HEIGHT	104.3 (41.1)	111.0 (43.7)	97.3 (38.3)	121.3 (47.8)	125.0 (49.2)	114.3 (45.0)
8 CROTCH HEIGHT	75.3 (29.6)	70.6 (27.8)	68.1 (26.8)	91.8 (36.1)	83.1 (32.7)	84.6 (33.3)
9 GLUTEAL FURROW HEIGHT	73.6 (29.0)		66.4 (26.1)	89.2 (35.1)		81.7 (32.2)
10 KNEE (MID-PATELLA) HEIGHT	46.1 (18.1)	49.8 (19.6)	41.7 (16.4)	55.2 (21.7)	59.4 (23.4)	50.3 (19.8)
11 CALF HEIGHT	31.6 (12.4)		27.8 (10.9)	40.6 (16.0)		35.7 (14.1)
12 FUNCTIONAL (THUMB TIP) REACH	71.7 (28.2)	76.7 (30.2)	67.7 (26.7)	88.6 (34.9)	93.2 (36.7)	80.5 (31.7)
13 FUNCTIONAL REACH, EXTENDED	80.5 (31.7)		73.5 (28.9)	94.2 (37.1)		92.3 (36.3)
Seated Body Dimensions						
14 VERTICAL ARM REACH, SITTING	128.6 (50.6)		123.3 (48.5)	153.2 (60.3)		141.8 (55.8)
15 SITTING HEIGHT, ERECT	85.2 (33.5)	89.7 (35.3)	79.5 (31.3)	97.2 (38.3)	101.9 (40.1)	91.0 (35.8)
16 SITTING HEIGHT, RELAXED	81.8 (32.1)		78.9 (31.1)	94.8 (37.3)		89.7 (35.3)
17 EYE HEIGHT SITTING, ERECT	72.9 (28.7)	75.7 (29.0)	68.5 (27.0)	85.2 (33.5)	86.4 (34.0)	79.4 (31.3)
18 EYE HEIGHT SITTING, RELAXED	70.0 (27.6)		66.2 (26.1)	82.5 (32.5)		77.9 (30.7)
19 MID-SHOULDER HEIGHT	57.2 (22.5)	59.0 (23.2)	53.9 (21.2)	68.6 (27.0)	70.1 (27.6)	63.1 (24.8)
20 SHOULDER HEIGHT, SITTING	54.9 (21.6)		50.9 (20.0)	64.6 (25.4)		60.4 (23.8)
21 SHOULDER-ELBOW LENGTH	34.0 (13.4)	38.1 (15.0)	28.3 (11.1)	40.2 (15.8)	42.7 (16.8)	36.5 (14.4)
22 ELBOW-GRIP LENGTH	33.2 (13.1)		30.0 (11.8)	39.1 (15.4)		35.8 (14.1)
23 ELBOW-FINGERTIP LENGTH	44.4 (17.5)		40.6 (16.0)	52.4 (20.6)		48.3 (19.0)
24 ELBOW REST HEIGHT	18.4 (7.2)	17.0 (6.7)	17.6 (6.9)	28.6 (11.3)	27.9 (11.0)	26.9 (10.6)
25 THIGH CLEARANCE HEIGHT	13.7 (5.4)	18.0 (7.1)	10.4 (4.1)	19.0 (7.5)	21.1 (8.3)	18.0 (7.1)
26 KNEE HEIGHT, SITTING	50.0 (19.7)	56.6 (22.3)	47.4 (18.7)	60.6 (23.9)	64.5 (25.4)	56.0 (22.0)
27 POPLITEAL HEIGHT	40.5 (15.6)	40.0 (15.8)	35.1 (13.8)	50.0 (19.7)	45.5 (17.9)	44.1 (17.4)
28 BUTTOCK-KNEE LENGTH	55.2 (21.7)	60.2 (23.7)	53.2 (20.9)	66.7 (26.3)	68.3 (26.9)	64.0 (25.2)
29 BUTTOCK-POPLITEAL LENGTH	45.6 (18.0)	43.9 (17.3)	43.5 (17.1)	54.6 (21.5)		52.8 (20.8)
30 OMITTED						
31 FUNCTIONAL LEG LENGTH	100.2 (39.4)		93.3 (36.7)	116.9 (46.0)		109.4 (43.1)

TABLE 22 *Continued*

	5th Percentile, cm (in.)			95th Percentile, cm (in.)		
	Male	Arctic ^A 61.6 kg (135.8 lbs)	Female 46.4 kg (102.3 lbs)	Male	Arctic ^A 98.1 kg (216.3 lbs)	Female 77.0 kg (169.8 lbs)
Depth and Breadth Dimensions						
32 CHEST DEPTH	20.4 (8.0)	30.2 (11.9)	20.9 (8.2)	28.0 (11.0)	33.3 (13.1)	27.8 (10.9)
Depth and Breadth Dimensions						
33 BUTTOCK DEPTH	21.2 (8.3)		18.4 (7.2)	28.6 (11.3)		26.5 (10.4)
34 CHEST BREADTH	27.8 (10.8)	45.2 (17.8)	25.0 (9.8)	36.7 (14.4)	47.2 (18.6)	31.5 (12.4)
35 HIP BREADTH, STANDING	30.5 (12.0)	39.9 (15.7)	30.8 (12.1)	38.3 (15.1)	47.8 (18.8)	38.8 (15.3)
36 SHOULDER (BIDELTOID) BREADTH	41.8 (16.5)	48.0 (18.9)	38.2 (15.0)	53.5 (21.1)	59.9 (23.6)	47.2 (18.6)
37 FOREARM-FOREARM BREADTH	47.7 (18.8)		41.5 (16.3)	62.1 (24.4)		52.8 (20.8)
38 HIP BREADTH, SITTING	31.1 (12.2)	41.4 (16.3)	33.8 (13.3)	41.3 (16.3)	51.8 (20.4)	43.3 (17.0)
39 NOT USED						
Circumference and Surface Dimensions						
40 NECK CIRCUMFERENCE	34.7 (13.7)	69.3 (27.3)	29.2 (11.5)	41.6 (16.4)	67.1 (26.4)	36.7 (14.4)
41 CHEST (BUST) CIRCUMFERENCE	85.5 (33.7)	108.2 (42.6)	81.4 (32.0)	111.3 (43.8)	134.7 (53.0)	102.2 (40.2)
42a WAIST CIRCUMFERENCE (OMPHALION)	70.2 (27.6)		67.6 (26.6)	101.6 (40.0)		94.6 (37.2)
42b WAIST CIRCUMFERENCE, (NATURAL INDENTATION)	71.9 (28.3)	100.8 (39.7)	59.5 (23.4)	98.4 (38.7)	129.3 (50.9)	84.3 (33.2)
43 HIP (BUTTOCK) CIRCUMFERENCE, STANDING	86.7 (34.1)	119.1 (46.9)	85.8 (33.8)	109.0 (42.9)	143.3 (56.4)	107.0 (42.1)
44 NOT USED						
45 VERTICAL TRUNK CIRCUMFERENCE, STANDING	150.6 (59.3)		142.0 (55.9)	180.7 (71.1)		166.3 (65.5)
46 NOT USED						
47 ARM SCYE CIRCUMFERENCE	39.9 (15.7)		33.6 (13.2)	49.8 (19.6)		41.2 (16.2)
48 BICEPS CIRCUMFERENCE, FLEXED	27.7 (10.9)		23.3 (9.2)	38.5 (15.2)		32.1 (12.6)
49 ELBOW CIRCUMFERENCE, FLEXED	25.3 (10.0)		21.8 (8.6)	35.0 (13.8)		30.0 (11.8)
50 FOREARM CIRCUMFERENCE, FLEXED	26.5 (10.4)		23.0 (9.1)	33.6 (13.2)		27.9 (11.0)
51 WRIST CIRCUMFERENCE	15.7 (6.2)		13.8 (5.4)	18.8 (7.4)		16.3 (6.4)
52 UPPER THIGH CIRCUMFERENCE	49.1 (19.3)	62.2 (24.5)	48.7 (19.2)	67.9 (26.7)	81.0 (31.9)	65.7 (25.9)
53 CALF CIRCUMFERENCE	32.7 (12.9)	51.8 (20.4)	31.5 (12.4)	42.1 (16.6)	58.9 (23.2)	39.1 (15.4)
54 ANKLE CIRCUMFERENCE	20.0 (7.9)	40.4 (15.9)	18.6 (7.3)	25.0 (9.8)	46.5 (18.3)	23.3 (9.2)
55a WAIST (OMPHALION) BACK LENGTH	43.5 (17.1)		40.4 (15.9)	52.3 (20.6)		48.5 (19.1)
55b WAIST (NATURAL INDENTATION) BACK LENGTH	37.4 (14.7)		32.7 (12.9)	45.1 (17.8)		44.3 (17.4)
56a WAIST (OMPHALION) FRONT LENGTH	35.9 (14.1)		35.5 (14.0)	45.7 (18.0)		42.8 (16.9)
56a WAIST (NATURAL INDENTATION) FRONT LENGTH	31.0 (12.2)		27.5 (10.8)	38.1 (15.0)		36.9 (14.5)
Hand and Foot Dimensions						
57 HAND LENGTH	17.5 (6.9)	21.1 (8.3)	16.5 (6.5)	21.1 (8.3)	24.6 (9.7)	20.1 (7.9)
58 PALM LENGTH	9.6 (3.8)	10.4 (4.1)	9.0 (3.5)	11.7 (4.6)	12.4 (4.9)	10.8 (4.3)
59 HAND BREADTH	8.2 (3.2)	12.7 (5.0)	6.9 (2.7)	9.8 (3.9)	12.2 (4.8)	8.6 (3.4)
60 HAND CIRCUMFERENCE	19.9 (7.8)		16.8 (6.6)	23.5 (9.3)		20.0 (7.9)

TABLE 22 *Continued*

	5th Percentile, cm (in.)			95th Percentile, cm (in.)		
	Male	Arctic ^A 61.6 kg (135.8 lbs)	Female 46.4 kg (102.3 lbs)	Male	Arctic ^A 98.1 kg (216.3 lbs)	Female 77.0 kg (169.8 lbs)
61 NOT USED						
62 FOOD LENGTH	24.6 (9.7)		22.2 (8.7)	29.2 (11.5)		26.5 (10.4)
63 INSTEP LENGTH	17.9 (7.0)		16.4 (6.5)	21.4 (8.4)		19.5 (7.7)
64 FOOT BREADTH	9.0 (3.5)	12.2 (4.0)	8.0 (3.1)	11.0 (4.3)	13.5 (5.3)	9.8 (3.9)
Head and Face Dimensions						
65 FOOT CIRCUMFERENCE	22.9 (9.0)		20.5 (8.1)	27.3 (10.7)		24.2 (9.5)
66 HEEL-ANKLE CIRCUMFERENCE	31.3 (12.3)		28.1 (11.1)	36.9 (14.5)		33.0 (13.0)
67 HEAD CIRCUMFERENCE	53.6 (21.1)	91.9 (36.2)	52.3 (20.6)	59.7 (23.5)	92.2 (36.3)	57.6 (22.7)
68 BITRAGION-CORONAL CURVATURE	33.2 (13.1)		31.6 (12.4)	38.0 (15.0)		36.3 (14.3)
69 BITRAGION-MENTON CURVATURE	30.4 (12.0)		28.2 (11.1)	34.8 (13.7)		32.6 (12.8)
70 BITRAGION-SUBMANDIBULAR CURVATURE	27.8 (10.9)		25.6 (10.1)	33.0 (13.0)		29.7 (11.7)
71 HEAD LENGTH	18.3 (7.2)		17.3 (6.8)	21.0 (8.3)		19.8 (7.8)
72 PRONASALE TO WALL	20.5 (8.1)		19.7 (7.8)	23.6 (9.3)		22.9 (9.0)
73 TRAGION TO WALL	8.6 (3.4)		8.6 (3.4)	12.6 (5.0)		11.8 (4.6)
74 HEAD BREADTH	14.3 (5.6)		13.5 (5.3)	16.5 (6.5)		15.5 (6.1)
75 NOT USED						
76 BITRAGION BREADTH	12.6 (5.0)		12.1 (4.8)	15.5 (6.1)		14.5 (5.7)
77 BIAURICULAR BREADTH	17.4 (6.9)		14.2 (5.6)	21.0 (8.3)		19.5 (7.7)
78 HEAD HEIGHT (TRAGION TO TOP OF HEAD)	12.1 (4.8)		11.3 (4.4)	14.5 (5.7)		14.1 (5.6)
79 GLABELLA TO TOP OF HEAD	7.6 (3.3)		7.7 (3.0)	10.8 (4.3)		10.0 (3.9)
80 PRONASALE TO TOP OF HEAD	13.8 (5.4)		12.8 (5.0)	16.6 (6.5)		16.8 (6.6)
81 FACE LENGTH (MENTON-SELLION)	10.7 (4.2)		9.6 (3.8)	13.3 (5.2)		12.4 (4.9)
82 FACE (BIZYGOMATIC) BREADTH	13.1 (5.2)		11.9 (4.7)	15.0 (5.9)		14.0 (5.5)
83 BILOCULAR BREADTH	11.3 (4.4)		11.1 (4.4)	13.1 (5.2)		12.9 (5.1)
84 INTERPUPILLARY BREADTH	5.4 (2.1)		5.1 (2.0)	7.1 (2.8)		6.9 (2.7)
85 NOT USED						
86 NOT USED						
87 LIP LENGTH (MOUTH BREADTH)	4.4 (1.7)		3.7 (1.5)	6.3 (2.5)		6.2 (2.4)
88 NOT USED						
89 EAR LENGTH ABOVE TRAGION	2.5 (1.0)		2.5 (1.0)	3.6 (1.4)		3.3 (1.3)
90 EAR BREADTH	3.2 (1.3)		2.4 (0.9)	4.2 (1.7)		3.9 (1.5)
91 EAR PROTRUSION	1.7 (0.7)		1.7 (0.7)	3.0 (1.2)		2.7 (1.1)

^ANumbers are for males only dressed in arctic clothing.

31. Workspace Design Requirements

31.1 *General*—The following criteria apply to workspace design requirements.

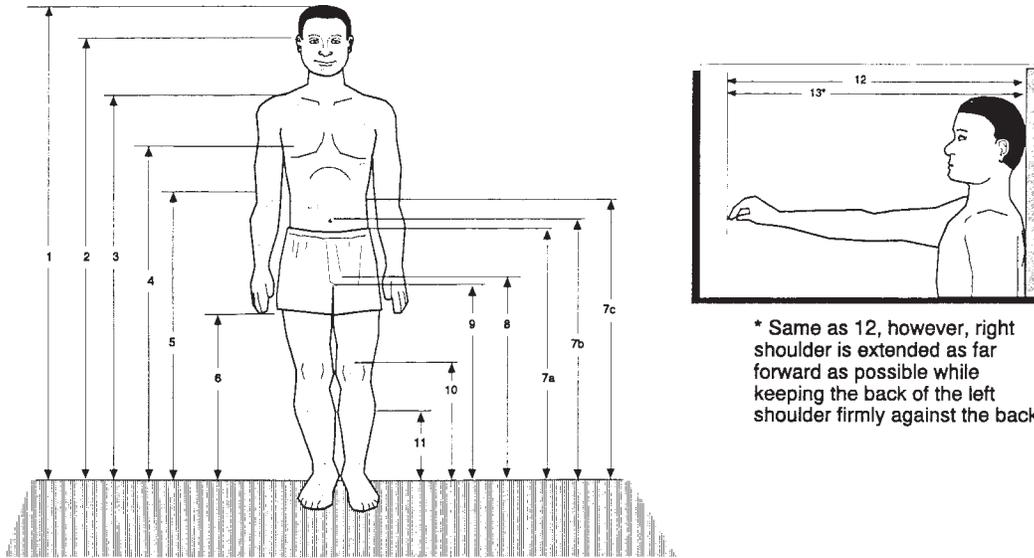


FIG. 53 Standing Body Dimensions

* Same as 12, however, right shoulder is extended as far forward as possible while keeping the back of the left shoulder firmly against the back

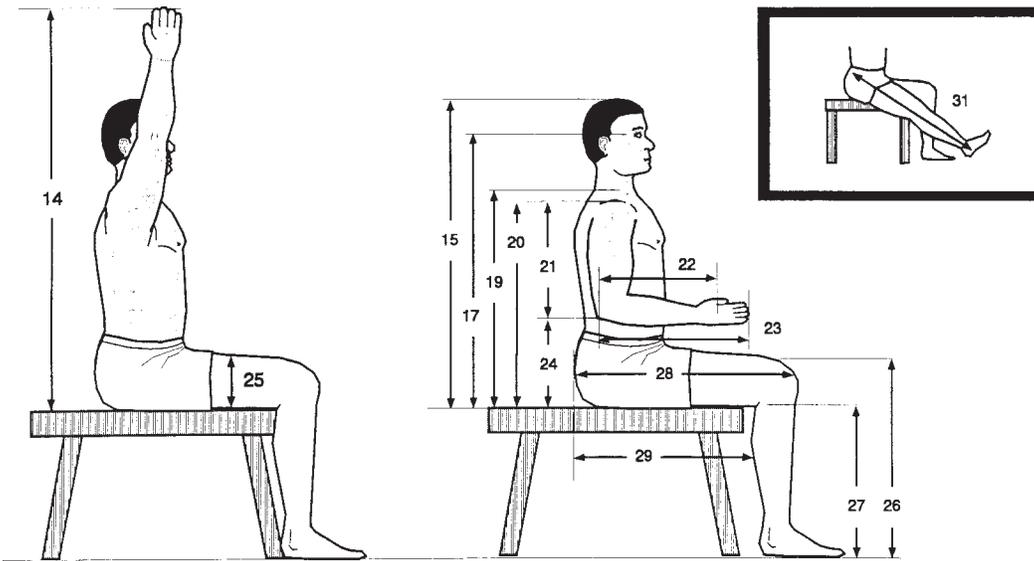


FIG. 54 Seated Body Dimensions

31.1.1 *Kick Space*—All cabinets, consoles, and work surfaces that require an operator to stand or sit close to their front surfaces shall contain a kick space at the base at least 100 mm (4 in.) deep and 100 mm (4 in.) high to allow for protective or specialized apparel.

31.1.2 *Handles*—Handles on cabinets and consoles shall be recessed whenever practicable to eliminate projections on the surface. If handles cannot be recessed, they shall be designed such that they shall neither injure personnel nor entangle clothing or equipment.

31.1.3 *Work Space*—Work space shall be provided to perform all operational and maintenance tasks by the fifth to ninety-fifth percentile person wearing the appropriate clothing and using the required tools. In establishing the work space, consideration shall be given to the number of personnel required to perform the work and the body positions required

to do the work. Dimensions for typical work positions are shown in Fig. 64 and Table 24.

31.1.3.1 *Depth of Work Area*—Clearance from the front of the rack to the nearest facing surface or obstacle shall not be less than 1.07 m (42 in.). The minimum space between rows of cabinets shall be 200 mm (8 in.) greater than the depth of the deepest drawer (equipment).

31.1.3.2 *Lateral Work Space*—The minimum lateral work-space for racks having drawers or removable equipment shall be as follows (measured from the drawers or equipment in the extended position):

(a) For racks having drawers or removable items weighing less than 20 kg (44 lbs): 460 mm (18 in.) on one side and 100 mm (4 in.) on the other.

(b) For racks having drawers or removable items weighing over 20 kg (44 lbs): 460 mm (18 in.) on each side.

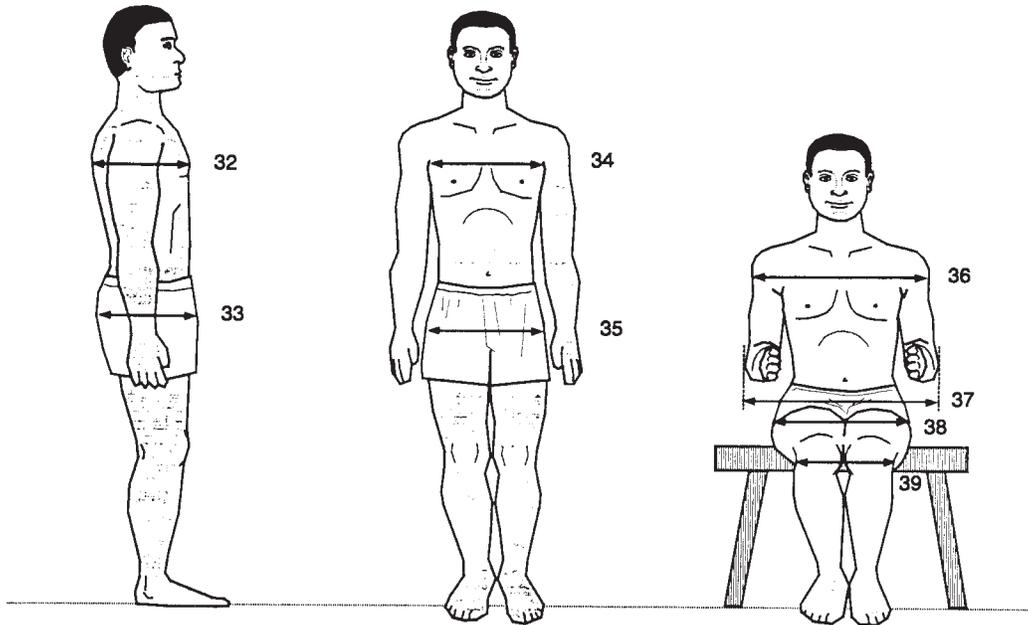


FIG. 55 Depth and Breadth Dimensions

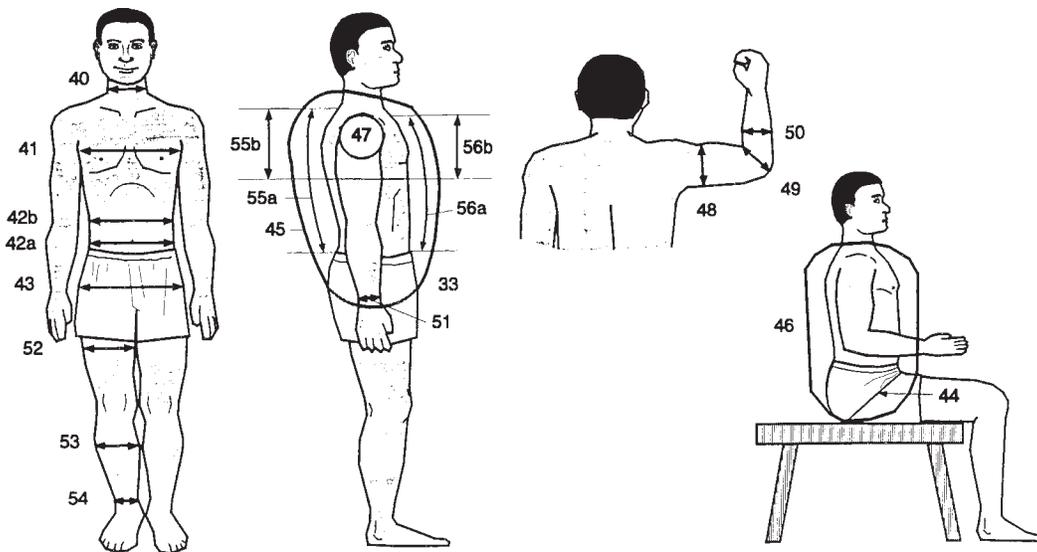


FIG. 56 Circumferences and Surface Dimensions

31.1.3.3 *Space Between Rows of Cabinets*—The minimum space between rows of cabinets shall be 200 mm (8 in.) greater than the depth of the deepest drawer or cabinet.

31.1.4 *Storage Space*—Adequate and suitable space shall be provided on consoles or immediate work space for the storage of manuals, worksheets, and other materials that are required for use by the operational or maintenance personnel.

31.2 *Standing Operations:*

31.2.1 *Work Surface*—Standing work surface and space dimensions are shown in Table 25, Fig. 65 and Fig. 66.

31.2.2 *Displays/Controls in a Standing Workplace*—Displays and controls located for use by a standing operator (for example, gage boards, bulkhead mounted, fiddle-boards, consoles, and so forth) shall be located as shown in Figs. 67-69 and as described herein.

31.2.3 *Display Placement, Normal*—Visual displays mounted on vertical panels and used in normal equipment operation shall be placed between 1.04 m (41 in.) and 1.78 m (70 in.) above the standing surface except that displays above that height are permitted, up to 2.13 m (84 in.), provided they are tilted down (see Fig. 69).

31.2.4 *Display Placement, Special*—Displays requiring precise and frequent reading shall be placed between 1.27 m (50 in.) and 1.65 m (65 in.) above the standing surface.

31.2.5 *Control Placement, Normal*—All controls (except valve handwheels) mounted on a vertical surface and used in normal equipment operation shall be located between 762 mm and 1.93 m (30 and 76 in.) above the standing surface with a maximum height of 1.78 m (70 in.) preferred (see Fig. 69). Valve handwheels shall be located as shown in Fig. 38.

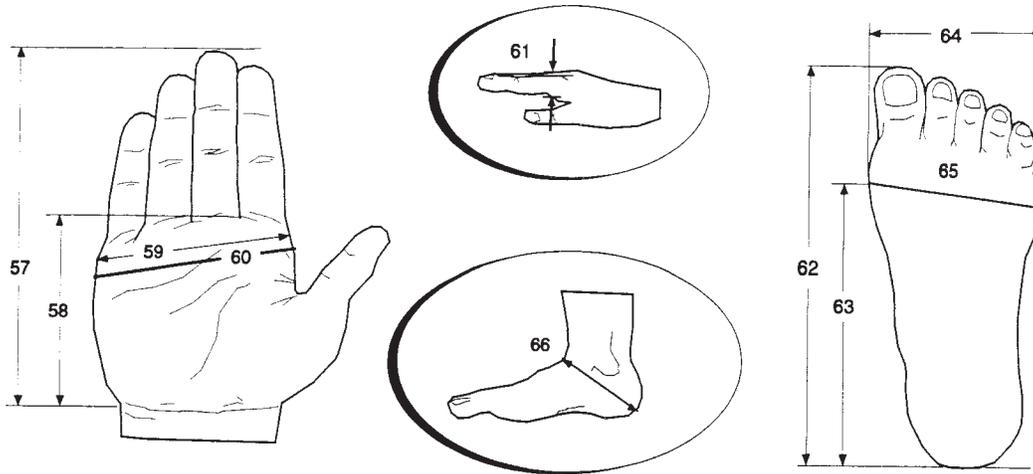
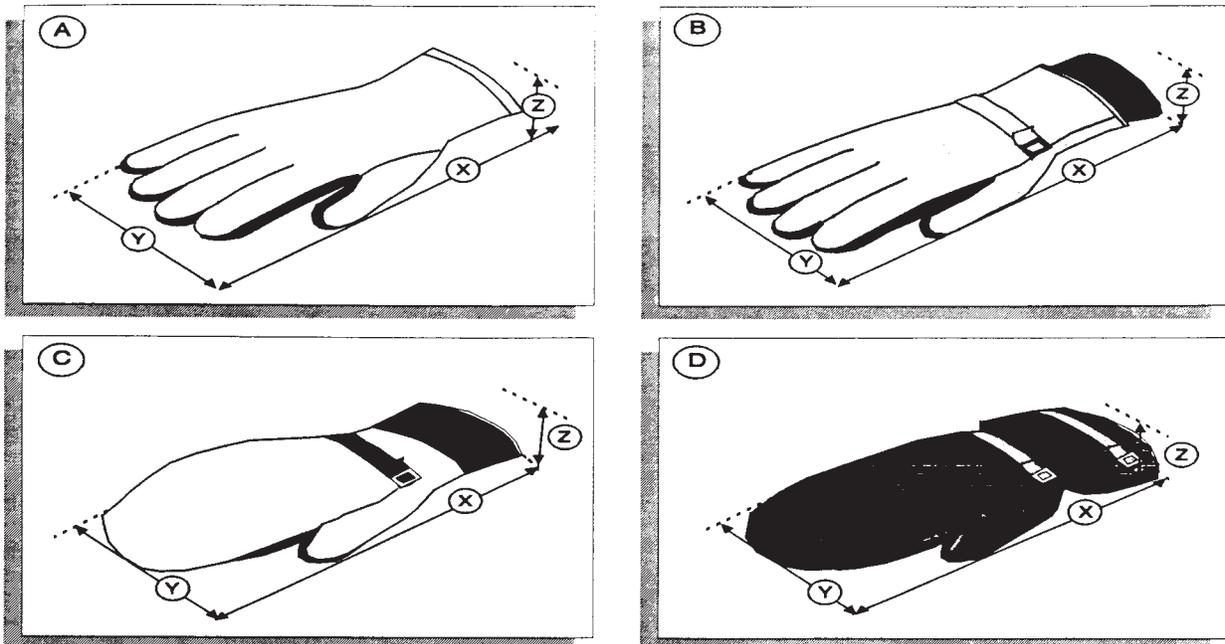


FIG. 57 Hand and Foot Dimensions

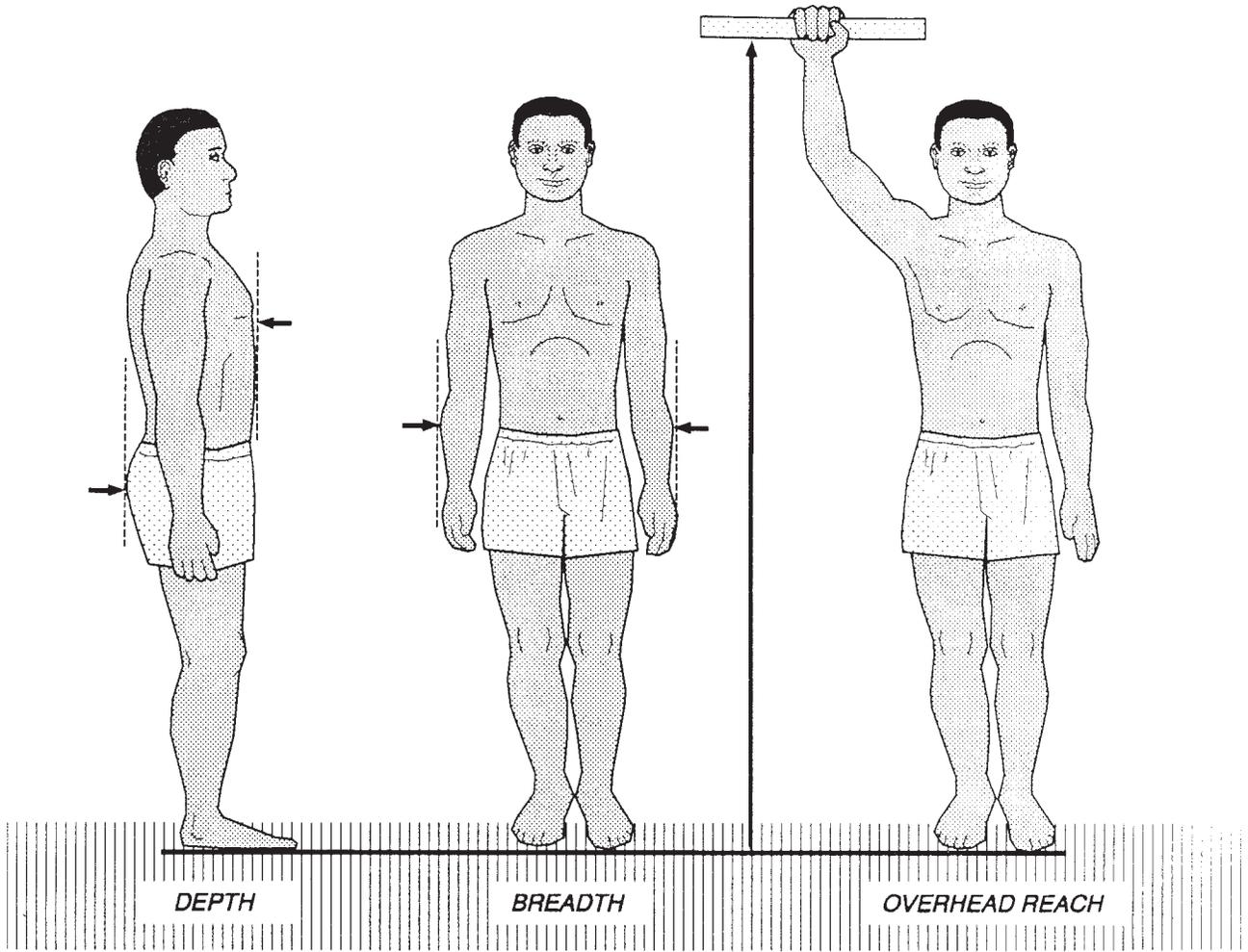


Hand Position cm (in)	A Antiocontact Glove, cm (in)			B Wet-Cold Glove, cm (in)			C Wet-Cold Glove, cm (in)			D Arctic Glove, cm (in)		
	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
Extended Flat	26.7 (10.5)	11.9 (4.8)	8.4 (2.5)	27.2 (10.7)	14.5 (5.7)	7.6 (3.0)	36.1 (14.2)	15.2 (6.0)	8.1 (3.2)	42.2 (16.6)	13.7 (5.4)	9.1 (3.6)
Closed as Flat	17.8 (7.0)	12.7 (5.0)	8.4 (3.3)	18.5 (7.3)	14.7 (5.8)	9.4 (3.7)	29.2 (11.5)	14.7 (5.8)	9.7 (3.8)	36.3 (14.3)	13.2 (5.2)	13.7 (5.4)
Grasping Handle												
0.8 (1/4) diameter	17.8 (7.0)	12.7 (5.0)	8.9 (3.5)	18.5 (7.3)	14.0 (5.5)	10.2 (4.0)	27.4 (10.8)	14.5 (5.7)	10.7 (4.2)	35.8 (14.0)	14.0 (5.5)	11.4 (4.5)
2.5 (1) diameter	17.8 (7.0)	12.7 (5.0)	8.9 (3.5)	18.5 (7.3)	13.5 (5.3)	10.2 (4.0)	27.4 (10.8)	13.2 (5.2)	11.4 (4.5)	25.6 (10.0)	13.2 (5.2)	11.4 (4.5)
5.0 (2) diameter	19.0 (7.5)	11.4 (4.5)	10.7 (4.2)	20.3 (8.0)	11.9 (4.7)	10.2 (4.0)	30.5 (12.0)	13.2 (5.2)	11.9 (4.7)	38.1 (15.0)	13.7 (5.4)	12.7 (5.0)
Grasping Knob												
0.8 (1/4) diameter	20.0 (7.4)	9.7 (3.8)	10.9 (4.3)	22.9 (9.0)	11.7 (4.6)	10.2 (2.0)	29.2 (11.5)	12.7 (5.0)	10.7 (4.2)	39.4 (15.5)	12.2 (4.8)	11.4 (4.5)
2.5 (1) diameter	22.9 (9.0)	8.9 (3.5)	10.2 (4.0)	22.9 (9.0)	11.4 (4.5)	10.2 (4.0)	30.5 (12.0)	12.7 (5.0)	10.7 (4.2)	39.4 (15.5)	12.2 (4.8)	12.2 (4.8)
5.0 (2) diameter	24.1 (9.5)	8.4 (3.7)	9.4 (3.7)	23.4 (9.2)	11.4 (4.5)	10.7 (4.2)	31.8 (12.5)	11.9 (4.7)	11.2 (4.4)	40.8 (16.0)	11.9 (4.7)	12.2 (4.8)

FIG. 58 Head and Face Dimensions

31.2.6 *Control Placement, Special*—Controls requiring precise or frequent operation and emergency controls shall be mounted between 860 mm and 1.35 m (34 and 53 in.) above the standing surface and no farther than 530 mm (21 in.) laterally from the centerline.

31.2.7 *Window Placement*—Work stations requiring vision outside through windows shall be designed so the lower edge of the window is no more than 1.3 m (52 in.) and the upper edge no less than 1.85 m (74 in.) above the deck, except for forward bridge windows which shall be no less than 1.98 m (79



Measurement, cm (in)	5th % Male	Mean	95th % Percentile Male	SD
Maximum body depth	25.7 (10.1)	29.2 (11.5)	33.0 (13.0)	2.2 (0.88)
Maximum body breadth	47.8 (18.8)	53.1 (20.9)	57.9 (22.8)	3.0 (1.19)
Overhead Reach	195.1 (76.8)	209.6 (82.5)	209.6 (82.5)	8.5 (3.33)

FIG. 59 Anthropometric Data for Body Positions Involved in Work Activities

in.) above the deck. Where reflection from window glass could be a problem, the window shall be angled from the vertical, top out and bottom-in, 15°, but in no case shall the angle be less than 8° or more than 25°.

31.3 Seated Operations:

31.3.1 Desk Dimensions—Dimensions for a seated desk-type work station are provided in Fig. 70 and Table 26.

31.3.1.1 Work Surface Width and Depth—A lateral workspace of at least 760 mm (30 in.) wide and 400 mm (16 in.) deep shall be 740 to 790 mm (29 to 31 in.) above the floor, unless otherwise specified.

31.3.2 Writing Surfaces—Where a writing surface is required on equipment consoles, it shall be at least 400 mm (16

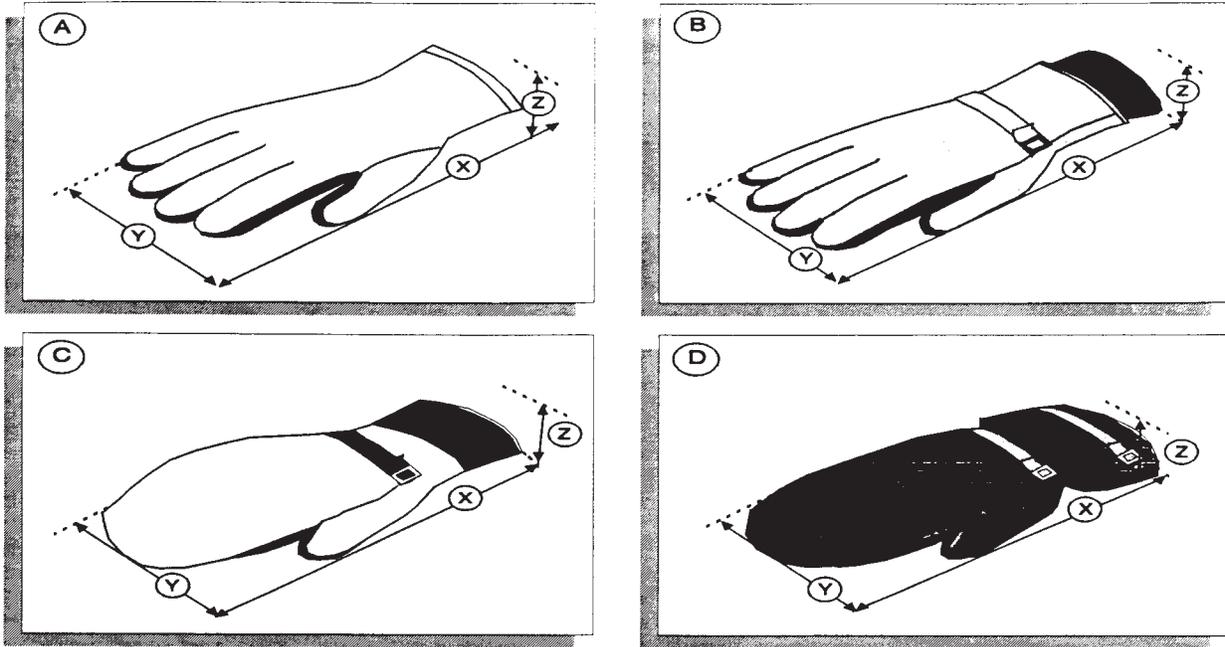
in.) deep and shall be 610 mm (24 in.) wide, when consistent with operator reach requirements.

31.3.3 Seating:

31.3.3.1 Compatibility—Work seating shall provide an adequate supporting framework for the body relative to the activities that must be carried out. Chairs to be used with sit-down consoles shall be designed operationally compatible with the console configuration.

31.3.3.2 Vertical Adjustment—Provision shall be made for vertical seat adjustment from 380 to 535 mm (15 to 21 in.) in increments of no more than 25 mm (1 in.) each.

31.3.3.3 Backrest—A supporting backrest that reclines between 1745 and 2005 mrad (100 and 115°) shall be provided.



Hand Position cm (in)	A Anticold Glove, cm (in)			B Wet-Cold Glove, cm (in)			C Wet-Cold Glove, cm (in)			D Arctic Glove, cm (in)		
	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
Extended Flat	26.7 (10.5)	11.9 (4.8)	8.4 (2.5)	27.2 (10.7)	14.5 (5.7)	7.6 (3.0)	36.1 (14.2)	15.2 (6.0)	6.1 (3.2)	42.2 (16.6)	13.7 (5.4)	9.1 (3.6)
Closed as Fist	17.8 (7.0)	12.7 (5.0)	8.4 (3.3)	18.5 (7.3)	14.7 (5.8)	9.4 (3.7)	29.2 (11.5)	14.7 (5.8)	9.7 (3.8)	36.3 (14.3)	13.2 (5.2)	13.7 (5.4)
Grasping Handle												
0.6 (1/4) diameter	17.8 (7.0)	12.7 (5.0)	8.9 (3.5)	18.5 (7.3)	14.0 (5.5)	10.2 (4.0)	27.4 (10.8)	14.5 (5.7)	10.7 (4.2)	35.8 (14.0)	14.0 (5.5)	11.4 (4.5)
2.5 (1) diameter	17.8 (7.0)	12.7 (5.0)	8.9 (3.5)	18.5 (7.3)	13.5 (5.3)	10.2 (4.0)	27.4 (10.8)	13.2 (5.2)	11.4 (4.5)	25.8 (10.1)	13.2 (5.2)	11.4 (4.5)
5.0 (2) diameter	19.0 (7.5)	11.4 (4.5)	10.7 (4.2)	20.3 (8.0)	11.9 (4.7)	10.2 (4.0)	30.5 (12.0)	13.2 (5.2)	11.9 (4.7)	38.1 (15.0)	13.7 (5.4)	12.7 (5.0)
Grasping Knob												
0.6 (1/4) diameter	20.0 (7.4)	9.7 (3.8)	10.9 (4.3)	22.9 (9.0)	11.7 (4.6)	10.2 (2.0)	29.2 (11.5)	12.7 (5.0)	10.7 (4.2)	39.4 (15.5)	12.2 (4.8)	11.4 (4.5)
2.5 (1) diameter	22.9 (9.0)	8.9 (3.5)	10.2 (4.0)	22.9 (9.0)	11.4 (4.5)	10.2 (4.0)	30.5 (12.0)	12.7 (5.0)	10.7 (4.2)	39.4 (15.5)	12.2 (4.8)	12.2 (4.8)
5.0 (2) diameter	24.1 (9.5)	9.4 (3.7)	9.4 (3.7)	23.4 (9.2)	11.4 (4.5)	10.7 (4.2)	31.8 (12.5)	11.9 (4.7)	11.2 (4.4)	40.8 (16.0)	11.9 (4.7)	12.2 (4.8)

FIG. 60 95th Percentile Gloved-Hand Dimensions (Male)

The backrest shall engage the lumbar and thoracic regions of the back and shall support the torso in such a position that the operator's eyes can be to the normal line of sight (Fig. 8) with no more than 75 mm (3 in.) of forward body movement.

31.3.3.4 *Cushioning*—Where applicable, both the backrest and seat shall be cushioned with at least 25 mm (1 in.) of compressible material and provided with a smooth surface.

31.3.3.5 *Work Surface Height*—Desk tops and writing tables shall be 740 to 790 mm (29 to 31 in.) above the floor, unless otherwise specified.

31.3.3.6 *Armrests*—Modified or retractable armrests shall be provided when necessary to maintain compatibility. Alone with an associated console and shall be adjustable from 190 to 280 mm (7.5 to 11 in.) above the compressed sitting surface.

31.3.3.7 *Knee Room*—Knee and foot room that equals or exceeds the following minimum dimensions shall be provided beneath work surfaces:

(a) Height: 640 mm (25 in.). If a fixed footrest or a foot-operated control is provided, this dimension shall be increased accordingly.

(b) Width: 510 mm (20 in.).

(c) Depth: 460 mm (18 in.).

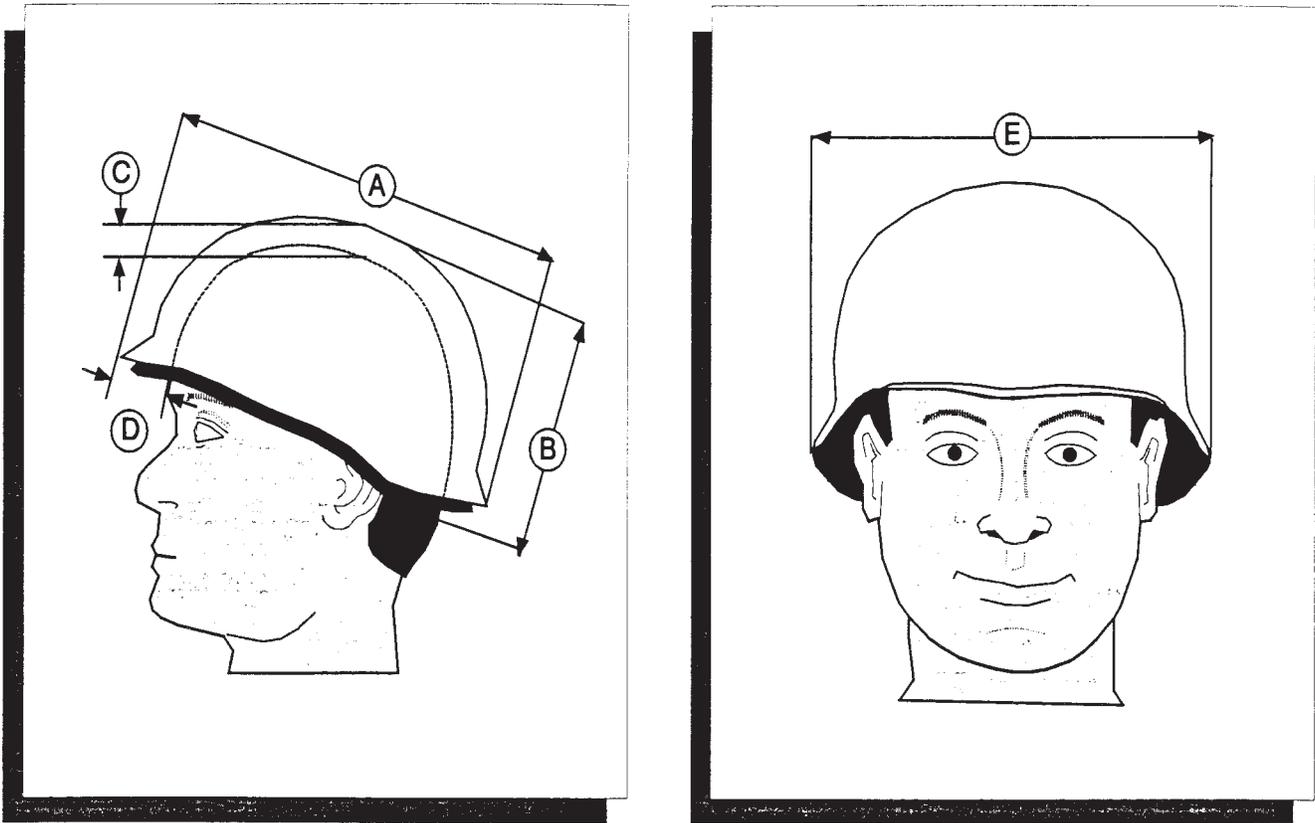
31.3.3.8 *Seating at Tables*—For single or multiple persons sitting at tables or other nondesk-type of work stations, the dimensions shown in Fig. 71 shall be provided. Table height, knee clearance, and so forth, shall be the same as in Fig. 70.

31.3.3.9 *Seating at CRT-Type Work Stations*—Seating dimensions for stool or chair seating at CRT-type displays or other similar work stations is shown in Fig. 72.

31.3.3.10 *Swing-Away Seats*—Where permanent seats cannot be provided, swing-away seats shown in Fig. 73 shall be provided.

31.3.4 *Display Placement, Normal*—Visual displays mounted on vertical panels and used in normal equipment operation shall be placed in an area between 150 and 1170 mm (6 and 46 in.) above the sitting surface.

31.3.5 *Display Placement, Special*—Indicators that must be read precisely and frequently shall be placed in an area between 360 and 890 mm (14 and 35 in.) above the sitting surface and no further than 530 mm (21 in.) laterally from the centerline.



DIMENSION	MAXIMUM SIZE
A. Length, front rim to rear rim	280.0 mm (11.2 in)
B. Height	170.0 mm (6.8 in)
C. Top of head to top of helmet	50.0 mm (2 in)
D. Eyebrow ridge to front rim	50.0 mm (2 in)
E. Width, rim to rim	235.0 mm (9.4 in)

FIG. 61 Helmet Dimensions

31.3.6 *Warning Displays*—For “sit” consoles requiring horizontal vision over the top, critical visual warning displays shall be mounted at least 570 mm (22.5 in.) above the sitting surface.

31.3.7 *Control Placement, Normal*—All controls mounted on a vertical surface and used in normal equipment operation shall be located between 200 and 860 mm (8 and 34 in.) above the sitting surface.

31.3.8 *Control Placement, Special*—Controls requiring precise or frequent operation shall be mounted between 200 and 740 mm (8 and 29 in.) above the sitting surface.

31.3.9 *Window Placement*—Seated work stations requiring vision outside, through windows, shall be designed so the lower edge of the window shall be no higher than 1.0 m (40 in.) above the deck.

31.4 *Standard Console Design:*

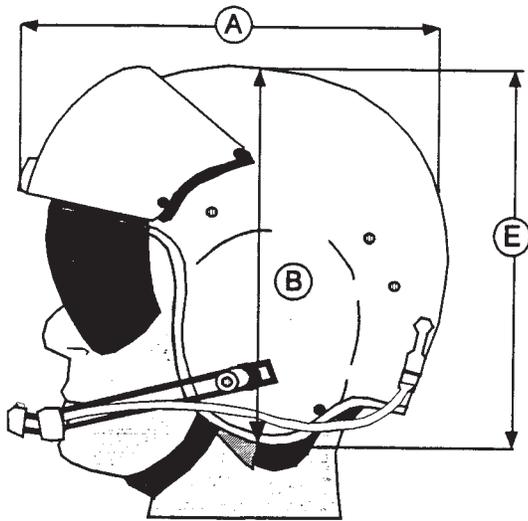
31.4.1 *Dimensions*—For purposes of standardization, consoles and the units and racks that constitute operator work stations shall be designed to conform with the dimensions shown in Fig. 74 and Table 27.

31.4.2 *Configurations*—The configurations represented in Fig. 74 and Table 27 may not be applicable to all design situations, since, in some cases, operational requirements may necessitate unique design solutions. However, because of the benefits and economies inherent in a standard console, design shall conform with the standard configurations whenever possible.

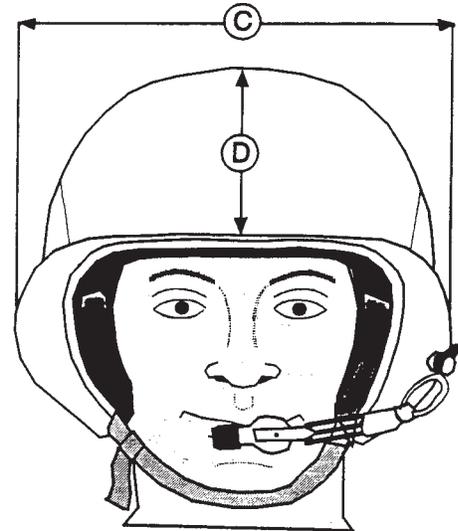
31.4.3 *Variables*—The selected console design shall accommodate the following requirements, as applicable:

31.4.3.1 Visibility over the top of the console.

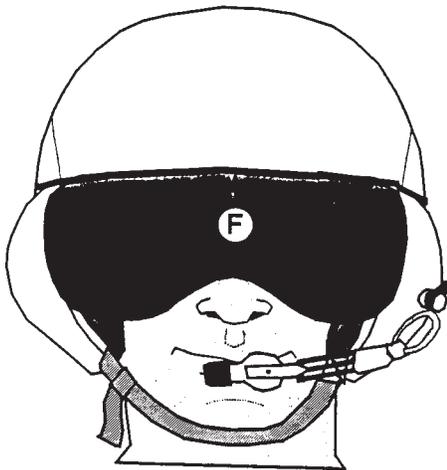
31.4.3.2 Operator mobility (sit, stand, or sit-stand requirements).



Side View



Visor Up



Visor Down

DIMENSION	SIZE
A. Length of helmet	280 mm (11.2 in)
B. Height of helmet shell	240 mm (9.6 in)
C. Helmet breadth	290 mm (11.6 in)
D. Height from front to top	140 mm (5.6 in)
E. Height from back to top	180 mm (7.2 in)
F. Sun shield at nose cut-away	65 mm (2.6 in)

FIG. 62 Aircrewman's Helmet (Size Extra Large)

31.4.3.3 Panel space (note Columns "B" and "E," Table 27).

31.4.3.4 Volume in the area below the writing surface.

31.4.4 *Console Selection*—On the basis of the considerations in 31.4.3, the particular configuration that will best meet the requirements shall be selected from among the console types represented in Figs. 75-77, or a special design created which meets requirements of 31.4.3 and the particular unique requirements imposed on the console, as long as the console configuration is operable and maintainable by the fifth to ninety-fifth percentile operator.

31.5 *Special-Purpose Console Design:*

31.5.1 *One- or Two-Tier (Horizontal Wraparound):*

See Fig. 75.

31.5.1.1 *Panel Width*—When requirements for preferred panel space for a single-seated operator exceed a panel width

of 1.12 m (44 in.), a flat-surface, segmented, wraparound console shall be provided to place all controls within the reach of the fifth percentile stationary operator.

31.5.1.2 *Panel Angle*—The left and right segments shall be placed at an angle, measured from the frontal plane of the central segment, such that they can be reached by the fifth percentile stationary operator.

31.5.1.3 *Dimensions With Vision Over Top*—Where vision over the top is required, console height shall be in accordance with Table 27. The width of the central segment shall not exceed 1.12 m (44 in.), with 915 mm (36 in.) preferred, and that of the left and right segments shall not exceed 610 mm (24 in.).

31.5.1.4 *Dimensions Without Vision Over Top*—Where vision over the top is not required, the total console height shall

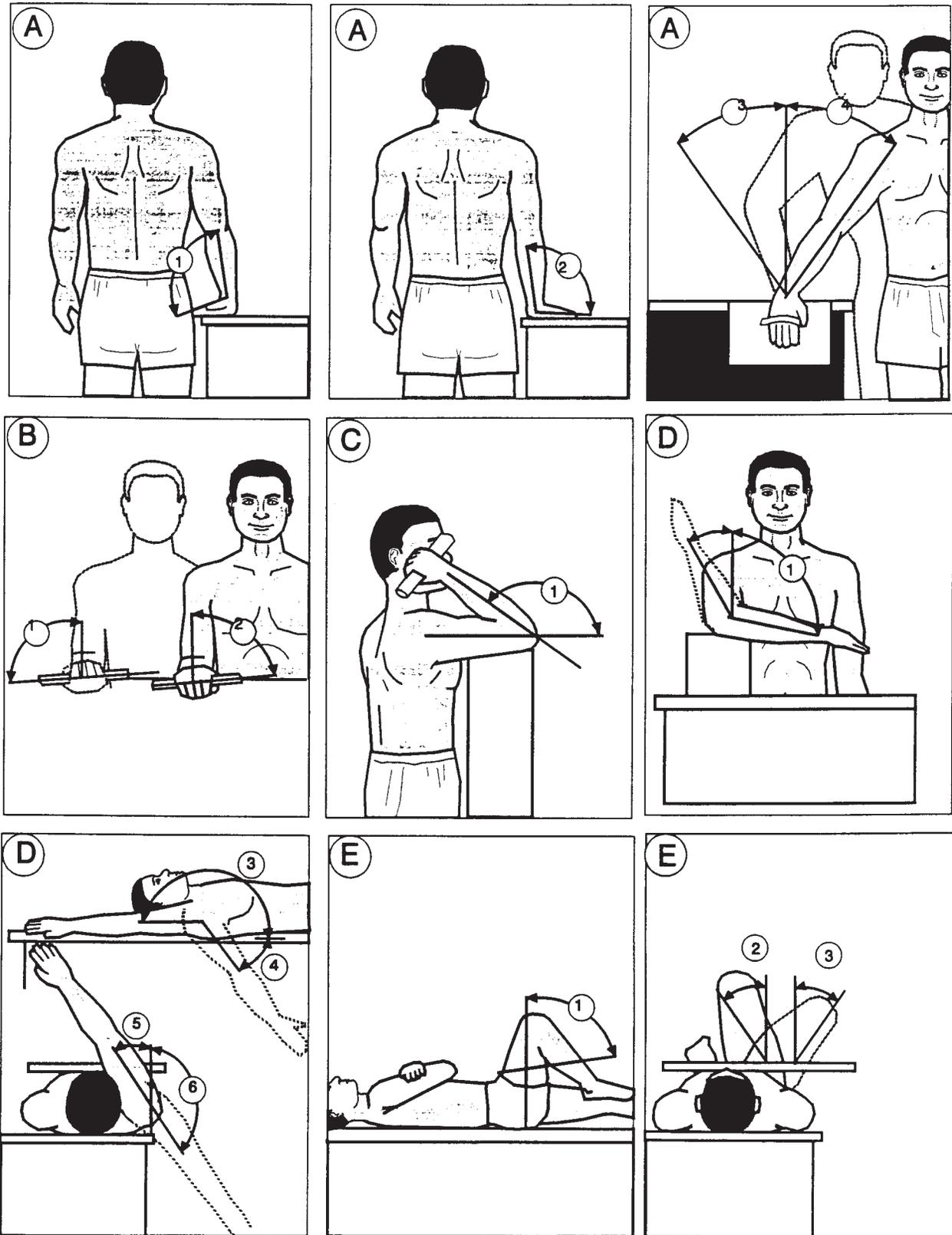


FIG. 63 Range of Human Motion

be in accordance with Table 27. The width of the central

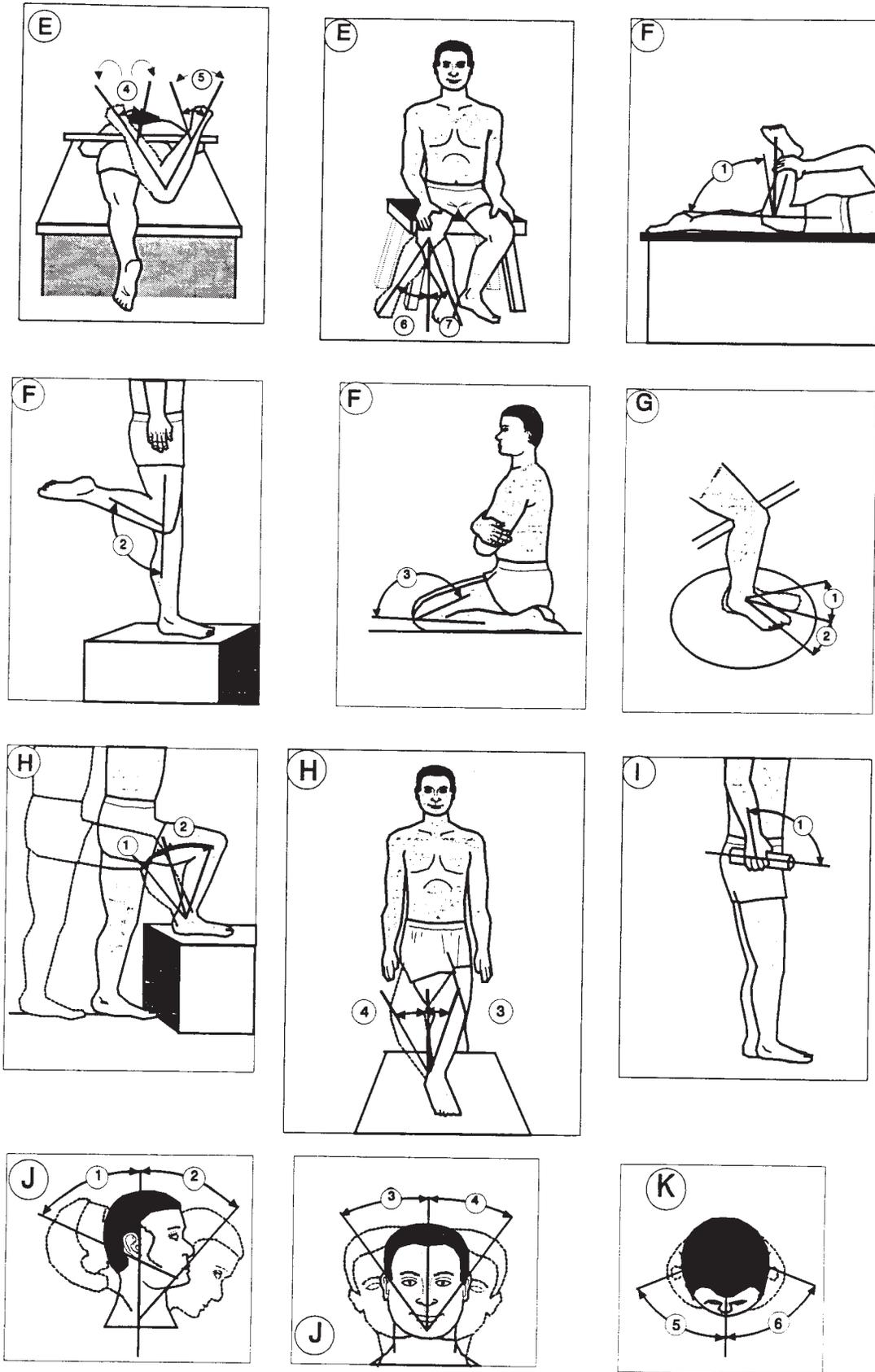


FIG. 63 Range of Human Motion (continued)

TABLE 23 Range of Human Motion

Body Member	Movement	Lower Limit		Average		Upper Limit	
				Radians (Degrees)			
A. Wrist	1. Flexion	1.36	(78)	1.57	(90)	1.78	(102)
	2. Extension	1.50	(86)	1.73	(99)	1.95	(112)
	3. Adduction	0.31	(16)	0.63	(36)	0.47	(27)
	4. Abduction	0.70	(40)	0.94	(54)	0.82	(47)
B. Forearm	1. Supination	1.58	(91)	2.36	(113)	2.36	(135)
	2. Pronation	0.92	(53)	1.34	(77)	1.76	(101)
C. Elbow	1. Flexion	2.30	(132)	2.48	(142)	2.65	(152)
D. Shoulder	1. Lateral rotation	0.36	(21)	0.59	(34)	0.82	(47)
	2. Medial rotation	1.31	(75)	1.69	(97)	2.08	(119)
	3. Extension	0.82	(47)	1.06	(61)	1.31	(75)
	4. Flexion	3.07	(176)	3.28	(188)	3.32	(190)
	5. Adduction	0.68	(39)	0.84	(48)	0.99	(57)
	6. Abduction	2.04	(117)	2.34	(134)	2.64	(151)
E. Hip	1. Flexion	1.75	(100)	1.97	(113)	2.20	(126)
	2. Adduction	0.33	(19)	0.54	(31)	0.75	(43)
	3. Abduction	0.72	(41)	0.92	(53)	1.13	(65)
	4. Medial rotation (prone)	0.51	(29)	0.68	(39)	0.86	(49)
	5. Lateral rotation (prone)	0.42	(24)	0.59	(34)	0.77	(44)
	6. Lateral rotation (sitting)	0.37	(21)	0.52	(30)	0.68	(39)
	7. Medial rotation (sitting)	0.38	(22)	0.54	(31)	0.70	(40)
F. Knee flexion	1. Prone	2.01	(115)	2.18	(125)	2.36	(135)
	2. Standing	1.75	(100)	1.97	(113)	2.20	(126)
	3. Kneeling	2.62	(150)	2.77	(159)	2.93	(168)
G. Foot rotation	1. Medial	0.40	(23)	0.61	(35)	0.82	(47)
	2. Lateral	0.54	(31)	0.75	(43)	0.96	(55)
H. Ankle	1. Extension	0.45	(26)	0.66	(38)	0.87	(50)
	2. Flexion	0.49	(28)	0.61	(35)	0.73	(42)
	3. Adduction	0.26	(15)	0.58	(33)	0.42	(24)
	4. Abduction	0.28	(16)	0.52	(30)	0.40	(23)
I. Grip angle		1.66	(95)	1.78	(102)	1.90	(109)
J. Neck flexion	1. Dorsal (back)	0.77	(44)	1.08	(61)	1.54	(88)
	2. Ventral (forward)	0.84	(48)	1.05	(60)	1.26	(72)
	3. Right	0.59	(34)	0.72	(41)	0.84	(48)
	4. Left	0.59	(34)	0.72	(41)	0.84	(48)
K. Neck rotation	1. Right	1.13	(65)	1.38	(79)	1.62	(93)
	2. Left	1.13	(65)	1.38	(79)	1.62	(93)

Notes: These values are based on the nude body. The ranges are larger than they would be for clothed personnel.

Flexion: Bending or decreasing the angle between parts of the body.

Extension: Straightening or increasing the angle between parts of the body.

Adduction: Moving toward the midline of the body.

Abduction: Moving away from the midline of the body.

Medial rotation: Turning toward the midplane of the body.

Lateral rotation: Turning away from the midplane of the body.

Pronation: Rotation of the palm of the hand downward.

Supination: Rotation of the palm of the hand upward.

segment shall not exceed 915 mm (36 in.) and that of the left and right segments shall not exceed 610 mm (24 in.).

31.5.1.5 *Viewing Angle*—The total required left-to-right viewing angle shall not exceed 3.32 rad (190°). This angle shall be reduced whenever possible through appropriate control-display layout.

31.5.2 *Three-Tier Flat and Wraparound (Also Called Vertical/Stacked Segments)*—(See Fig. 76 for example).

31.5.2.1 *Panel Division*—Where direct forward vision over the top of the console is not required by a seated operator, and when lateral space is limited, the panel may be divided into three tier segments with surfaces perpendicular to the operator's line of sight with little or no head movement.

31.5.2.2 *Height*—The height from the seat reference point to the centerline of the #2 tier shall be 737 mm (29 in.) preferred and 800 mm (31.5 in.) maximum. The height of the #2 tier shall be from 406 mm (16 in.) to 530 mm (21 in.) maximum. If feasible, no controls shall be placed on the third

tier but displays only. If controls are placed on the third tier, they shall be reachable by a seated fifth percentile person.

31.5.3 *Desk Top:*

(See Fig. 77 for example).

31.5.3.1 *Dimensions*—Console height at the forward edge shall be 900 mm (36 in.) and the maximum width shall be 1.2 m (48 in.). The depth, measured along the face of the console, shall be 800 mm (32 in.). The face of the console shall be tilted up, between 0.23 and 0.30 rad (13 to 17°) from the horizontal. A recessed tow board of 100 mm (4 in.) square shall be provided.

31.5.3.2 *Control Placement*—Controls requiring frequent or accurate settings shall not be placed more than 675 mm (27 in.) from the front edge of the console.

31.6 *Console Orientation in the Ship:*

31.6.1 *Propulsion, Steering, and Navigation*—Operator consoles associated with control of the propulsion engines, boilers, and so forth, navigation (chart tables), and steering

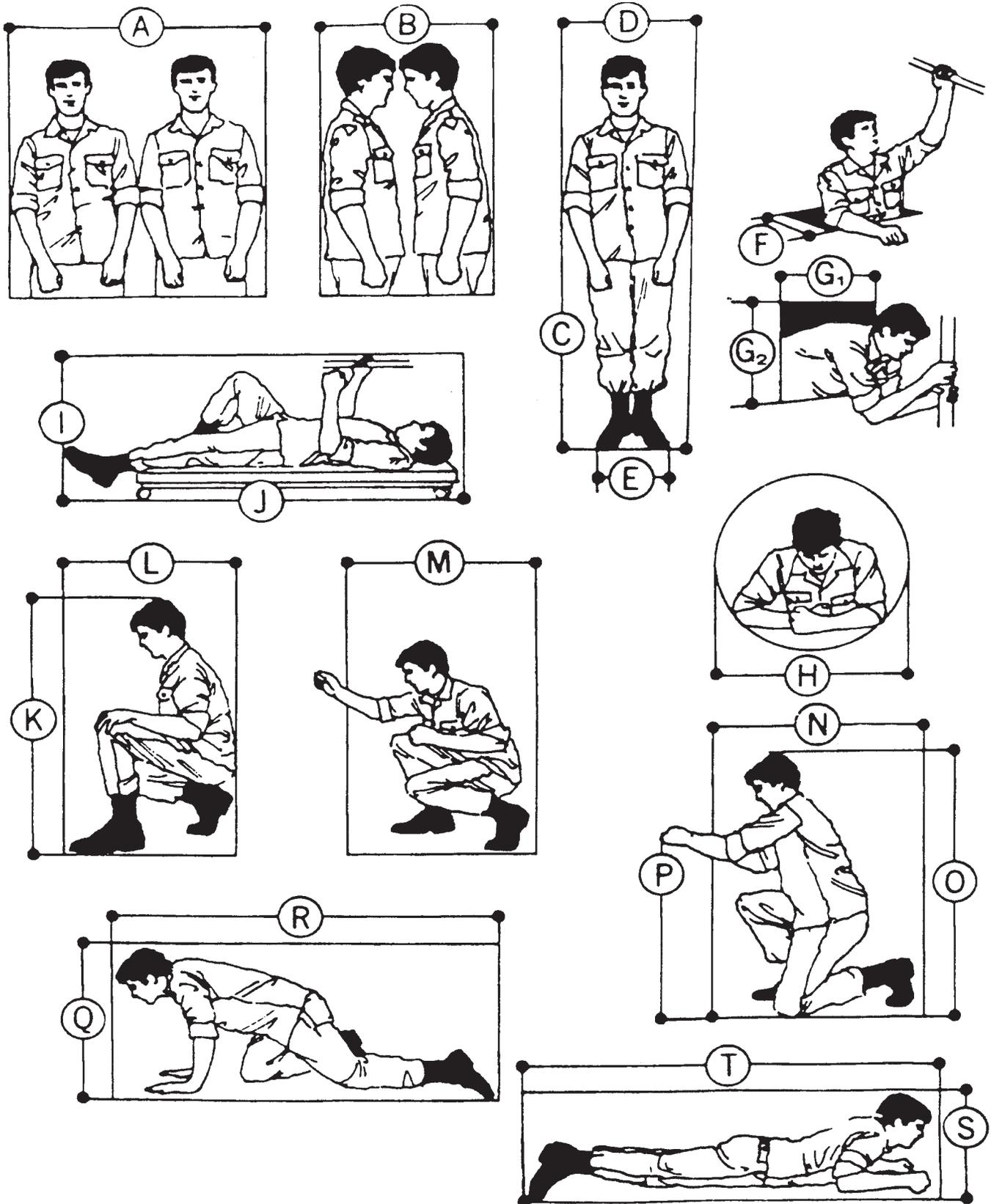


FIG. 64 Mobile Workspace Dimensions

(especially the emergency steering system) shall be installed so the operator faces forward (in the direction of vessel move-

ment). This shall be done whether or not the console operator has visual capability to the outside.



TABLE 24 Mobile Work Space Dimensions

	Minimum		Referred		Arctic Clothed	
	mm	(in.)	mm	(in.)	mm	(in.)
Passageway:						
A. Two men passing abreast	914	(36)	1370	(55)	1530	(60)
B. Two men passing facing	760	(30)	910	(36)	910	(36)
Catwalk dimension:						
C. Height	1600	(64)	1860	(75)	1910	(7)
D. Shoulder width	560	(22)	610	(24)	810	(32)
E. Walking width	305	(12)	380	(15)	380	(15)
Vertical entry hatch:						
F. Square	459	(18)	560	(22)	810	(32)
Round	560	(22)	610	(24)	...	...
Horizontal entry hatch:						
G1. Shoulder width	535	(21)	610	(24)	810	(32)
G2. Height	380	(15)	510	(20)	610	(24)
Crawl through pipe:						
H. Round or square	635	(25)	760	(30)	810	(32)
Supine work space:						
I. Height	510	(20)	610	(24)	660	(26)
J. Length	1860	(74)	1910	(74)	1980	(78)
Squatting work space:						
K. Height	1220	(48)	...	...	1290	(51)
L. Depth	685	(27)	910	(36)	...	...
M. Depth	660	(26)	1020	(40)	1220	(44)
Kneeling work space:						
N. Depth	1060	(42)	1220	(48)	1270	(50)
O. Height	1420	(56)	...	...	1500	(60)
P. Depth	...	...	685	27	...	...
Crawling space:						
Q. Height	785	(31)	910	(36)	965	(38)
R. Length	1500	(60)	...	...	1760	(70)
Prone work or crawl space:						
S. Height	430	(17)	510	(20)	610	(24)
T. Length	2860	(113)	...	...	...	...

31.6.2 *Auxiliary Machinery*—Consoles controlling auxiliary machinery (ship service generators) shall be oriented so that the operator faces forward. If there is more than one auxiliary machinery room, with a control console in each, all consoles shall face in the same direction (operator facing forward preferred).

31.6.3 *Damage Control, Ballast Control, and Other Consoles*—Ballast or damage control consoles shall be installed so that the operator faces forward or inward from the starboard side. Other consoles may be installed in a manner best suited to placing the controls and displays on the console so that they are in direct relationship to their respective equipment's location in the vessel.

31.7 Console Layout:

31.7.1 *Spatial Relationships*—Where a console contains controls and displays related to specific equipment located in a vessel, the location of the controls and displays on the console shall be in the same spatial relationship as the equipment they control or monitor. Therefore, controls and displays on the left side of the console shall be associated with equipment physically located to the left side of the console operator, and controls and displays on the right side of the console shall be associated with equipment physically located to the right side of the operator as the operator faces the console. Where a console is arranged so that the control and display arrangement correlates directly to equipment physically located in the vessel laid out from bow to stern, the controls and displays closest to the right side or top of the console shall control or monitor the

equipment closest to the bow. The controls and displays at the left side or bottom of the console shall control or monitor the equipment closest to the stern.

31.7.2 *Primary Displays*—The primary visual surface on consoles or instrument panels shall be reserved for displays that are used frequently or are critical to successful operation. In general, this area shall correspond to the preferred viewing area shown in Fig. 78.

31.7.3 *Design Principals Displays*—Consoles shall follow the design principals listed below:

31.7.3.1 Indicators used for long, uninterrupted periods shall be in the primary display area.

31.7.3.2 Preferred viewing distance from the operator's eyes to displays is 635 mm (25 in.).

31.7.3.3 Viewing distance to displays shall not be less than 250 to 300 mm (10 to 12 in.) for short viewing periods and preferably not less than 400 mm (16 in.).

31.7.3.4 Angular deviation from the operator's line of sight up to 0.79 rad (45°) for display location is acceptable provided accurate instrument reading is not essential and parallax is not great.

31.7.3.5 Displays shall be shaped and oriented so that they correspond with the direction and magnitude of what they are representing.

31.7.3.6 Digital displays shall be used only when exact values are required and rate of change information is not required.

31.7.4 *Design Principals, Controls*—The optimum space for locating controls on a console (for optimum speed and accuracy of manipulation) is shown in Fig. 79. Other principals include the following:

31.7.4.1 Primary controls shall be located between shoulder level and waist height.

31.7.4.2 Controls shall be located so that simultaneous operation of two controls will not necessitate a crossing or interchanging of hands.

31.7.4.3 When controls are operated frequently, they shall be located to the left front or right of the operator.

31.7.4.4 Frequently used controls shall be grouped together, unless there are overriding reasons for separating them.

31.7.4.5 Frequently used controls shall be located for right-hand operation.

31.7.4.6 Frequently used controls shall be within a radius of 400 mm (16 in.) from the normal working position.

31.7.4.7 Occasionally used controls shall be within a radius of 500 mm (20 in.).

31.7.4.8 Infrequently used controls shall be within a radius of 700 mm (28 in.).

31.7.4.9 The movement of controls related to the ship's motion shall correspond to the direction of desired motion.

31.7.4.10 All controls associated with ship movement shall be located so that the operator faces forward.

31.7.5 *Dual Operation*—Where two operators must use the same control or display (for example, in monitoring system status), the following criteria shall be applied:

31.7.5.1 If the controls and displays have high priority, duplicate sets shall be provided whenever there is adequate

TABLE 25 Standing Work Space Dimensions for Work Clearances

Work Clearances	Minimum		Preferred		Arctic	
	mm	(in.)	mm	(in.)	mm	(in.)
A ₁ . Standard bench height above floor	...	...	910	(38)	...	...
A ₂ . Podium height above floor	...	...	1040	(41)	...	...
B ₁ . Standard bench width above floor	...	...	990	(40)	...	...
B ₂ . Podium width above floor	...	...	910	(36)	...	...
C. Passing body depth	330	(13)	380	(15)	380	(15)
D. Working space	635	(25)	910	(36)	...	...
E. Foot space	100 × 100	(4 × 4)	...	...	...	...
F. Overhead clearance	1855	(73)	1950	(76)	2030	(80)
G. Overhead reach, max	...	...	685	(27)	635	(25)
H. Depth of reach, max	...	...	585	(23)	585	(23)
I. Walking width space	305	(12)	380	(15)	380	(15)
J. Passing body width	510	(20)	810	(32)	810	(32)

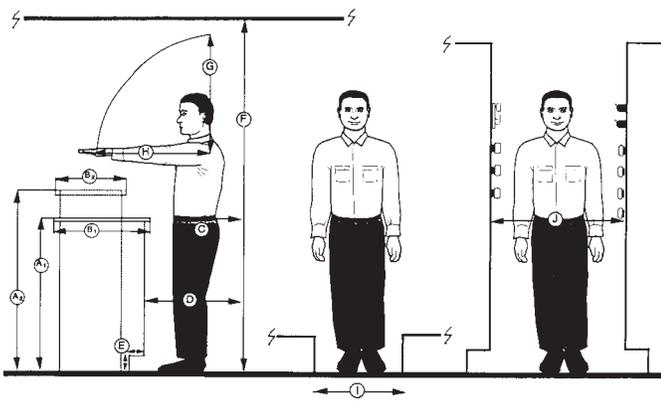


FIG. 65 Standing Workspace Dimensions—Cabinets and Electrical Equipment Racks

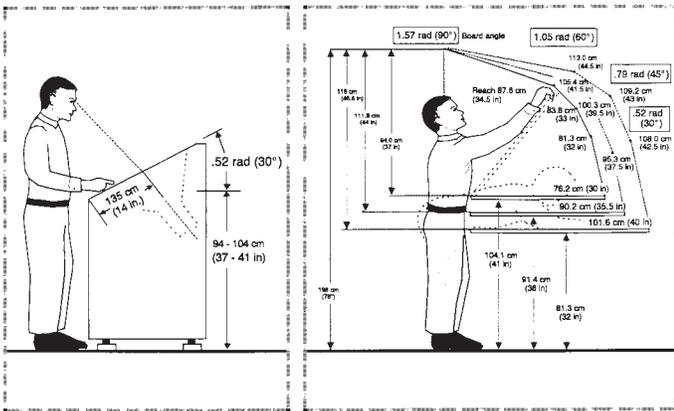


FIG. 66 Standing Workspace Dimension—CRTs and Table

space. Otherwise, controls and displays shall be centered between the operators.

31.7.5.2 If secondary controls and displays must be shared, they shall be centered between the operators if they are equally important to each operator. If the controls or displays are more important to one operator than to the other, they shall be placed nearest the operator having the principal requirements for using them.

31.7.5.3 If the primary or secondary controls must be operated with the user's preferred hand (keyboards, keysenders, and so forth), duplicate controls must be provided. Such controls shall not be centered between the operators.

31.7.5.4 Where personnel will work from standing or seated positions, console dimensions shall conform to those of Table 27. However, where smaller consoles are provided, operators shall be spaced no closer than the dimensions shown in Fig. 71.

31.7.6 *Sit-Stand Consoles*—Where personnel will work from standing or seated positions, console dimensions shall conform to those of Table 27.

31.8 *Stairs, Stair-Ladders, Fixed Ladders, and Ramps:*

31.8.1 *General Criteria:*

31.8.1.1 Stairs, stair-ladders, fixed ladders, and ramps shall be provided whenever personnel must abruptly change elevation by more than 305 mm (12 in.).

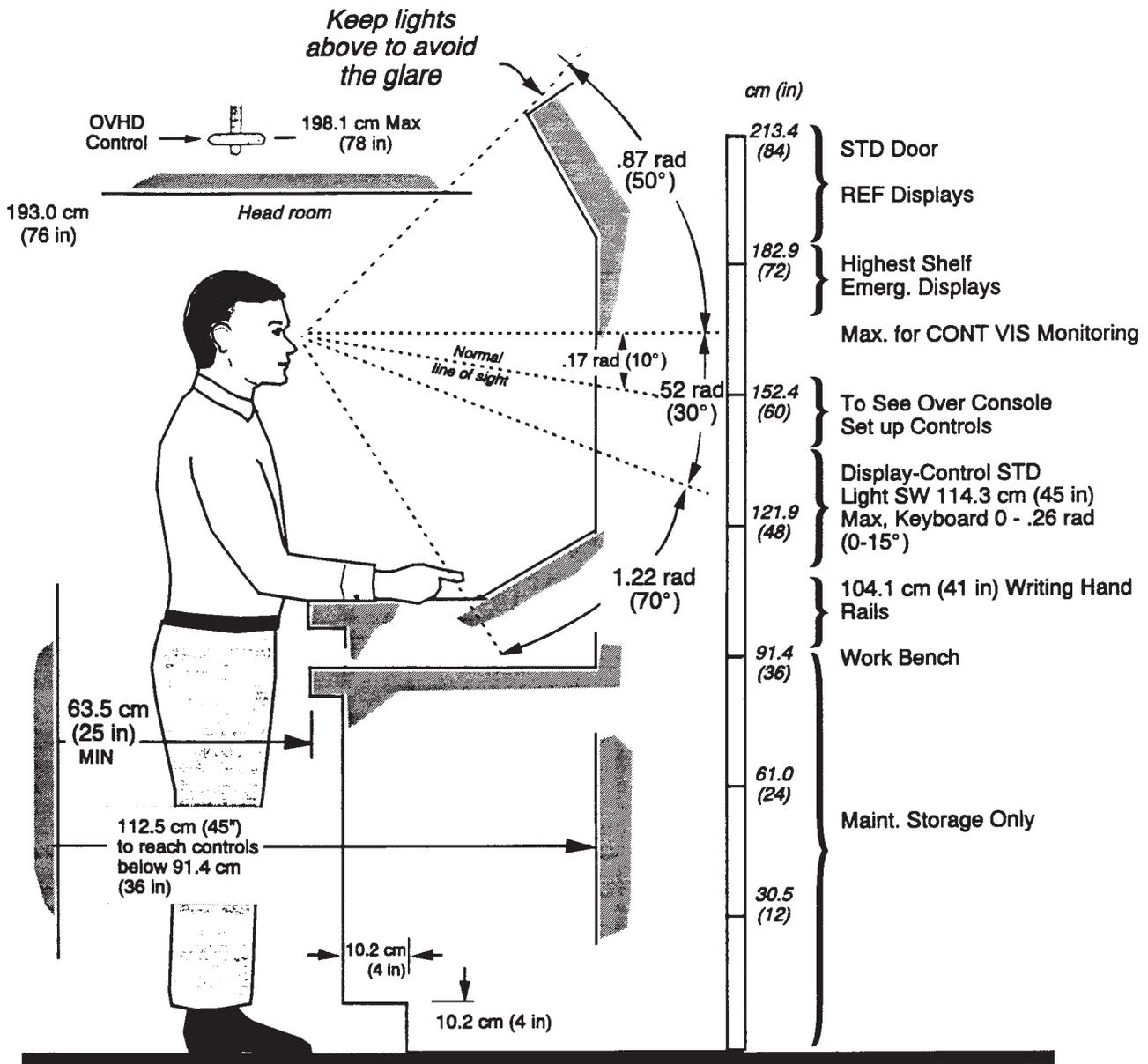
31.8.1.2 *Selection*—The selection of stairs, stair-ladders, fixed ladders, or ramps for specific applications shall be based on the angle of ascent required and the criteria in Fig. 80.

31.8.1.3 *Provision for Hand-Carrying Equipment*—Ramps, elevators, or equivalent means shall be provided when equipment must be hand carried. Ladders shall not be selected in such cases, since both hands shall be free to grasp the ladder. Stairs and steps shall not be used where hand-carrying bulky loads or loads in excess of 13 kg (29 lbs) is required.

31.8.1.4 *Handrails and Guardrails*—Stairs, stairladders, fixed ladders, and ramps shall be equipped with handrails or guardrails or both as described below:

(a) *Handrails*—A handrail shall be installed on the enclosed side and a guardrail installed on the open side. If both sides are enclosed, handrails shall be installed on both sides if the width of the stair, stair-ladder, or ramp is more than 1118 mm (44 in.). If both sides are open, guardrails shall be installed on both sides. Stairs with three or more steps shall be equipped with handrails or guardrails. Stairs wider than 224 cm (88 in.) shall be equipped with a handrail in the center. Handrails shall be circular, not square or rectangular, and shall be of a diameter and mounting height shown in Figs. 81 and 82.

(b) *Guardrails*—Guardrails shall be provided at the open side of any surface whenever that surface is 610 mm (24 in.) or higher above the adjacent surface and where a person could fall from the upper to lower surface. The height of all guardrails shall be 1067 mm (42 in.) from the centerline of the top rail to the top of the walking surface. Guardrails shall have at least one intermediate rail and a toe board at least 76 mm (3 in.) high. If one intermediate rail is used, it shall be equal distance between the bottom of the top rail and the top of the toe board. A clearance of 51 mm (2 in.) minimum, 76 mm (3 in.)



NOTE: Reduce height values 12.7 cm (5 in) for comfortable use by women.

FIG. 67 Standing Workspace Dimensions—Consoles and Work Benches

recommended, shall be provided between the back of the top rail and the nearest object. Any opening between adjacent guardrails or between a guardrail and permanent structure greater than 152 mm (6 in.) shall be protected with a chain at each rail height. The chains shall be taut enough so that no more than 25 mm (1 in.) of slack is measured at the chain's centerspan. Wherever there are changes in walking surface elevations, both of which are protected by guardrails, there shall be transition guardrails provided to protect a person

moving from one elevation to another. The transition guardrail may be provided in any manner as long as it maintains the 1067-mm (42-in.) height above the walking surface used to transition between the two walking elevations. If it is possible that material could be placed in an area protected by a guardrail to such a height that the toeboard would not prevent its passing through the guardrails and falling to a lower level, then between rail protection via expanded metal screen, netting, or

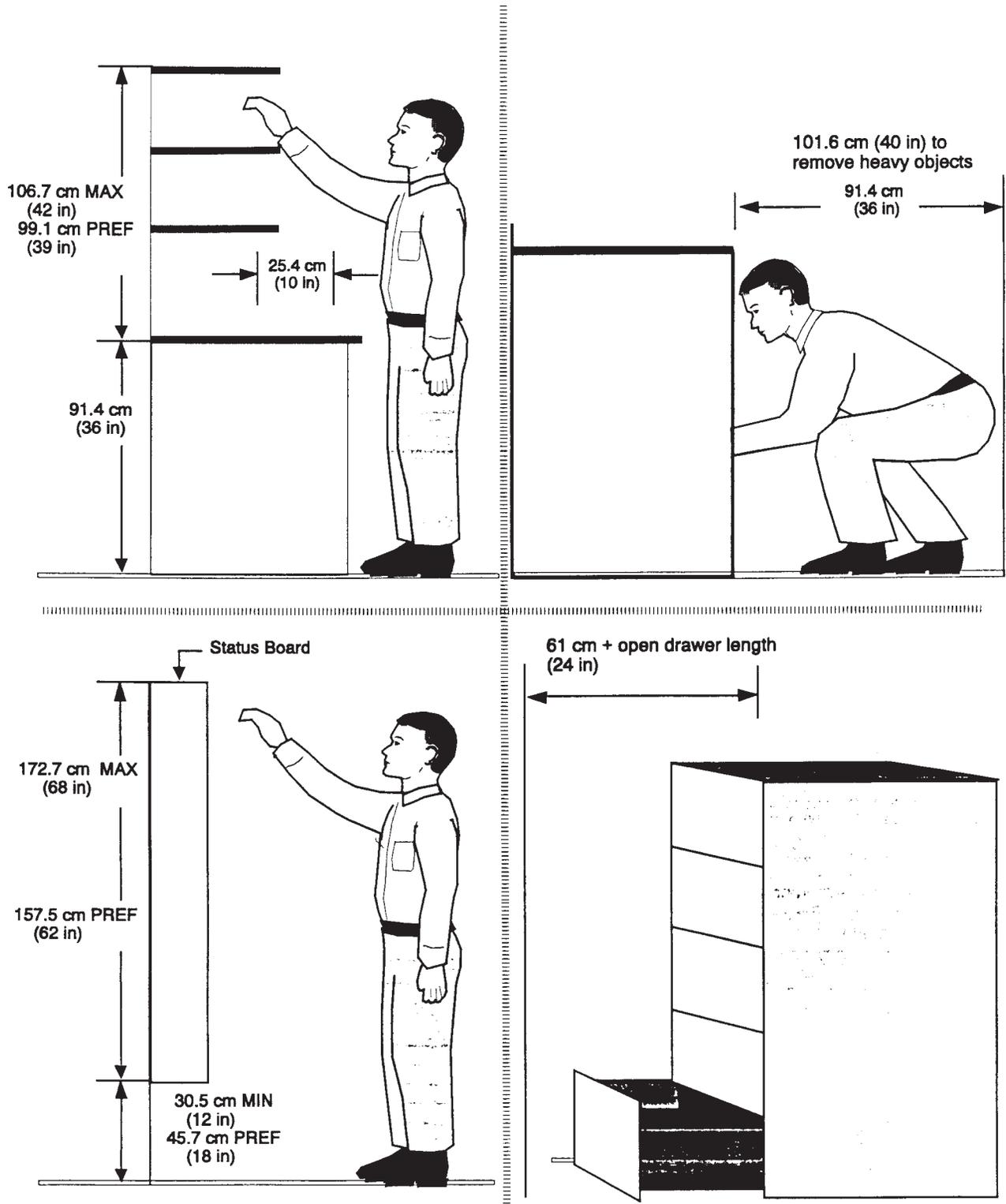


FIG. 68 Standing Workspace for Typical Work Positions

other suitable material shall be added between the rails to a height equal to that of the expected stacked material.

31.8.2 *Tread Color Marking*—25 mm (1 in.) at the leading edge of each tread and the face of the tread shall be painted red or yellow (yellow preferred) to make the front edge of each tread visually distinctive from the rest of the tread surface.

31.8.3 *Stairs*—Stair dimensions shall conform with the recommended values and shall be within the minimum and maximum limits of Fig. 81. Long flights of stairs shall be avoided. There shall be at least one landing for each story 2.44 to 3.66 m (8 to 12 ft) of elevation change, and landings are recommended every ten to twelve treads. Each landing shall be

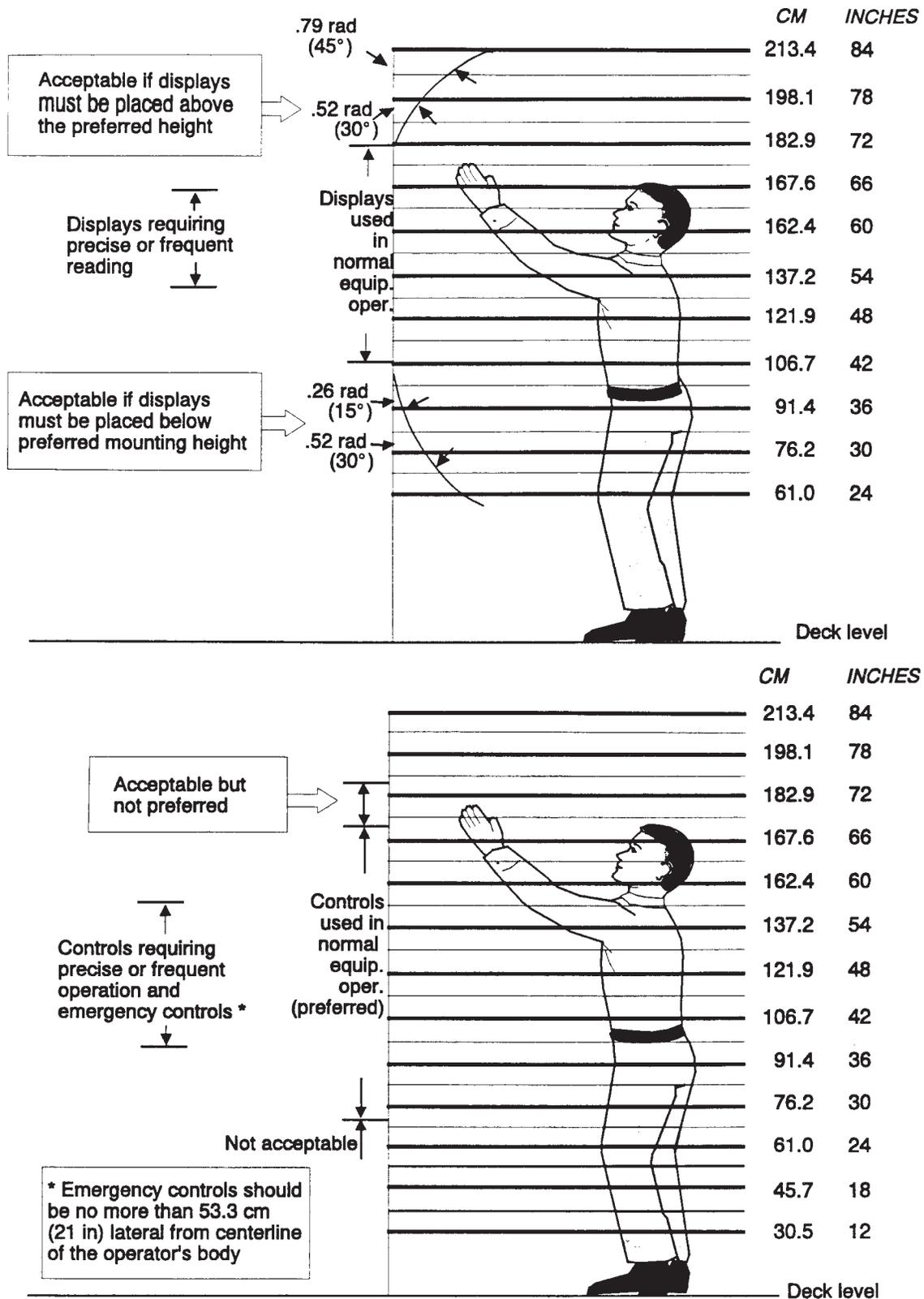


FIG. 69 Display (Top) and Control (Bottom) Locations for Standing Crew Work Stations

a minimum of the stairway width and a minimum of 915 mm (36 in.) and a maximum of 1220 mm (48 in.) long measured in the direction of travel. Treads shall be open unless screens or kick plates are required to protect personnel or equipment

under the stairs. When personnel carry loads weighing more than 9 kg (20 lbs), or where stairs are more than two stories high, use deep treads, 300 mm (12 in.) and low risers, 125 mm (5 in.).

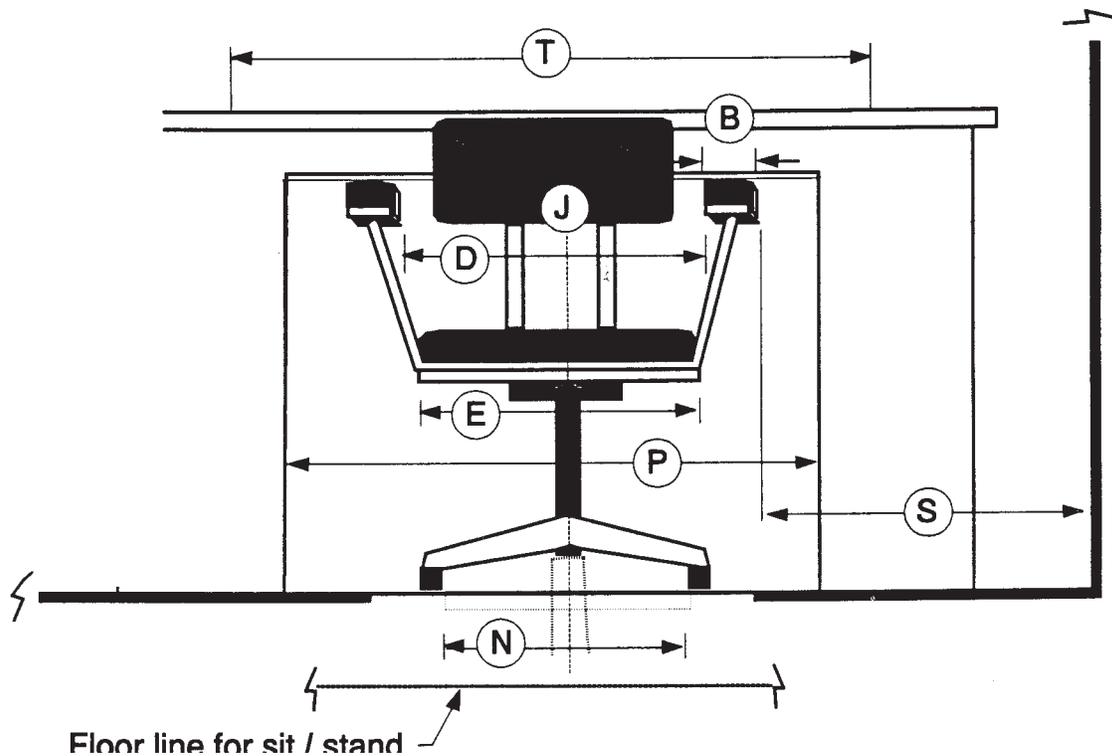
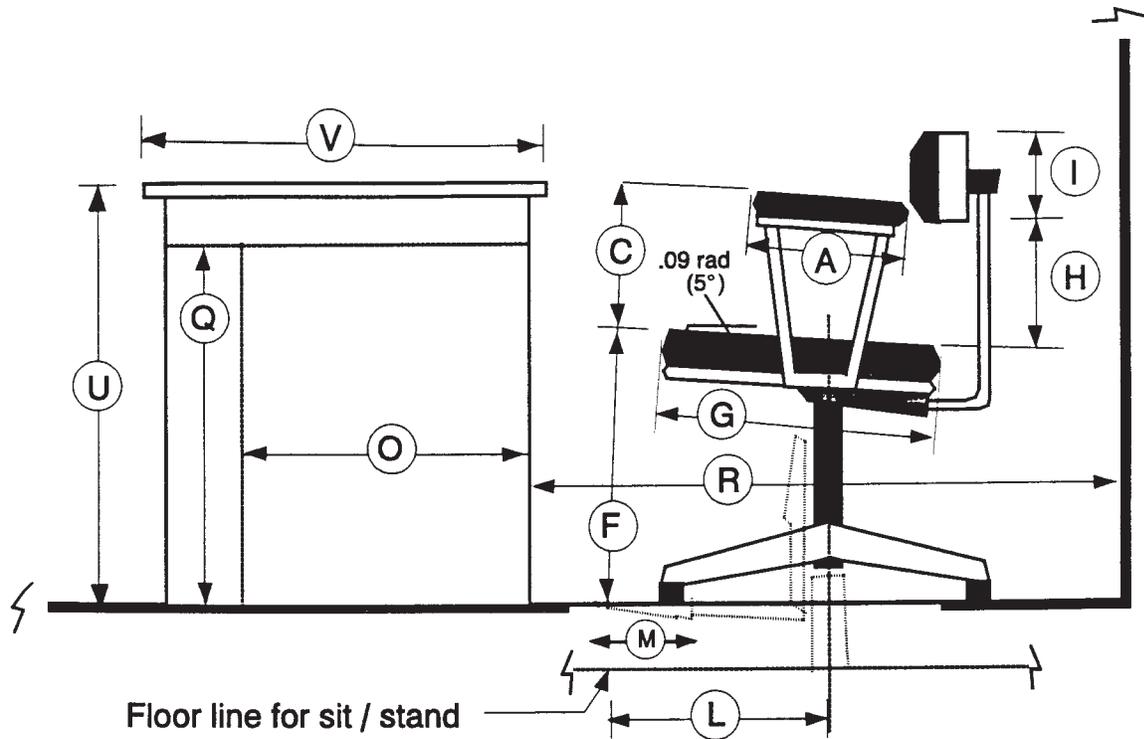


FIG. 70 Seated Workspace Dimensions

31.8.4 *Incline Ladders*—Incline ladder dimensions shall conform with the recommended values and shall be within the specified minimum and maximum limits of Fig. 82. The tread

rise shall be open at the rear. Landings shall be provided every tenth or twelfth tread. The surface of treads on exterior stair ladders shall be constructed of open grating material or shall be



TABLE 26 Seated Work Space Dimensions

Dimensions	Fixed		Adjust	
	mm	in.		
Chair	A. Length	25	10	
Arm rests:	B. Width	50	2	
	C. Height	215	8.5	
	D. Separation	460	18	
Seat:	E. Width	405	16	75 mm (3 in.)—in increments of no more than 25 mm (1 in.) each
	F. Height	460	18	
	G. Depth	405	16	
	H. Space	150	60	75 mm (3 in.)—in increments of no more than 25 mm (1 in.) each
Backrest:	I. Height		380	
	J. Width	405	165	
	L. From center	180	150	
Footrests:	M. Width	150	60	
	N. Length	255	105	
	Work space		minimum	preferred
	O. Knee hole depth	460	18	...
	P. Knee hole width	510	20	...
	Q. Knee hole height (standard office)	635	25	...
	R. Desk to wall	810	32	...
	T. Lateral work clearance	610	24	
	(1) Shoulders	585	23	
	(2) Elbows	635	25	
	(3) Best overall	1000	40	
	U. Height of work surface	735	29	760 mm (30 in.)
	V. Width of work surface			
	(1) Elbow rest alone	100	4	200 mm (8 in.)
	(2) Writing surface	305	12	405 mm (16 in.)
	(3) Desk work alone			910 mm (36 in.)

treated with nonskid material. Handrails shall have nonslip surfaces. Netting, or additional rails, shall be placed between the top handrail and step on all stair ladders located on the main deck or above and within 2.1 m (7 ft) from the edge of the ship.

31.8.5 *Vertical Ladders*—Vertical ladder dimensions shall conform with the recommended values and shall be within the specified minimum and maximum limits of Fig. 83 except that rung spacing shall be equal throughout the length of the ladder and the top rung shall be even with the top landing. Ladder stringers shall be 28 to 51 mm (1½ to 2 in.) in diameter. Flat bar shall not be used for ladder stringers.

31.8.5.1 *Ladder Clearances*—For ladders without cages, the minimum perpendicular horizontal clearance from the rung centerline to the nearest obstruction on the climbing side shall be 762 mm (30 in.). Overhead clearance above the top rung of the ladder shall be 2032 mm (80 in.). The minimum horizontal distance from the ladder centerline to the nearest obstruction on either side of a ladder shall be 381 mm (15 in.). The step-across distance from the back of the ladder rung to the nearest edge of the top landing shall be not less than 64 mm (2½ in.) nor more than 305 mm (12 in.).

31.8.5.2 *Ladder Heights*—Maximum heights of unbroken ladders shall be 9.12 m (30 ft). Where vertical ladder heights exceed 9.12 m (30 ft), intermediate landings and separate, multiple ladder runs of equal length shall be provided. Exceptions to this requirement are allowed where space does not provide for separate ladder runs, and approval is given by the organization or agency acquiring the ladders to waive this requirement, and the ladder is equipped with a positive climber fall protection device.

31.8.5.3 *Ladder Horizontal Spacing*—Horizontal spacing between ladder sections described above shall not exceed 457 mm (18 in.) at the point where the climber moves from one ladder section to another.

31.8.5.4 *Safety Gates*—A self-closing safety gate covering the full width of the vertical ladder opening shall be installed at the top of each vertical ladder.

31.8.5.5 *Ladders as Work Platforms*—Ladders attached to tanks, pressure vessels, structure, or any object to provide access to a work site that requires the worker to work from the ladder shall be equipped with either a dedicated work platform, a climber safety rail, or a permanent attachment point on the tank, vessel, or structure so the worker can safely secure himself with his climbing harness while completing his tasks.

31.8.5.6 *Special Ladder Requirements*—Any permanent vertical ladder, regardless of its height, located within 1.84 m (6 ft) of the edge of a deck level which is higher than 914 mm (36 in.) above an adjacent level (measured from the ladder centerline to the break in the deck elevations) shall be equipped with a climber fall safety device to prevent a worker from falling from the ladder to the lower level.

31.8.5.7 *Climber Fall Protection Device*—Climber fall protection devices shall be installed on all vertical ladders exceeding 4.45 m (15 ft), and positive protection devices (that is, safety rails, cables, bars) shall be installed on all vertical ladders 7.4 m (25 ft) or higher whether they are equipped with cages or not. Where cages are used, they shall extend 914 mm (36 in.) minimum and 1067 mm (42 in.) preferred above the top landing. Climber safety rails, cables, and bars shall run continuously beginning 914 mm (36 in.) above the standing surface at the bottom of the ladder to 1067 mm (42 in.) above the standing surface at the top landing.

31.8.6 *Steps*—Individual steps, comprised of a tread surface attached directly to a structure, may be used to change vertical elevations anywhere the total rise in height between waling surfaces does not exceed 610 mm (24 in.) and where a stair or ramp is not practical.

31.8.7 *Individual Ladder Rungs*—Individual circular bar rungs may be attached directly to a bulkhead, tank, or steel structure and used as a vertical ladder provided that the change in vertical height is 3 m (10 ft) or less and that all design requirements for vertical ladder rungs provided in Fig. 83 are satisfied.

31.8.8 *Stair and Ladder Attachment*—Stairs and ladders may be pinned at the top and bottom for easy removal in locations where their removal would enhance ease of equipment removal for maintenance or replacement. However, stairs or ladders that serve as a required means of egress in emergencies shall be permanently installed.

31.8.9 *Spiral Stairs*—Spiral stairs shall not be permitted except on tanks or other round structures whose diameter is greater than 2.4 m (8 ft) and when a normal stair design is not practical.

31.8.10 *Ramps*:

31.8.10.1 *Cleating*—Where special environmental conditions require cleating of pedestrian ramps, the cleats shall be spaced 360 mm (14 in.) apart and extend from handrail to handrail at right angles to the line of traffic.

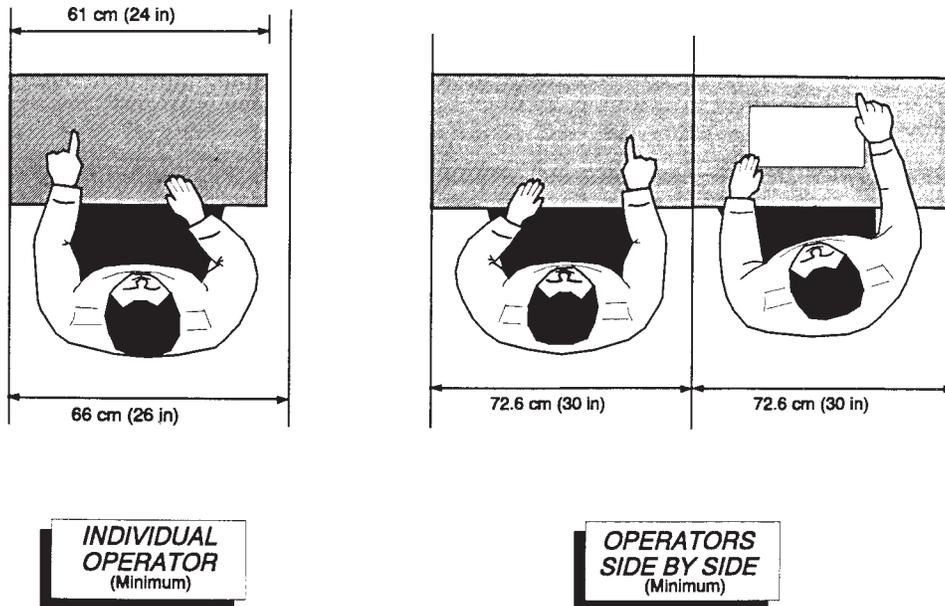


FIG. 71 Dimensions for Single or Multiple Personnel at a Table or Other Duty Station Not Requiring a Desk

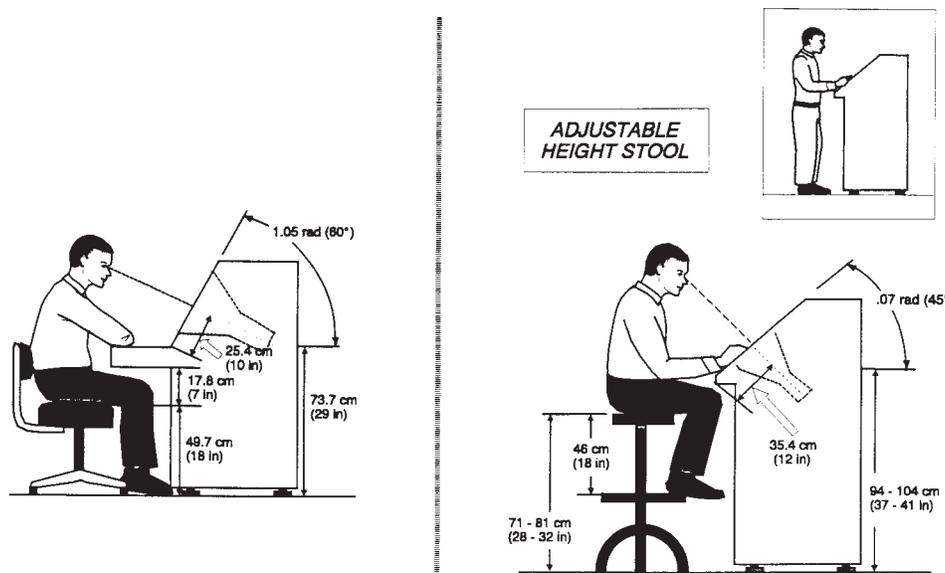


FIG. 72 Seating at CRT-Type Work Stations

31.8.10.2 *Mixed Traffic*—When a ramp is required for both pedestrian and vehicle traffic, the vehicle-bearing surface shall be located in the center of the ramp, with the pedestrian surface next to the handrails. (A vehicle ramp with an adjacent pedestrian stairway is preferred for this situation.) From the standpoint of space and speed, stairways carry pedestrian traffic more efficiently than ramps do.

31.8.11 *Personnel Platforms and Work Areas*—The surfaces of exterior personnel platforms and work areas shall be constructed of open metal grating. Exterior personnel platforms, for which utilization of open grating is impractical, and interior walkways shall be treated with nonskid material. All open sides of personnel platforms shall be equipped with guardrails (with intermediate rails), with a top rail height not less than 1.070 m (42 in.) and a toeboard or guard screen height

not less than 75 mm (3 in.). Handholds shall be furnished where needed. The distance between the platform edge and the centerline of the railing shall not exceed 65 mm (2.5 in.).

31.8.12 *Elevated Work Platform*—Where these items are required, the following shall be provided:

31.8.12.1 Maximum load signs, located where they can be easily seen.

31.8.12.2 Guards, to prevent accidental operation of the lift.

31.8.12.3 Limit stops, to prevent injury to personnel and damage to equipment.

31.8.12.4 An automatic failsafe brake or other self-locking device in case of lift mechanism failure.

31.8.12.5 Provision for manually lowering the platform or elevator when feasible.

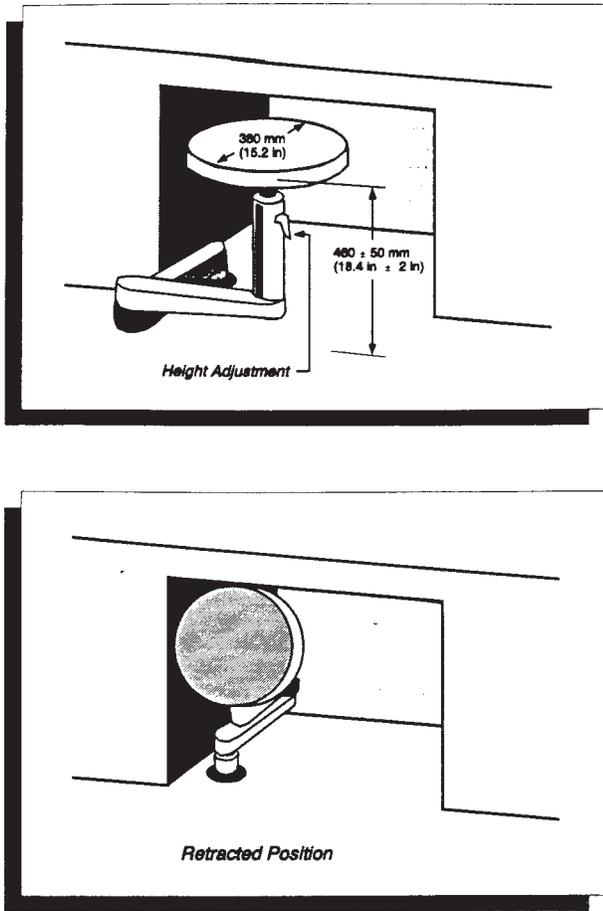
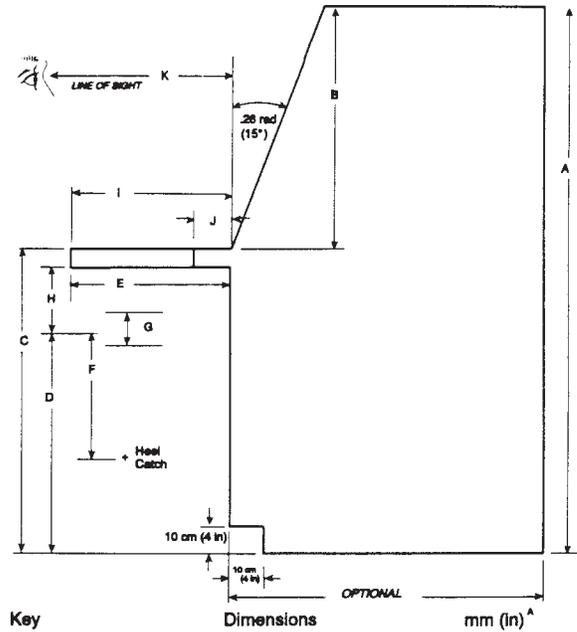


FIG. 73 Swingaway Seat for Short-Term Operations



Key	Dimensions	mm (in) ^A
A	Minimum total console height from standing surface	...
B	Suggested vertical dimension of panel, including sills	...
C	Writing surface: shelf height from standing surface	...
D	Seat height from standing surface at midpoint of "G"	...
E ^B	Minimum knee clearance	460 (18)
F ^B	Foot support to sitting surface	460 (18)
G ^B	Seat adjustability	150 (6)
H ^B	Minimum thigh clearance at midpoint of "G"	190 (7.5)
I	Writing surface depth including shelf	400 (16)
J	Minimum shelf depth	100 (4)
K	Eye line-to-console front distance	400 (16)

^A For A through D, see Table 26.
^B Not applicable to console Types 4 and 5 of Table 26.
^C Since this dimension must not be exceeded, a heel catch must be added to the chair if "D" exceeds 400 mm (18 in).
 NOTE- A shelf thickness of 25 mm (1 in) is assumed. For other shelf thicknesses, suitable adjustments should be made.

FIG. 74 Standard Console Dimensions Key

31.8.12.6 Surface construction or treatment of open platforms, in accordance with 31.8.11.

31.8.12.7 Provision of a work space at least 762 mm (30 in.) wide and 915 mm (36 in.) long.

31.8.12.8 Ability to hold one or two persons (not more than two).

31.8.12.9 Ability to hold the heaviest combination of equipment and personnel (use 250 lbs (118.4 kg)) for each person. A well-designed work platform is shown in Fig. 84.

31.8.12.10 Work platforms shall be located whenever possible so the worker performs his task at the height of 965 to 1270 mm (38 to 50 in.) above the standing surface of the platform.

31.9 Ingress and Egress:

31.9.1 Doors—Sliding or vertical doors are recommended for large vehicles, pieces of equipment, or cargo that must be moved into or out of a compartment. Separate hinged doors shall be inserted into the sliding or vertical doors for personnel use. However, vertical or sliding doors must never be the only exit from an area. There must always be another way to escape. Door dimensions shall be as shown in Fig. 85.

31.9.2 Hatches—Hatches shall be flush with the floor where structural considerations will permit this arrangement.

31.9.2.1 Operation—Hatches shall open with a single motion of the hand or foot.

31.9.2.2 Force Requirements—When a handle is used for unlocking a hatch, the unlocking force required shall not exceed 90 N (20 lbs). Hatches placed in the overhead position shall require no more than 220-N (50-lbs) force for opening and closing and shall be operable by a suitably equipped and clothed user with fifth percentile arm and hand strength. The force of gravity shall be used, where possible, for ease of opening.

31.9.2.3 Locking Mechanisms—Hatches shall have a locking mechanism such that the hatch is locked in the open position as soon as the hatch opens 1.57 rad (90°). The latching mechanism shall require a deliberate effort by a crew member to override before the hatch can be closed. Further, the locking mechanism shall be designed so that the hatch cannot close inadvertently during severe ship motion or wear on the locking mechanism.

31.9.2.4 Access—When an overhead hatch is reached via a ladder, the edge of the hatch opening shall be no more than 203 mm (8 in.) from the face of the ladder rung (see Fig. 86). Hatches mounted in vertical walls shall be sized and located as shown in Fig. 87.

TABLE 27 Standard Console Dimensions

Type of Console	Maximum Total Console Height from Standing Surface		Suggested Vertical Dimension of Panel (Including Sills)		Writing Surface: Shelf Height from Standing Surface		Seat Height from Standing Surface at Midpoint of G		Maximum Console Width (Not Shown)	
	A		B		C		D		E	
	m	(in.)	mm	(in.)	mm	(in.)	mm	(in.)	mm	(in.)
1. Sit (with vision over top) ^A	1.170	(46.0)	520	(20.5)	650	(25.5)	435	(17.0)	1120	(44.0)
	1.335	(52.5)	520	(20.5)	810	(32.0)	595	(23.5)	1120	(44.0)
	1.435	(56.5)	520	(20.5)	910	(36.0)	695	(27.5)	1120	(44.0)
2. Sit (without vision over top)	1.310	(51.5)	660	(26.0)	650	(25.5)	435	(17.0)	910	(36.0)
	1.470	(58.0)	660	(26.0)	810	(32.0)	595	(23.5)	910	(36.0)
3. Sit-stand (with standing vision over top)	1.570	(62.0)	660	(26.0)	910	(36.0)	695	(27.5)	910	(36.0)
	1.535	(60.5)	620	(24.5)	910	(36.0)	695	(27.5)	910	(36.0)
4. Stand (with vision over top)	1.535	(60.5)	620	(24.5)	910	(36.0)	NA	NA	1120	(44.0)
5. Stand (without vision over top)	1.830	(72.0)	910	(36.0)	910	(36.0)	NA	NA	910	(36.0)

^AThe range in "A" is provided to allow latitude in the volume of the lower part of the console; note relationship to "C" and "D."

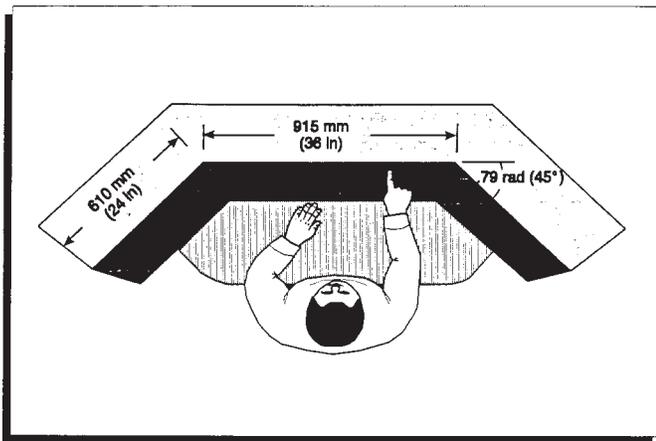


FIG. 75 Example of One- or Two-Tier Wraparound Console

31.9.2.5 *Dimensions*—Hatches shall be sized and located to accommodate the suitably equipped and clothed fifth to ninety-fifth percentile user. Recommended hatch dimensions are shown in Fig. 88 and shall be used unless otherwise specified.

31.9.2.6 *Kick-Out Hatches*—Emergency escape kick-out hatches shall be provided in spaces where it is impractical or impossible to provide a second door or hatch for emergency escape. The kick-out panels shall be clearly marked on both sides, and shall not be covered by furniture, cabinets, equipment, or any other item that could prevent direct and unobstructed access to the panel. Kick-out panels shall be sized and located to accommodate the fifth to ninety-fifth percentile person easily, but in no case shall they be smaller than 725 mm (29 in.) wide and 850 mm (34 in.) high.

31.9.2.7 *Whole-Body Access*—Where rescue of personnel may be required because of environmental hazards (for example, toxic fumes) within the work place, larger access openings for two-person ingress and egress may be necessary. Where step down through a top access exceeds 690 mm (27 in.), appropriate foot rests or steps shall be provided.

31.9.3 *Passing Openings*—Openings provided between compartments for passing printed information by a seated operator shall be between 610 to 635 mm (24 to 25 in.) above the deck. For standing operators, they shall be 920 to 1520 mm (36 to 60 in.) above the deck.

31.10 *Walkways and Passageways:*

31.10.1 *Dimensions*—In machinery spaces, store rooms, and other areas of limited space, the following dimensions shall be provided for walkways and passageways:

31.10.1.1 For one person to walk sideways, 330 mm (13 in.), 410 mm (16 in.), when wearing bulky clothing.

31.10.1.2 For one person to walk forward, minimum walking envelope is shown in the top illustration of Fig. 89. However, where grated walkways or passageways are provided, they shall be at least 510 mm (20 in.) wide and 760 mm (30 in.) if possible. Major passageways for two-way pedestrian traffic shall be a minimum of 914 mm (36 in.) wide. No items (for example, circuit breakers, electrical junction boxes, battle lanterns, and so forth) shall be mounted on the walls or bulkheads of these passageways to reduce the effective width of the passageway less than 914 mm (36 in.). If such items must be mounted to a bulkhead, they shall be mounted as shown. Every effort shall be made to install items 1960 mm (77 in.) or more above the standing deck level. T-butt and other deck mounted equipment with raised foundations shall be recessed into the walkway grating whenever clear walkway widths would be less than 914 mm (36 in.) with the raised foundations.

31.11 *Miscellaneous Work Station Design Requirements:*

31.11.1 *Hand Pumps*—Hand pumps shall be installed so the lowest point of travel for the handle is no lower than 635 ± 25 mm (25 ± 1 in.), nor higher than 1168 ± 25 mm (46 ± 1 in.) above the level on which the pump operator stands. Gratings or other permanent footing shall be provided in front of hand pumps. Hand pumps shall be located so that no obstacles (equipment, piping, guardrails, rotating shafts, and so forth) are between the pump and the pump operators. Where a hand pump is capable of, or required, to be operated by two persons simultaneously, provide sufficient room for both operators to work. Hand pumps shall be located so that the pump face is parallel with the operator's body (the operator faces the pump handle). Clearance shall be provided around the pump to permit the operator's body to move during the cranking operation.

31.11.2 *Phone Booths*—Phone booths shall be turned so the opening is at least 1.57 rad (90°) from the noise source. Desk surface of phone booths shall be 94 to 104 cm (37 to 41 in.) above the standing surface. A minimum of 46-cm (18-in.) clearance between the booth face and any obstruction in front of the booth shall be provided.

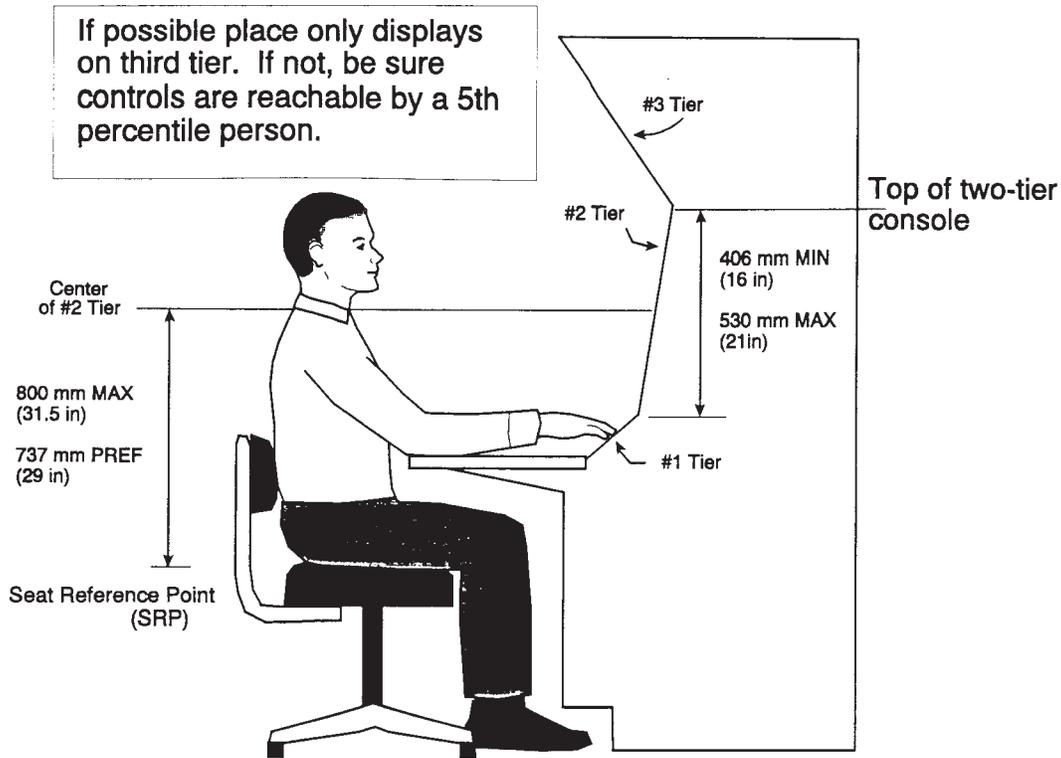


FIG. 76 Examples of Three-Tier Consoles

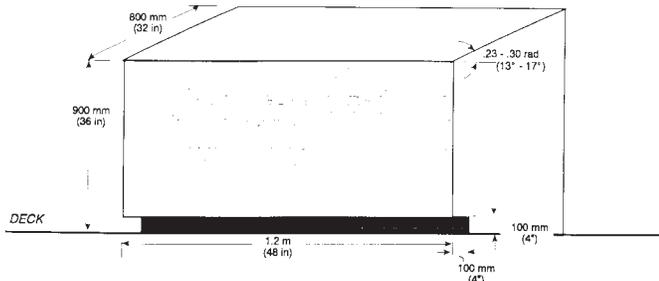


FIG. 77 Example of a Desktop Console

31.11.3 Deck Machinery Control:

31.11.3.1 *Control Pedestals*—Controls mounted on pedestals shall be 104 cm (41 in.) above the deck. Control pedestals for boat davit operation shall be located so that the operator faces the davit but within 76 cm (30 in.) of the emergency brake on boat davit wrench. The pedestal shall be located so that the operator can see the boat in the water.

31.11.3.2 *Stores and Cargo Handling*—Doors at the load-unload stations for vertical package conveyors, dumbwaiters, and elevators shall open 2.09 rad (120°). Control stations for elevators, package conveyors, and dumbwaiters shall be located on the side of the door opposite the hinges, or above the door opening, and shall be placed so that the operator has an unobstructed view into the trunk when the doors are open. For double-door elevators, the controls shall be located so that the operator has direct access to the emergency shutoff button with the doors open, yet allows the operator to see into the trunk with the doors open. Control stations shall be mounted so that no control is less than 102 cm (40 in.), or more than 152 cm (60

in.), above the deck (for control stations located beside the door) and no higher than 193 cm (76 in.) for stations placed above the door.

31.11.3.3 *Emergency Stop Buttons*—Emergency stop buttons for deck cranes elevators, vertical package conveyors, and other similar machinery shall be mounted between 114 cm (45 in.) and 135 cm (53 in.) above the deck. They shall be red in color, clearly labeled, and free of any nearby obstructions.

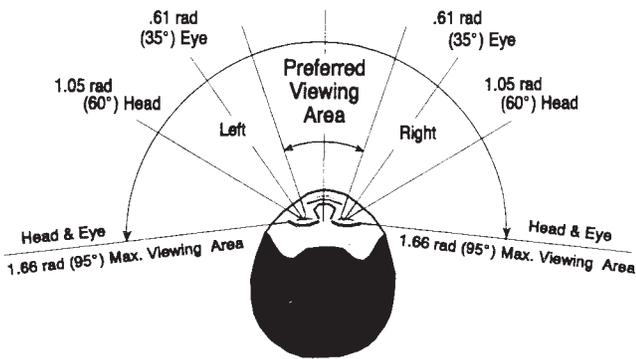
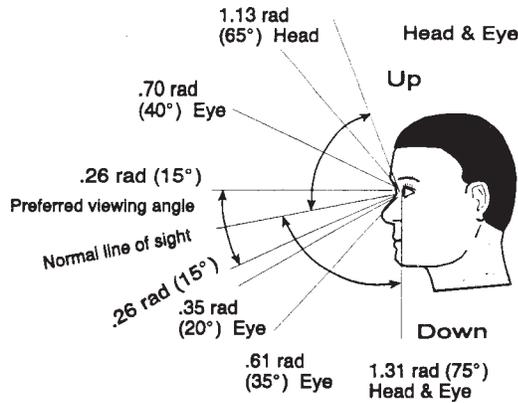
31.11.3.4 *Anchor Controls*—Speed and brake handwheel controls shall be between 102 to 107 cm (40 to 42 in.) above the deck and at least 61 cm (24 in.) from adjacent ship structures, pipes, and so forth. A 97-cm (38-in.) high safety shield shall be installed between the controls and anchor windlass and capstan.

31.11.3.5 *Shore Power Connectors*—Shore power connectors shall be no higher than 165 cm (65 in.) above the deck. Connector cables shall be stored as close to the connectors as possible and at least on the same deck level.

31.12 *Colors*—Bulkhead, deck, overhead, and furnishing colors shall be selected on the basis of such factor as ease of maintenance, function of room (sleeping, eating, recreating, and so forth), and size and location of space. All colors shall conform to FED-STD-595. Well-established negative mood-setting colors such as red, pink, and black shall not be used.

32. Environment

32.1 *General*—To maximize the effectiveness of the human operator/maintainer, the designer must consider the environmental limits to which the system and the human being will be subjected and the potential impact this environment can have on the performance of both the hardware and the human. Once



	PREFERRED rad (degrees)	EYE ROTATION ONLY rad (degrees)	MAXIMUM* HEAD ROTATION rad (degrees)	HEAD AND EYE ROTATION rad (degrees)
UP	.26 (15)	.70 (40)	1.13 (65)	1.57 (90)
DOWN	.26 (15)	.35 (20)	.61 (35)	1.48 (85)
RIGHT	.26 (15)	.61 (35)	1.05 (60)	1.66 (95)
LEFT	.26 (15)	.61 (35)	1.05 (60)	1.66 (95)

* Display area on the console defined by the angles measured from the Normal Line of Sight.

FIG. 78 Preferred Viewing Area

the designer has identified the limits of the environment (noise, temperature, fumes, vibration, and so forth), the information contained herein shall be used to determine if, and to what extent, the human being can perform the required tasks.

32.2 Temperature:

32.2.1 *Effective Temperature Defined*—The effective temperature (ET) of an environment is an empirical thermal index that considers how combinations of dry-bulb air temperature, humidity, air movement, and clothing affect people. This temperature may be read from Fig. 90. This chart is based on wearing customary indoor clothing and doing sedentary or light muscular work. It does not include any additional heat stresses from special purpose clothing such as gas masks, chemical protective clothing, or body armor. Likewise, it does not consider radiant heat inputs such as radiation from the sun or equipment components.

32.2.1.1 *Maximum Effective Temperature (Air Conditioning)*—A maximum effective temperature of 29.5°C (106.5°F) shall be considered for reliable human performance. When air-conditioning systems are necessary to obtain this temperature, they shall be designed such that cold-air discharge is not directed on personnel. The flow of cold air passing the person shall be between 9.1 to 13.7 m (30 to 45 ft) per minute.

32.2.1.2 *Minimum Effective Temperature (Heating)*—Minimum temperature requirements are dependent upon the tasks to be performed in specific applications. However, within permanent and semipermanent facilities, an effective temperature (ET) of not less than 18°C (65°F) shall be maintained unless dictated otherwise by heavy workload or extremely heavy clothing. When heating systems are provided to maintain this minimum effective temperature, they shall be designed so hot air is not directly discharged on the personnel. Heating shall be provided within mobile personnel enclosures used for detailed work or occupied during extended periods of time to maintain interior dry bulb temperature above 10°C (50°F).

32.2.2 *Optimum Effective Temperatures*—For maximum physical comfort while normally dressed appropriate to the season climate, the optimum range of effective temperature for accomplishing light work shall be the following:

32.2.2.1 In a warm climate or during summer, 21 to 24°C (70 to 75°F).

32.2.2.2 In a colder climate or during winter, 18 to 21°C (64 to 70°F).

32.2.3 *Temperature Variance*—The temperature of the air at floor level and at head level shall not differ by more than 5.5°C (10°F). Sidewalls of a compartment shall be kept at equal temperatures insofar as possible with differences of 52°F (11°C) being the maximum allowed.

32.2.4 The effect of temperatures on the physical and mental performance of human beings is shown in Tables 28-30.

32.3 *Humidity*—Humidity shall be maintained between 20 and 60 % with 40 to 45 % preferred. A good design goal is 45 % relative humidity provided at 21°C (70°F). This value shall decrease with rising temperatures, but shall remain above 20 % to prevent irritation and drying of body tissues, eyes, skin, and respiratory tract. Tolerable humidity-temperature zones are shown in Fig. 90.

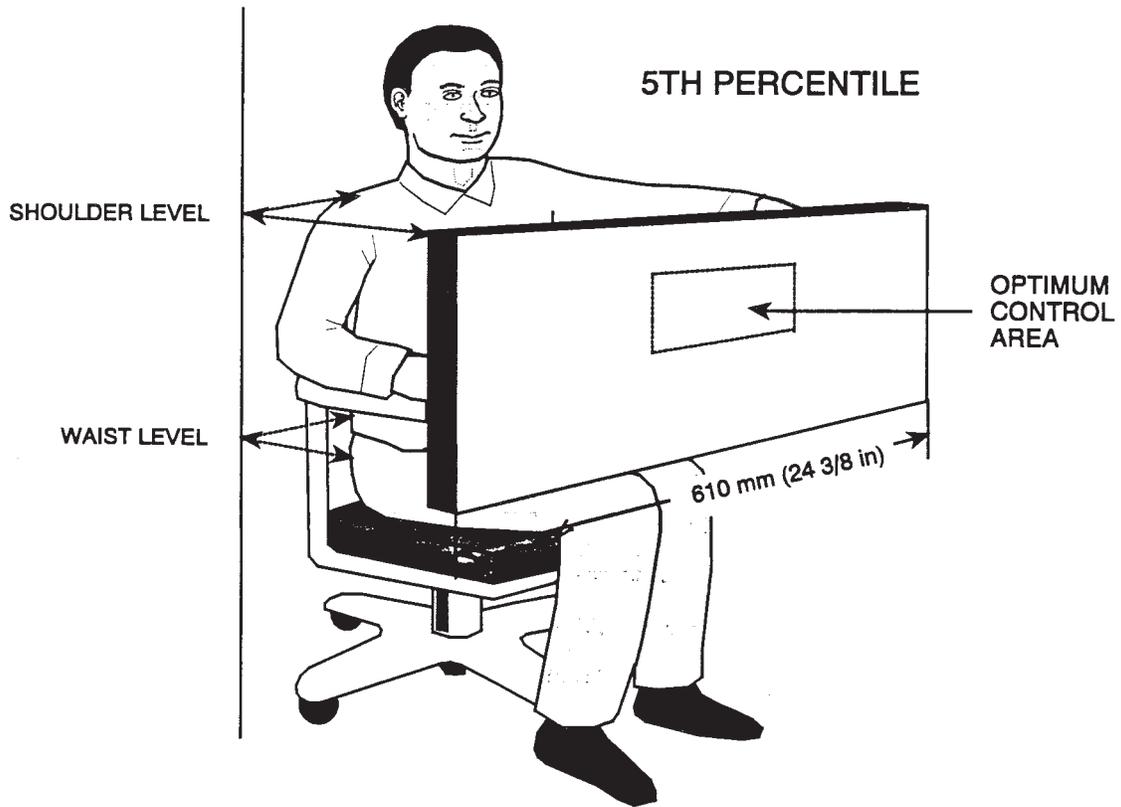
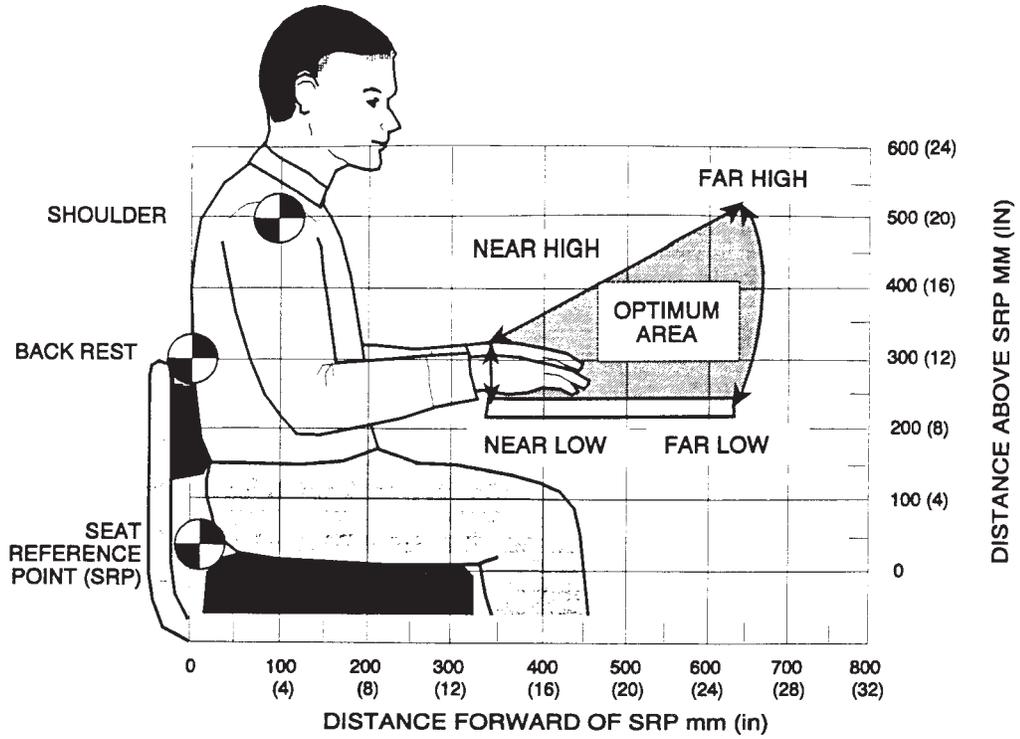


FIG. 79 Seated Optimum Manual Control Space

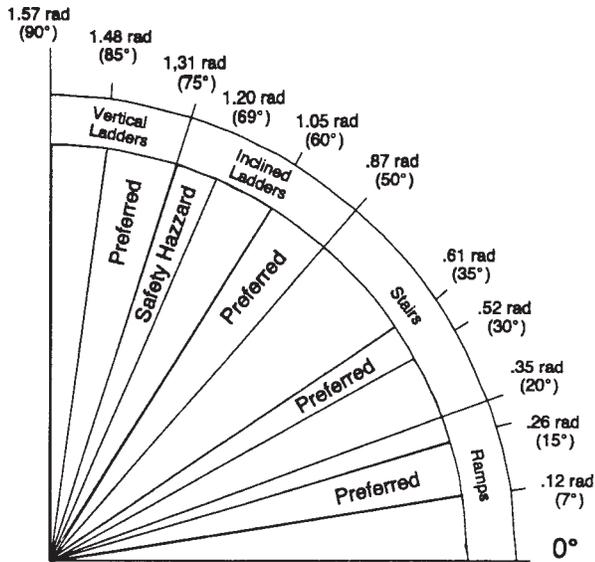
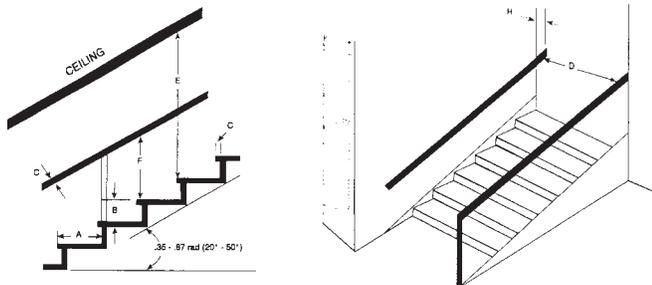


FIG. 80 Type of Ladder, Stair, or Ramp to be Used in Relation to Angle of Ascent

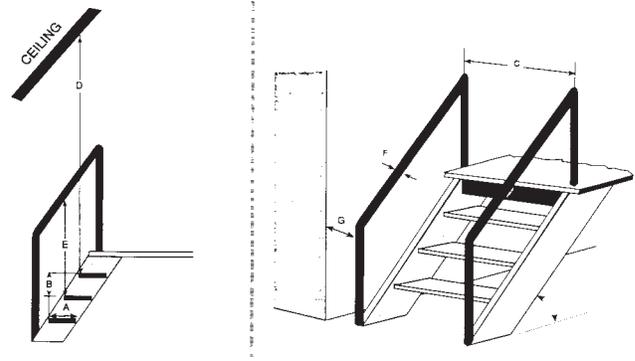


DIMENSION	MINIMUM mm (in)	MAXIMUM mm (in)	RECOMMENDED mm (in)
A. Tread depth (including nosing)	240 (9 1/2)	300 (12)	280-300 (11-12)
B. Riser Height	125 (5)	200 (8)	165-180 (6 1/2-7)
C. Depth of nosing (where applicable)	19 (3/4)	38 (1 1/2)	25 (1)
D. Width (handrail to handrail):			
One-way stairs	760 (30)	—	910 (36)
Two-way stairs	1220 (48)	—	1300 (51)
E. Overhead Clearance	1981 (78)	—	2032 (80)
F. Height of handrail (from leading edge of tread)	760 (30)	910 (36)	840 (33)
G. Handrail diameter	32 (1 1/4)	75 (3)	38-51 (1 1/2-2)
H. Rail clearance from wall	45 (1 3/4)	—	75 (3)

FIG. 81 Stair Dimensions

32.4 *Wind and Windchill*—Fig. 91 depicts the relationship between temperature and wind for various windchill values. Fig. 92 gives the cooling power of wind expressed as “Equivalent Chill Temperature.” Frostbite can occur even in relatively warm temperatures if wind penetrates the layer of insulating air around the body to expose body tissue. A qualitative description of human reaction to windchill values to exposed skin is given in Table 31.

32.5 *Thermal Tolerance and Comfort Zones*—Temperature and humidity exposure shall not exceed the effective temperature limits given in Fig. 90 when corrected for air velocity (Fig. 91).



	MINIMUM mm (in)	MAXIMUM mm (in)	RECOMMENDED mm (in)
A. Tread depth range:			
For .87-1.05 rad (50-60°) rise	150 (6)	250 (10)	215 (8 1/2)
For 1.20-1.31 rad (69°-75°) rise (open ladders only)	75 (3)	140 (5 1/2)	100 (4)
B. Riser Height	180 (7)	300 (12)	230 (9)
C. Width (handrail to handrail)	530 (21)	610 (24)	560 (22)
D. Overhead clearance*	1930 (76)	—	2032 (78)
E. Height of handrail (from leading edge of tread)	860 (34)	940 (37)	890 (35)
F. Handrail diameter	32 (1 1/4)	75 (3)	38-51 (1 1/2-2)
G. Rail clearance from wall	50 (2)	—	75 (3)

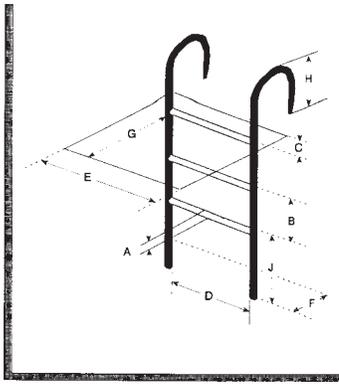
*Whenever the distance D is less than 1.880 m (74 in), the overhead obstruction should be painted with yellow and black stripes.

FIG. 82 Incline-Ladder Dimensions

32.6 *Personal Equipment Thermal Control*—When special protective clothing or personal equipment, including full and partial pressure suits, fuel handler suits, body armor, arctic clothing, and temperature-regulated clothing are required and worn, a comfort microclimate between 20°C (68°F), 14-mm (0.6-in.) mercury ambient water vapor pressure and 35°C (95°F), 3-mm (0.1-in.) mercury ambient water vapor pressure is desirable and, where possible, shall be maintained by heat transfer systems.

32.7 *Limited Thermal Tolerance Zones*—Where hard physical work is to be required for more than 2 h, an environment not exceeding a WBGT or WD index of 25°C (77°F) shall be provided. Where the wearing of protective clothing systems (which reduce evaporation of sweat from the skin) is required, this index shall be decreased 5°C (10°F) for complete chemical protective uniforms, 4°C (7°F) for intermediate clothing systems, and 3°C (5°F) for body armor.

32.8 *Ventilation*—Adequate ventilation shall be assured by introducing fresh air into any personnel enclosure. If the enclosure volume is 4.25 m³ (150 ft³) or less per person, a minimum of 0.85 m³ (30 ft³) of ventilation air per minute shall be introduced into the enclosure; approximately two thirds shall be outdoor air. For larger enclosures, the air supply per person may be in accordance with the curves in Fig. 93. Air shall be moved past personnel at a velocity not more than 60 m (200 ft) per minute. Where manuals or loose papers are used, airspeed past these items shall be not more than 30 m (100 ft) per minute—20 m (65 ft) per minute if possible, to preclude



DIMENSION	MINIMUM mm (in)	MAXIMUM mm (in)	RECOMMENDED mm (in)
A Rung thickness			
Wood	32 (1 1/8)	38 (1 1/2)	35 (1 3/8)
Protected metal	19 (3/4)	38 (1 1/2)	35 (1 3/8)
Corrosive metal	25 (1)	38 (1 1/2)	35 (1 3/8)
B Rung spacing	230 (9)	380 (15)	300 (12)
C Height, rung to landing	150 (6)	380 (15)	380 (15)
D Width between stringers	300 (12)	—	460-530 (18 - 21)
E Climbing clearance width	610 (24)	—	760 (30)
Clearance depth:			
F In back of ladder	150 (6)	—	200 (8)
G On climbing side (range)	910 (36) for 1.30 rad (75°) to 760 (30) for 1.57 rad (90°)		
H Height of stringer above landing	910 (36)	1067 (42)	1067 (42)
J Height from lower elevation to bottom rung		380 (15)	

FIG. 83 Vertical-Ladder Dimensions

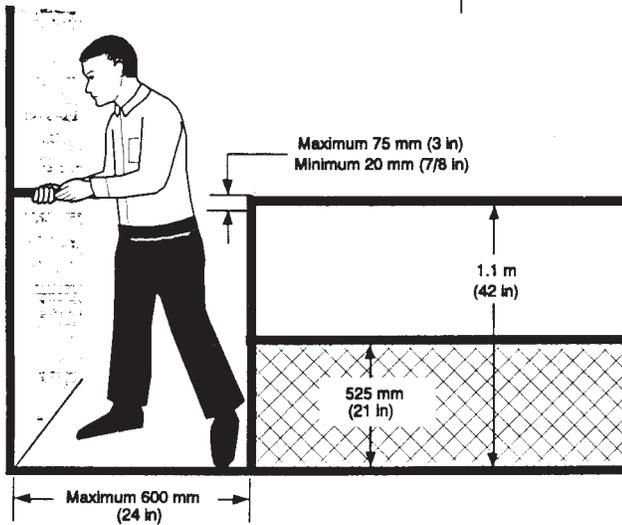
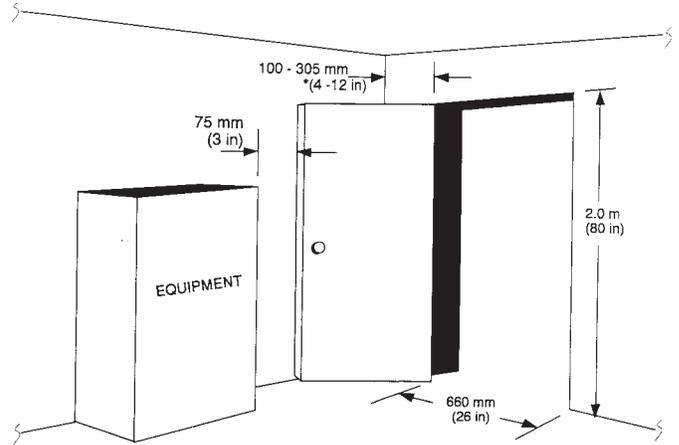


FIG. 84 Well-Designed Work Platform

pages in manuals from being turned by the air or papers from being blown off work surfaces. Under NBC conditions, ventilation requirements shall be modified as required. Ventilation or other protective measures shall be provided to keep gases, vapors, dust, and fumes within the permissible exposure limits specified by 29 CFR 1910 and the limits specified in the American Conference of Governmental Industrial Hygienists Threshold Limit Values.



IF THE DOOR OPENS ON TO A PASSAGEWAY WHICH INTERSECTS ANOTHER PASSAGEWAY, OR IF THE PASSAGEWAY TURNS A CORNER AT THE DOOR, THE DOOR SHOULD BE AT LEAST 1.5 m (60 in) FROM THE CORNER.

FIG. 85 Door Dimensions

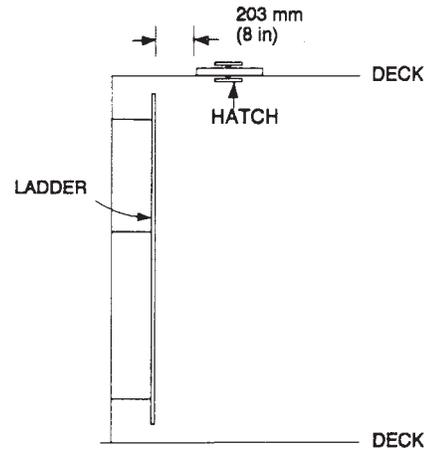


FIG. 86 Hatches Mounted Overhead

32.8.1 *CBR Ventilation*—Under chemical-bacteriological warfare, all air used for breathing and ventilation will require filtration. Under these conditions, the ambient air temperature can raise as much as 0.75°C (1.5°F). For sedentary persons, a minimum of 0.1 m³ per minute of intake air will provide adequate oxygen and acceptable carbon dioxide concentration.

32.8.2 *Ventilation Intakes/Outlets*—Intakes for ventilation systems shall be located to minimize the introduction of contaminated air from such sources as exhaust pipes. Ventilation outlets in machinery spaces shall not be located so that air is discharged directly into an access opening for the engine, reduction gear, or other moving machinery.

32.9 *Illuminance*—Where equipment is to be used in enclosures and is not subject to blackout or special low-level lighting requirements, illumination levels shall be as specified by Table 32 and shall be distributed so as to reduce glare and specular reflection. Capability for dimming shall be provided. Adequate illumination shall be provided for maintenance tasks. General and supplementary lighting shall be used, as appropriate, to ensure that illumination is compatible with each task situation. Portable lights shall be provided for personnel performing

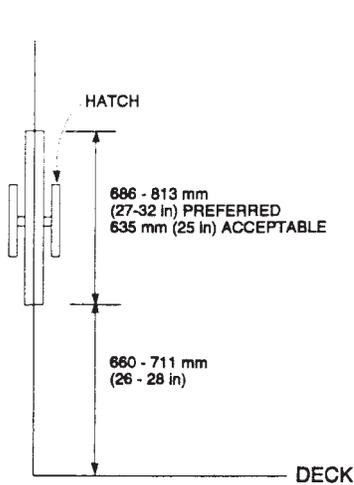
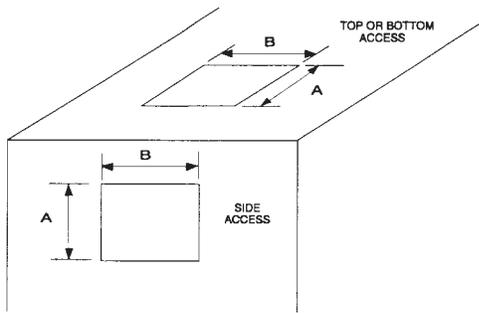


FIG. 87 Hatches Mounted on Vertical Walls



HATCH SHAPE	RECTANGLE		SQUARE		CIRCULAR	
	CLOTHING	LIGHT	BULKY	LIGHT	BULKY	LIGHT	BULKY
TOP ENTRY	A	33 cm (13 in)	41 cm (16 in)	58 cm (23 in)	64 cm (25 in)	71 cm (28 in)
	B	81 cm (26 in)	71 cm (28 in)	69 cm (27 in)	64 cm (25 in)	71 cm (28 in)
SIDE ENTRY	A	66 cm (26 in)	74 cm (29 in)	66 cm (26 in)	69 cm (27 in)	81 cm (32 in)
	B	76 cm (30 in)	81 cm (32 in)	79 cm (31 in)	69 cm (27 in)	81 cm (32 in)

FIG. 88 Hatch Dimensions

visual tasks in areas where fixed illumination is not provided. For display lighting, see Table 33.

32.10 Reflectance:

32.10.1 General—Large surface areas shall be covered with nonsaturated colors such as tints, pastels, and warm grays that are nonglossy. Some noncritical small areas such as door frames and molding may be glossy if ease of cleaning is essential.

32.10.2 Surface Reflectance Values—Generally recommended surface reflectance values for work places such as control rooms, offices, and maintenance areas are indicated in Fig. 94.

32.11 Dark Adaptation:

32.11.1 General—Dark adaptation is the process by which the eyes become more sensitive in dim light. The eyes adapt almost completely in about 30 min, but the time required for dark adaptation depends on the color curation of exposure and intensity of the previous light.

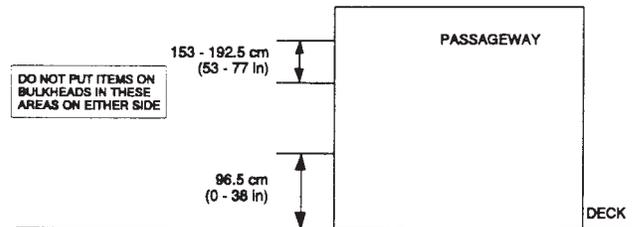
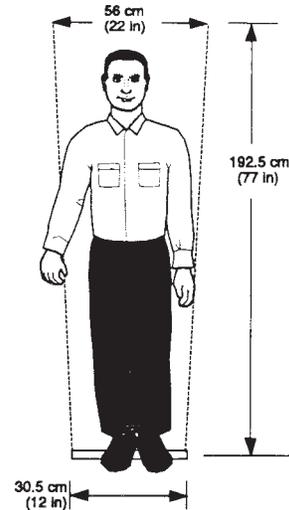


FIG. 89 Walkway and Passageway Dimensions

32.11.2 White Light—Low-level white light is as compatible for dark adaptation as is red light and permits the use of color coding. Colors often appear different under different types of illumination; so, unless a display will always be used under white light, do not use color coding.

32.11.3 Red Light—Red light may be used to do visual work and for instrument and display markings between 0.07 cd/m² (0.02 ft-L) and 0.35 cd/m² (0.1 ft-L) where maintaining maximum dark adaptation is required. This red light is obtained by passing white light through a filter that transmits only wavelengths longer than 620 nm (24 in.) (red).

32.11.4 Green Light—Where detection by enemy image intensifier night vision devices is a threat or where night vision goggles could be worn by operating personnel while viewing displays or working in a dark adaptive environment, a low-density blue-green light (incandescent filament through a high pass filter with a 600-nm cutoff) may be used for control/display or space lighting.

32.12 Acoustical Noise:

32.12.1 General—Personnel shall be provided an acoustical environment that will not cause personnel injury, interfere with voice or any other communications, cause fatigue, or in any other way degrade overall system effectiveness. The fact that a component which contributes to the overall noise may be government furnished equipment shall not eliminate the requirement that the total system conform to the criteria herein.

32.12.2 Hazardous Noise—Equipment shall not generate noise in excess of maximum allowable levels prescribed herein for the various frequency ranges (see Tables 34-37).



TABLE 28 Human Performance Effects at Various Effective Temperatures

NOTE—These temperature effects are based on relatively still air and normal humidity (40 to 60 %). Higher temperatures are acceptable if airflow is increased and humidity is lowered (a shift from 1 to 4°); lower temperatures are less acceptable if airflow increases (a shift upward of 1 to 2°).

Table with 2 columns: Effective Temperature, °C (°F) and Performance Effects. Rows range from 32 (90) to 10 (50).

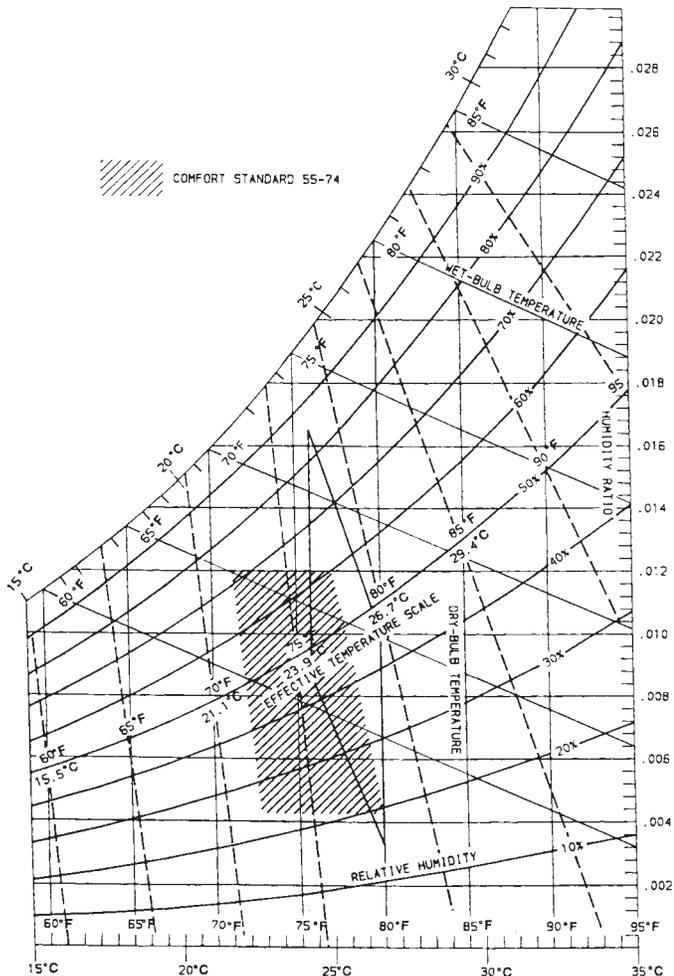


FIG. 90 Effective Temperature Scale

32.12.3 Nonhazardous Noise—Workspace noise shall be reduced to levels that permit necessary direct (person-to-person) and telephone communication and establish an acceptable acoustical work environment. Criteria for workspaces are defined by either the A-sound level (dB(A)) or the preferred speech interference level (PSIL) and are given in 32.12.3.1-32.12.3.6. The A-sound level is the desired requirement. Where it is not possible to meet the specified A-sound level, the corresponding PSIL requirement shall be met. Fig. 95 provides guidance on the relationship between required vocal-effort, speaker-to-listener distance and noise level.

32.12.3.1 General Workspaces—Areas requiring occasional telephone use or occasional direct communication at distances up to 1.5 m (5 ft) shall not exceed 75 dB(A) or 67 dB PSIL-4 or 68 db PSIL. (Examples: maintenance shops and shelters and shipboard engineering areas.)

32.12.3.2 Operational Areas—Areas requiring frequent telephone use or frequent direct communication at distances up to 1.5 m (5 ft) shall not exceed 65 dB(A) or 57 dB PSIL-4 or 58 dB PSIL. (Examples: operation centers, communication centers, combat information centers, and word processing centers.)

32.12.3.3 Large Workspaces—Areas requiring no difficulty with telephone use or requiring occasional direct communica-

tion at distances up to 4.6 m (15 ft) shall not exceed 55 dB(A) or 47 dB PSIL-4 or 48 dB PSIL.

32.12.3.4 Small Office Spaces Special Areas—Areas requiring no difficulty with direct communication shall not exceed 40 dB(A) or 42 dB PSIL-4 or 38 dB PSIL. (Examples: libraries, offices, and command and control centers.)

32.12.3.5 Extreme Quiet Area—Areas requiring extreme quiet shall not exceed 35 dB(A) or 27 dB PSIL-4 or 33 dB PSIL. (Example: medical wards.)

32.12.3.6 Shipboard Areas—Shipboard areas requiring a specified speech communication environment shall not exceed 5 dB above the levels shown in 32.12.3.1-32.12.3.5. Levels for spaces and categories not covered in these paragraphs shall be as given in the detailed shipbuilding specification, or established from the information provided in Tables 38-41.

32.12.4 Facility Design:

32.12.4.1 General Provision—In the design of a workspace or facility, the ambient noise level shall be controlled to the extent feasible through effective sound reduction or attenuation to meet the criteria herein.



TABLE 29 Physical and Perceptual Responses to Various Temperatures

Temperature of Skin, °C (°F)	Perceptual Response
37 (98)	Very hot
36 (96)	Unpleasantly warm
35 (94)	Slightly warm
34 (93)	Comfortable
33 (91)	Comfortably cool
31 (88)	Slightly too cool
30 (86)	Unpleasantly cool
29 (84)	Very cold

Temperature of Surface, °C (°F)	Physical Response Sensation of Effect
100 (212)	Second-degree burn on 15-s contact
82 (180)	Second-degree burn on 30-s contact
71 (160)	Second-degree burn on 60-s contact
60 (140)	Pain; tissue damage
49 (120)	Pain; burning heat
33 (91)	Warm; neutral (physiological zero)
12 (54)	Cool
3 (37)	"Cool heat" sensation
0 (32)	Pain
Below 0 (32)	Pain; tissue damage (freezing)

TABLE 30 Temperature and Its Effect on the Comfort of the Extremities

	Skin Temperature, °C (°F)	
	Hands	Feet
Maximum acceptable	20 (68)	23 (73)
Tolerable	20–15 (68–59)	23–18 (73–64)
Intolerable	10 (59–50)	18–13 (64–55)
Numbness sets in	<10 (<50)	<13 (<55)

32.12.4.2 *Attenuation by Materials and Layout*—Acoustic materials with high sound-absorption coefficients shall be provided in the construction of floors, walls, and ceiling to effect the required sound control. In the physical design and layout of rooms and work stations, excessive noise shall be attenuated by such means as staggered construction of walls, staggering of doors in corridors or between rooms, and use of thick-paned or double-paned windows.

32.12.5 *Reduction of Reverberation Time*—When speech communication is a consideration, the acoustical treatment of facilities shall be sufficient to reduce reverberation time, to the applicable limits of Fig. 96.

32.13 *Vibration:*

32.13.1 *Vehicular Vibration*—Vehicles or facilities for use on land or sea shall be designed to control the transmission of whole body vibration to levels that will permit safe operation and maintenance as shown in Fig. 97 (see ISO 2631). In the case of multidirectional vibration, each direction shall be evaluated independently with respect to the limits presented.

32.13.2 *Whole Body Vibration:*

32.13.2.1 *Safety Level*—To protect human health, whole body vibration shall not exceed twice the acceleration values shown on Fig. 97 for the time and frequencies indicated.

32.13.2.2 *Proficiency Level*—Where proficiency is required for operational and maintenance tasks, whole body vibration shall not exceed the acceleration values shown on Fig. 97 for the time and frequencies indicated.

32.13.2.3 *Comfort Level*—Where comfort is to be maintained, the acceleration values shown on Fig. 97 shall be divided by 3.15.

32.13.2.4 *Motion Sickness*—To prevent motionsickness, very low-frequency vibration shall not exceed the limits of Fig. 98.

32.13.3 *Building Vibration*—Facilities intended for occupation by humans shall be designed/located to control the transmission of whole body vibration levels that are acceptable to the occupants as specified by ISO 2631.

32.13.4 *Equipment Vibration*—Where whole body vibrations of the human operator or parts of the body are not a factor, equipment oscillations shall not impair human performance with respect to control manipulations or the readability of numerals or letters. Equipment vibrations in the upper figure of Fig. 97 shall be avoided.

32.14 *Noxious Substances:*

32.14.1 *General*—Enclosed crew compartments shall not be susceptible to accumulations of noxious substances generated by shipboard activities (diesel engine and gas turbine exhaust, firing of weapons, and so forth). From the practical standpoint of controlling health hazards, the critical contaminants are carbon monoxide, ammonia, nitrogen oxides, sulphur dioxide, and aldehydes (for example, methane). Other contaminants may also create health hazards, particularly when design changes are introduced or new fuels or propellants are used.

32.14.2 *Carbon Monoxide, Ammonia, Nitrogen Dioxide*—Carbon monoxide (CO) is particularly dangerous in that it is odorless, colorless, and tasteless and is not ordinarily detectable by the human senses. Excessive exposure can cause loss of mental alertness, disorientation, collapse, and even death. Its effects are cumulative, and doses that may be tolerable by individuals for brief periods can be ultimately dangerous when repeated often over several hours. Ammonia is a pulmonary irritant and asphyxiant and even in small concentrations can cause eye discomfort and watering. Nitrogen dioxide is both a pulmonary irritant and edemogenic agent.

32.14.3 *Nitrogen Oxides*—Nitrogen oxides can be dangerous because they produce relatively little discomfort, yet even low concentrations can produce grave damage in the lower respiratory tract. Thus, exposed personnel may experience little irritation while breathing concentrations of nitrogen oxides which will, 12 to 24 h later, prove fatal.

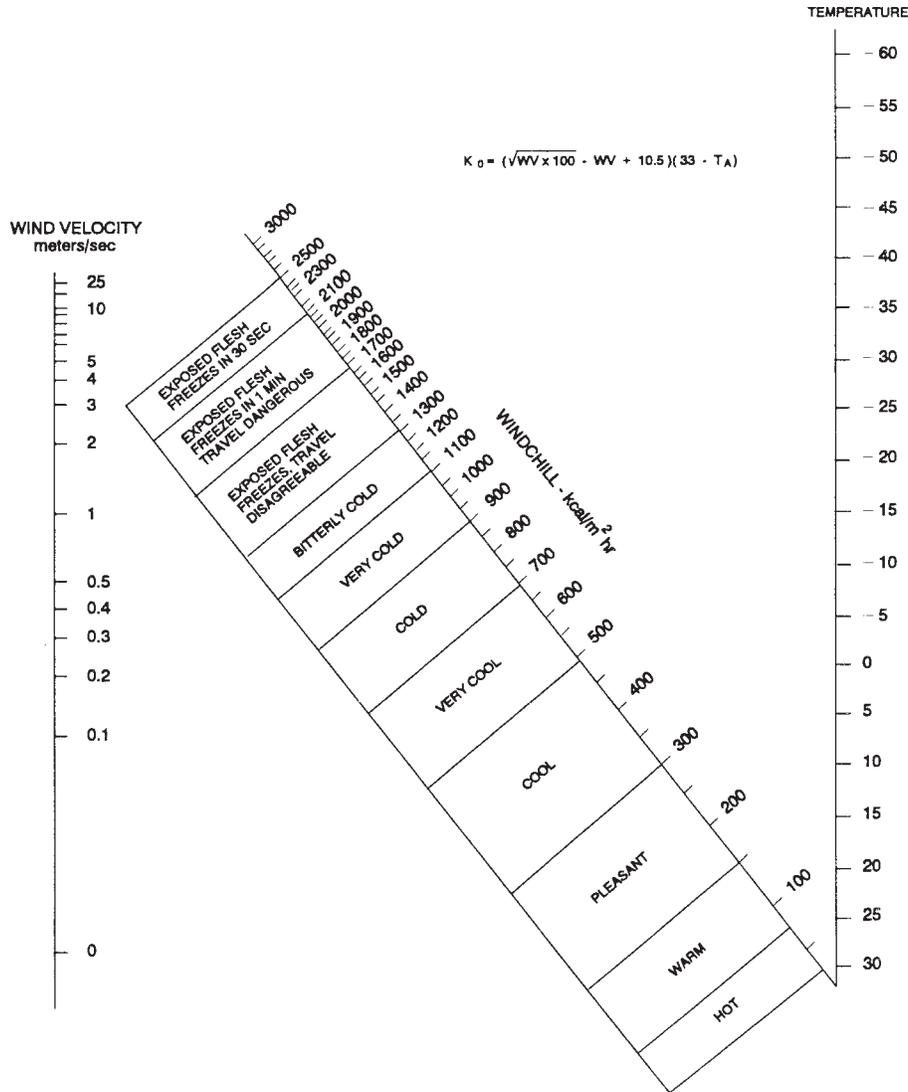
32.14.4 *Aldehydes*—Aldehydes can cause eye irritation, conjunctivitis, and nausea, causing temporary disability.

32.14.5 *Concentrations*—The presence of either carbon monoxide or ammonia in concentrations, in excess of that shown below can reduce the effectiveness of personnel and even cause collapse and unconsciousness. Current limits, expressed as a time-weight average (TWA), are as follows:

32.14.5.1 *Carbon Monoxide (CO)*—25 parts per million (ppm).

32.14.5.2 *Ammonia (NH₃)*—5 parts per million (ppm).

32.14.5.3 *Nitrogen Dioxide (NO₂)*—5 parts per million (ppm). The NO₂ limit particularly shall not be exceeded at any time.



In outdoor cold weather, the wind velocity has a profound, sometimes decisive, effect on the hazard to men who are exposed. The windchill concept dramatizes this well known fact by providing a means for quantitative comparison of various combinations of temperature and wind speed. Note for example that -45°C with an air movement of 0.045 m/s has the same windchill value, and therefore is predicated to produce the same sensation on exposed skin, as -22°C with a wind of only 0.45 m/s or -10°C with a wind of 2.2 m/s . The windchill index does not account for physiological adaptations or adjustments and should not be used in a rigorous manner. It is based on field measurements by Paul Siple during World War II of the rate of cooling of a container of water.

FIG. 91 Windchill Chart

32.14.6 *Weapon Fumes*—The fumes produced when weapons are fired contain carbon monoxide (approximately one third of the volume of fumes produced), oxides of nitrogen, and ammonia.

32.14.7 *Exhaust Fumes*—The exhaust products of carbon monoxide and carbon dioxide occur no matter which fuel is used.

32.14.7.1 When multifuel engines are using gasoline, the exhaust products include nitrogen, oxygen, and hydrogen.

32.14.7.2 When these engines are operated on CITE, JP4, JP5, or kerosene, the exhaust products include aldehydes, water, hydrogen, and free carbon.

32.14.7.3 When diesel fuel is used, the exhaust products include aldehydes, traces of nitrogen oxides, sulphur com-

pounds, oxygen, nitrogen, and methane. Table 42 shows some of the noxious exhaust products of engine fuels.

32.14.7.4 *Ventilation*—Careful consideration shall be given in designing compartments where vehicles could be stored and run (such as the well deck of an amphibious ship) to provide sufficient ventilation level, and the direction and dispersion of these products (the exhaust of multifuel engines) shall minimize exhaust concentrations.

32.15 *Protection Against Chemical Warfare Agents:*

32.15.1 *Basic Protection*—Ship designs shall be such that in the event of employment of chemical warfare agents, the first consideration must be the adequate protection of the crew members and, second, the maintenance of the ability to

WIND SPEED	COOLING POWER OF WIND EXPRESSED AS "EQUIVALENT CHILL TEMPERATURE"																				
M/SEC	TEMPERATURE (°C)																				
CALM	4	2	-1	-4	-7	-9	-12	-15	-18	-21	-23	-26	-29	-32	-34	-37	-40	-43	-46	-48	-51
2.2	2	-1	-4	-7	-9	-12	-15	-18	-20	-23	-26	-29	-32	-34	-37	-40	-43	-46	-48	-51	-57
4.5	-1	-7	-9	-12	-15	-18	-23	-26	-29	-32	-37	-40	-43	-46	-51	-54	-57	-59	-62	-68	-71
6.7	-4	-9	-12	-18	-21	-23	-29	-32	-34	-40	-43	-46	-51	-54	-57	-62	-65	-68	-73	-76	-79
8.9	-7	-12	-15	-18	-23	-26	-32	-34	-37	-43	-45	-51	-54	-59	-62	-65	-71	-73	-79	-82	-84
11.2	-9	-12	-18	-21	-26	-29	-34	-37	-43	-46	-51	-54	-59	-62	-68	-71	-76	-79	-84	-87	-93
13.4	-12	-15	-18	-23	-29	-32	-34	-40	-46	-48	-54	-57	-62	-65	-71	-73	-79	-82	-87	-90	-96
15.6	-12	-15	-21	-23	-29	-34	-37	-40	-46	-51	-54	-59	-62	-68	-73	-76	-82	-84	-90	-93	-98
17.9	-12	-18	-21	-26	-29	-34	-37	-43	-48	-51	-56	-59	-65	-71	-73	-79	-82	-87	-90	-96	-101

WINDS ABOVE 18 M/SEC HAVE LITTLE ADDITIONAL EFFECT

LITTLE DANGER

INCREASING DANGER (FLESH MAY FREEZE) (WITHIN 1 MINUTE)

GREAT DANGER (FLESH MAY FREEZE WITHIN 30 SECS)

FIG. 92 Equivalent Chill Temperature

TABLE 31 Human Reaction to Windchill

Windchill Value	Human Reaction
100	Warm
400	Pleasant
800	Cold
1000	Very cold
1200	Bitterly cold
1400	Exposed flesh freezes

continue operations. The three basic ways to provide protection against CW agents are as follows:

32.15.1.1 *Individual Protection*—Generally consists of a protective mask, protective clothing, and perhaps a decontamination kit.

32.15.1.2 *Collective Protection, Operator or Crew Station*—Each operator or crew member wears a protective mask connected to a centrally located gas particulate filter. The operator may or may not require protective clothing.

32.15.1.3 *Collective Protection, Overpressure*—The collective protection system (CPS) provides an overpressure in the entire personnel-occupied compartment. Protection masks and clothing are not required to be worn if the CPS is operating properly. Selection of the best method to provide protection against CW agents must be based upon the operational considerations, cost effectiveness, and the requirements documentation.

32.15.2 *General*—For personnel required to be in the environment during the accomplishment of their duties, the protective ensemble is the only feasible way to accomplish the required protection. For other situations, a choice between crew or operator station collective protection and overpressure collective protection must be made.

32.15.3 *Overpressure Collective Protection System (CPS)*—Whereas all three methods will protect personnel, the CPS has distinct advantages over the other two for interior environments. Primarily, the advantage lies in the fact that the CPS eliminates the requirement for masks and protective clothing to

be continually worn inside the protected area as long as the CPS is functioning properly. This eliminates the encumbrance of this equipment and any compatibility problem with equipment to be operated (keyboards, switchboards, telephones, optical equipment, and so forth). Additionally, there is no problem of mask hose interference or reduction of mobility. The advantage of the overpressure system carries over in that the danger of interior compartment contamination is minimized, therefore minimizing the requirement to decontaminate the compartment and its contents. This aspect must not be considered lightly in view that effective decontamination of electronic or optical equipment will be difficult if not impossible in the field, and because of the intimate contact of the personnel with instruments and controls, as well as other interior surfaces of the compartment, contamination of the interior cannot be tolerated. There is the possibility that the CPS will fail or be defeated, meaning that the crew will be required to complete all critical tasks wearing the protective clothing. Therefore, all critical work stations inside the CPS area shall be assigned to be operated and maintained if necessary by personnel wearing the NBC or other protective suits.

32.15.4 *Protective Ensemble*—Wearing the protective ensemble mask, hood, overgarment, and gloves poses some serious problems in functional efficiency degradation caused by heat stress, loss of visual field (particularly if there is a requirement to use optical equipment), mask lens fogging, reduction of manual dexterity, and an overall degradation in movement caused by the bulk of the protective suit.

32.15.5 *Human Factors Implication*—Because of the heat buildup in the protective suits, sufficient cooling shall be provided, or the time required for a suit to be worn will be limited so that the environment, delineated in 32.7, shall not be exceeded. Control devices, hand access openings, and so forth, shall be sized in accordance with the dimensions given in Fig. 60, Glove Type B. Limb and LC head movement ranges, wearing an NBC or other protective ensemble, have not been well defined. In lieu of better data, a good design practice is to



TABLE 32 Specific Task Illumination Requirements

NOTE 1—Some unusual inspection tasks may require up to 1000 ft-c (10 000 lux).

NOTE 2—As a guide in determining illumination requirements, the use of a steel scale with 1/64-in. divisions 180 ft-c (1950 lux) of light for optimum visibility.

Work Area or Type of Task	Illumination Levels	
	Recommended, ft-c (lux) ^A	Minimum, ft-c (lux) ^A
Assembly, missile component	100 (1075)	50 (540)
Assembly, general:		
coarse	50 (540)	30 (325)
medium	75 (810)	50 (540)
fine	100 (1075)	75 (810)
precise	300 (3230)	200 (2155)
Bakery	50 (540)	30 (325)
Bench work:		
rough	50 (540)	30 (325)
medium	75 (810)	50 (540)
fine	150 (1615)	100 (1075)
extra fine	300 (3230)	200 (2155)
Business machine operation (calculator, digital, input, and so forth)	100 (1075)	50 (540)
Chemical laboratory	50 (540)	30 (325)
Console surface	50 (540)	30 (325)
Corridors	20 (215)	10 (110)
Circuit diagram	100 (1075)	50 (540)
Dials	50 (540)	30 (325)
Electrical equipment testing	50 (540)	30 (325)
Elevators	30 (325)	20 (215)
Emergency lighting		3 (30)
Gages	50 (540)	30 (325)
Galley	70 (755)	50 (540)
Hallways	20 (215)	10 (110)
Inspection tasks, general:		
rough	50 (540)	30 (325)
medium	100 (1075)	50 (540)
fine	200 (2155)	100 (1075)
extra fine	300 (3230)	200 (2155)
Laundry:		
general		50 (540)
spotting		500 (4645)
hand pressing		150 (1395)
Machine shop:		
general	50 (540)	30 (325)
fine bench work	100 (1075)	80 (745)
Medical spaces:		
waiting areas	70 (755)	50 (540)
labs and examination rooms	100 (1075)	75 (810)
surgery		
Meters	50 (540)	30 (325)
Missiles:		
repair and servicing	100 (1075)	50 (540)
storage areas	20 (215)	10 (110)
general inspection	50 (540)	30 (325)
Office work, general	70 (755)	50 (540)
Ordinary seeing tasks	50 (540)	30 (325)
Paint room:		
general		30 (325)
color matching		200 (2155)
Panels:		
front	50 (540)	30 (325)
rear	30 (325)	10 (110)
Passageways	20 (215)	10 (110)
Reading:		
large print	30 (325)	10 (110)
newsprint	50 (540)	30 (325)
handwritten reports, in pencil	70 (755)	50 (540)
small type	70 (755)	50 (540)
prolonged reading	70 (755)	50 (540)
Recording	70 (755)	50 (540)
Repair work:		
general	50 (540)	30 (325)
instrument	200 (2155)	100 (1075)
Sanitary spaces:		
general		30 (325)
sink and mirror		50 (540)

TABLE 32 Continued

NOTE 1—Some unusual inspection tasks may require up to 1000 ft-c (10 000 lux).
 NOTE 2—As a guide in determining illumination requirements, the use of a steel scale with 1/64-in. divisions 180 ft-c (1950 lux) of light for optimum visibility.

Work Area or Type of Task	Illumination Levels	
	Recommended, ft-c (lux) ^A	Minimum, ft-c (lux) ^A
Scales	50 (540)	30 (325)
Screw fastening	50 (540)	30 (325)
Service areas, general	20 (215)	10 (110)
Sheet metal works:		
general		50 (540)
scribing		200 (2155)
Ship stores:		
aisles		30 (325)
Stairways	20 (215)	10 (110)
Storage:		
inactive or dead	5 (55)	3 (30)
general warehouse	10 (110)	5 (55)
live, rough or bulk	10 (110)	5 (55)
live, medium	30 (315)	20 (215)
live, fine	50 (540)	30 (325)
Switchboards	50 (540)	30 (325)
Tanks, containers	20 (215)	10 (110)
Testing:		
rough	50 (540)	30 (325)
fine	100 (1075)	50 (540)
extra fine	200 (2155)	100 (1075)
Transcribing and tabulation	100 (1075)	50 (540)
Welding:		
general		50 (540)
precision arc		1000 (10 765)
Woodworking:		
general		30 (325)
finishing		100 (1075)

^AAs measured at the task object or 760 mm (30 in.) above the floor.

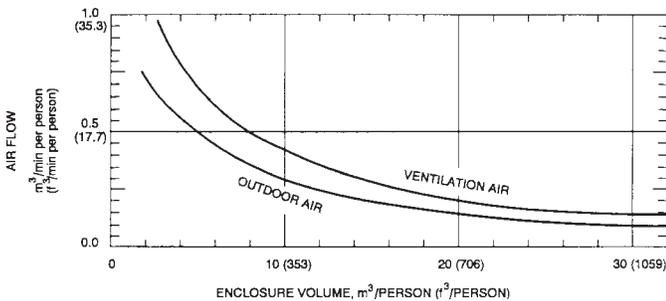


FIG. 93 Ventilation Requirement

place all controls and displays within the normal equipment operation lower limits shown in Fig. 69. As for the anthropometric dimensions of the human body in an NBC or other ensemble, use the dimensions shown in Figs. 53-58 and Table 22 for the arctic-clothed person as a best estimation of the effect of an NBC or other ensemble on the body dimensions for both static and dynamic situations.

33. Maintainability

33.1 General:

33.1.1 *Standardization*—Standard parts shall be used whenever practicable and shall meet the human engineering criteria herein.

33.1.2 *Special Tools*—Special tools shall be used only when common hand tools cannot be used or when they provide significant advantage over common hand tools. Special tools

required for operational adjustment maintenance shall be securely mounted within the equipment in a readily accessible location.

33.1.3 *Modular Replacement*—Equipment shall be replaceable as modular packages and shall be configured for removal and replacement by one person where permitted by structural, functional, and weight limitations (see 38.3).

33.1.4 *Separate Adjustability*—It shall be possible to check and adjust each item, or function of an item, individually.

33.1.5 *Malfunction Identification*—Equipment design shall facilitate rapid and positive fault detection and isolation of defective items to permit their prompt removal and replacement.

33.1.6 *Assembly and Disassembly*—Equipment shall be capable of being assembled and disassembled in its operational environment by a minimum number of trained personnel wearing clothing appropriate to the operating environment specified for the system maintenance concept.

33.1.7 *Clothing Constraints*—Equipment shall be capable of being removed, replaced, and repaired by personnel wearing personal and special purpose clothing and equipment appropriate to the maintenance concept, including NBC protective clothing in an NBC-contaminated environment.

33.1.8 *Errorproof Design*—Provisions to preclude improper mounting and installation shall include:

33.1.8.1 Physical measures to preclude interchange of items of a same or similar form that are not in fact functionally interchangeable.

TABLE 33 Recommendations for Display Lighting

Condition of Use	Lighting Technique ^A	Brightness of Markings cd/m ² (Ft-L)	Brightness Adjustment
Indicator reading, dark adaptation necessary	red flood, indirect, or both, with operator choice	0.07–0.35 (0.02–0.1)	cont. throughout range
Indicator reading, dark adaptation not necessary but desirable	red or low-color temperature white flood, indirect, or both, with operator choice	0.07–3.5 (0.02–1.0)	cont. throughout range
Indicator reading, dark adaptation not necessary	white flood	3.5–70 (1–20)	fixed or continuous
Panel monitoring, dark adaptation necessary	red edge lighting, red or white flood, or both, with operator choice	35–70 (10–20)	cont. throughout range
Panel monitoring, dark adaptation not necessary	white flood	35–70 (10–20)	fixed or continuous
Possible exposure to bright flashes, restricted daylight	white flood	35–70 (10–20)	fixed
Chart reading, dark adaptation necessary	red or white flood with operator choice	0.35–3.50 (0.1–1.0)	cont. throughout range
Chart reading, dark adaptation necessary	white flood	17–70 (5–20)	fixed or continuous

^AWhere detection of a ground vehicles or other protected assets by image intensifier night vision devices must be minimized, blue-green light (incandescent filament through a filter which passes only wave lengths shorter than 600 mm) should be used in lieu of red light.

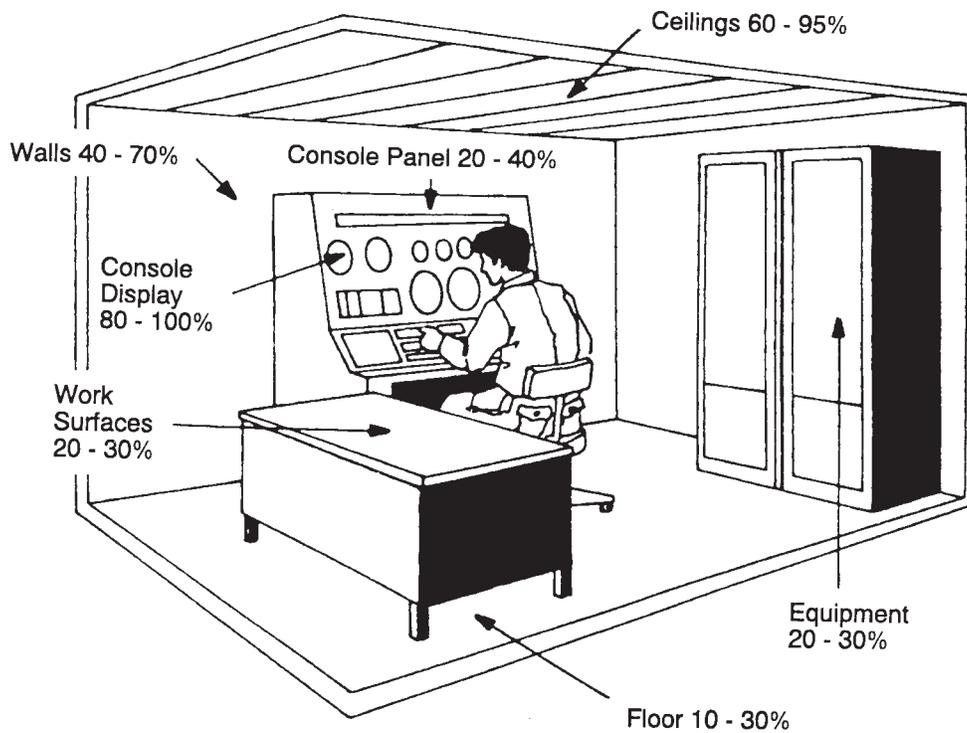


FIG. 94 Workspace Reflectance Values

33.1.8.2 Physical measures to preclude improper mounting of units or components.

33.1.8.3 Measures (for example, coding) to facilitate identification and interchange of interchangeable items.

33.1.8.4 Measures (for example, alignment pins) to facilitate proper mounting of items.

33.1.8.5 Measures to insure that identification, orientation, and alignment provisions include cables and connectors.

33.1.8.6 Provide for controls and displays that give the status of equipment indicating when maintenance must be preformed (for example, AP meter on strainer) and locate them so it is obvious which equipment they are associated with.

33.2 *Designing for Maintainability*—Designers shall incorporate the following features for maximum maintainability:

TABLE 34 Low-Frequency and Infrasonic Noise Limits to Prevent Ear Injury

Frequency, Hz	SPL, dB	Duration, min/day	
1–7	150	4	Should use earplugs to reduce unpleasant sensations
8–11	145	4	Should use earplugs to reduce unpleasant sensations
12–20	140	4	Should use earplugs to reduce unpleasant sensations
21–100	135	20	Without earplugs
21–100	150	20	With earplugs

33.2.1 Simplification of operator and maintenance functions.

**TABLE 35 Sound Exposure to Avoid Deafness**

Octave Band, Frequency, Hz	Maximum Permissible Sound Pressure Level, dB	
	Occasional (1 h or Less)	Continuous (Period of Months)
38–75	125	115
75–150	120	110
150–300	120	110
300–600	120	105
600–1200	115	100
1200– 2400	110	95
2400–4800	105	90
4800–9600	110	95

TABLE 36 Maximum Permissible Sound Pressure Level

Exposure Time	With Ears Unprotected, dB	With Earplugs, dB	With Earplugs and Earmuffs, dB
8 h	100	112	120
1 h	108	120	128
5 min	120	132	140
30 s	130	142	150

TABLE 37 OSHA Permissible Daily Noise

Duration, h	Sound Level, dBA
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105
0.5	110
0.25	115

33.2.2 Use of modular or unit packaging or throwaway components designed for rapid and easy removal and replacement by one person (if feasible) with the weight limitations contained in Table 43 in 38.3.1.

33.2.3 Use of self-lubricating principles.

33.2.4 Use of sealed and lubricated components and assemblies.

33.2.5 Use of built-in testing and calibration features for major components.

33.2.6 Use of self-adjusting mechanisms.

33.2.7 Use of gear-driven accessories to eliminate belts and pulleys.

33.2.8 Minimum number and complexity of maintenance tasks.

33.2.9 Design to minimize skills and training requirements of maintenance personnel.

33.2.10 Design for accessibility to all systems, equipment, and components requiring maintenance, inspection, removal, and replacement.

33.2.11 Design for maximum safety and protection for personnel and equipment.

33.2.12 Design to incorporate standard parts to the maximum extent feasible.

33.2.13 Design to facilitate manual handling required during maintenance and comply with established manual force criteria.

33.2.14 Design so inputs to and outputs from each unit shall be kept to a minimum by grouping functions to minimize criss-crossing of signals.

33.3 Mounting of Items Within Units:

33.3.1 *Stacking Avoidance*—Parts shall be mounted in an orderly array on a “two-dimensional” surface, rather than stacked one on another (that is, a lower layer shall not support an upper layer, so subassemblies do not have to be removed to access other subassemblies within the equipment).

33.3.2 *Similar Items*—Similar items shall use a common mounting design and orientation within the unit. This mounting design shall preclude interchange of items that are not functionally interchangeable. Similar items that are not functionally interchangeable shall be made distinguishable by labeling, color coding, marking, and so forth, to prevent unwanted substitution.

33.3.3 *Delicate Items*—Components susceptible to maintenance-induced damage through rough handling, static electricity, abrasion, lack of cleanliness, or other such factors shall be clearly identified and guarded from abuse both physically and by procedural requirements.

33.4 *Adjustment Controls*—Controls required for maintenance purposes shall comply with basic control design requirements in Sections 23, 24, and 25 and labeling requirements in Section 27.

33.4.1 *Knob Adjustments*—Knobs rather than screwdriver controls shall be used whenever adjustments occurring more often than once per month must be performed where access, weight, and related considerations permit their use. Knobs shall maintain setting following adjustment.

33.4.2 *Blind Screwdriver Adjustments*—Screwdriver adjustments made without visual access are permissible only if mechanical guides are provided to align the screwdriver. Screw travel shall be limited to prevent the screw from falling out of its intended position.

33.4.3 *Reference Scale for Adjustment Control*—A reference scale or other appropriate feedback shall be provided for all adjustment controls. The reference scale shall be readily visible to the person making the adjustment. Mirrors or flashlights shall not be required for adjustment.

33.4.4 *Control Limits*—Calibration or adjustment controls that are intended to have a limited degree of motion shall have mechanical stops with strength to prevent damage by a force or torque 100 times greater than the resistance to movement within the range of adjustment.

33.4.5 *Critical Controls*—Critical and sensitive adjustment controls shall incorporate features to prevent inadvertent or accidental actuation. If a locking device is to be used to prevent inadvertent or accidental actuation, operation of the locking device shall not change the adjustment setting. Where the operator or maintainer is subjected to disturbing vibrations or acceleration during the adjustment operation, suitable hand or arm support shall be provided near the control location to facilitate making adjustment.

33.4.6 *Hazardous Locations*—Adjustment controls shall not be located close to dangerous voltages, moving machinery, or any other hazards. If such location cannot be avoided, the controls shall be appropriately shielded and labeled.

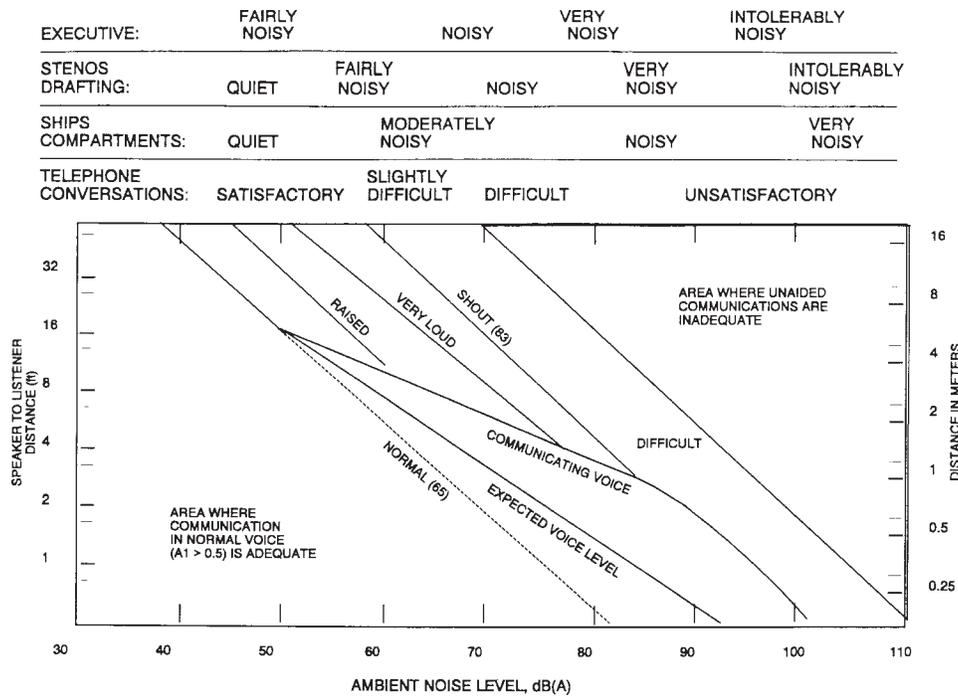


FIG. 95 Permissible Distance Between a Speaker and Listener's for Specified Voice Levels and Ambient Noise Levels

TABLE 38 Effects of Noise on Human Performance

Noise Level, dB	Effects
100	Serious reduction in alertness. Attention lapses occur, although attention duration is usually not affected. Temporary hearing loss occurs if no protection is provided in the region 600 to 1200 Hz. Most people will consider this level unacceptable, and 8 h is the maximum duration they will accept.
95	Considered to be upper acceptance level for occupied areas in which people expect the environment to be noisy. Temporary hearing loss often occurs in the range from 300 to 1200 Hz. Speech will be extremely difficult, and people will be required to shout, even though they may be talking directly into a listener's ear.
90	At least half of the people in any given group will judge the environment as being too noisy, even though they expected a noisy environment. Some temporary hearing loss in the range from 300 to 1200 Hz occurs. Skill errors and mental decrements will be frequent. The annoyance factor is high, and certain physiological changes often occur (for example, the pupils dilate, the blood pressure increases, and the stroke volume of the heart may decrease). Listening to a radio is impossible without good earphones. The maximum duration that most people will accept is 8 h.
85	The upper acceptance level (noise expected) in the range from 150 to 1200 Hz. Some hearing loss occurs in the range from 300 to 1200 Hz. This is considered the upper comfort level, although some cognitive performance decrement can be expected, especially where decision making is necessary.
80	Conversation is difficult (that is, people have to converse in a loud voice less than 1 ft apart). It is difficult to think clearly after about 1 h. There may be some stomach contraction and an increase in metabolic rate. Strong complaints can be expected from those exposed to this level in confined spaces, and 8 h is the maximum duration acceptable within the frequency range from 1200 to 4800 Hz.
75	Too noisy for adequate telephone conversation. A raised voice is required for conversant 0.68 m (2 ft) apart. Most people will still judge the environment as being too noisy.
70	The upper level for the normal conversation, even when conversants are close together (at a distance of 1.8 m (6 ft)) people will have persons such as industrial workers and shipboard personnel who are used to working in a noisy environment will accept this noise level, unprotected telephone conversation will be difficult (upper phone level is 68 dB).
65	The acceptance level when people expect a generally noisy environment. Intermittent personal conversation is acceptable. About half of the people in a given population will experience difficulty sleeping.
60	The upper limit for spaces used for dining, social conversation, and sedentary recreational activities. Most people will rate the environment as "good" for general daytime living conditions.
55	The upper acceptance level for spaces in which quiet is expected (150 to 2400 Hz). People will have to raise their voices slightly to converse over distances greater than 2.4 m (8 ft). This level of noise will awaken about half of a given population about half of the time. It is still annoying to people who are especially sensitive to noise.
50	Acceptable to most people where quiet is expected. About 25 % will be awakened or delayed in falling asleep. Normal conversation is possible at distances up to 2.4 m (8 ft).
40	Very acceptable to all. The recommended upper level for quiet living spaces, although a few people may still have sleep problems.
30	Necessary for specialized listening tasks (for example, threshold signal detection).
Below 30	Introduces additional problems: low-level intermittent sounds become disturbing. Some people have difficulty getting used to the extreme quiet, and a few may become psychologically disturbed.

**TABLE 39 Effects of High-Level Noise on Human Performance**

Noise Level, dB	Spectrum	Duration	Effects
105	Jet engine	2 min	Reduced visual acuity, stereoscopic acuity, and near point accommodation and permanent hearing loss when exposure continues over a long period of (months)
110	Machinery noise	8 h	Chronic fatigue and digestive disorders
120	Broadband	1 h	Loss of equilibrium
150	1–100 Hz	2 min	Reduced visual acuity, chest-wall vibration, changes in respiratory rhythm, and a “gagging” sensation

33.5.1 *Heat*—When monitoring, servicing, repair, or other similar maintenance tasks will be performed in areas in which the temperature will exceed 29.5°C (85°F), air conditioning shall be provided. For additional information on the effect of heat on human performance and behavior see 32.2.

33.5.2 *Cold*—Personal discomfort increases rapidly as the temperature drops below –12°C (10°F). When workers are properly dressed, they can perform to some point between 0 and –18°C (32 and 0°F) for 30 min without interference from cold itself. Below –18°C (0°F), the decrement in human performance rapidly increases as the temperature decreases. For additional information on the effects of cold temperatures on human performance see Tables 29-31.

33.5.3 *Design Features*—The following features shall be considered when equipment can be expected to require maintenance in cold weather.

33.5.3.1 Provide for drying of equipment which is to be returned to out-of-door arctic temperatures after shop maintenance has been performed on it. Moisture that has condensed on such equipment will cause it to freeze with possible resultant damage to equipment and subsequent increased maintenance.

33.5.3.2 Winterization equipment, such as preheaters, shall be positioned where they do not interfere with maintainer accessibility to perform maintenance tasks.

33.5.3.3 In locating access doors and panels, consider the effects of rain, snow, and formation of ice.

33.5.3.4 Provide work space access openings to accommodate personnel wearing cold weather clothing.

33.5.3.5 Provide drains that can be adequately accessed and operated by personnel wearing cold weather clothing to drain liquids as required to prevent damage caused by freezing.

33.6 *Mounting of Items Within Units.*

34. Accessibility

34.1 *General*—Proper accessibility is a fundamental requirement for good maintainability, and must be designed into the equipment and overall system. Accessibility means that all activities required can be completed by personnel using the appropriate body dimensions (see Section 30, Anthropometry), fifth to ninety-fifth percentile, wearing the appropriate clothing and carrying (or using) all necessary tools or test equipment, or both. Just because an item can be eventually reached (provided enough other items are removed, or valve handles or lagged

pipings has to be used as a “step ladder,” and so forth) does not mean the item is accessible.

34.2 *Psychological Aspects*—The more difficult or involved a maintenance task is, the more readily an operator or mechanic will put it off in preference to less demanding tasks. Periodic maintenance activities, such as checks, adjustments, or general troubleshooting may be unduly postponed or neglected entirely.

34.3 *Physical Access*—Consideration must be given to the position of the maintenance person with respect to the equipment and the task therein while performing the particular maintenance task. When the maintenance activities require the crew member to squat, sit down, stand sideways, proper accessibility shall be provided (see Figs. 99-103).

34.4 *Access Openings*—Provide access openings, as required, to all points, items, units, and components that require testing, servicing, adjusting, removing, replacing, and repairing. The type, size, and location of these openings (Figs. 104-106) shall be based on the following:

34.4.1 Operational location, setting, and environment of the unit.

34.4.2 Frequency of use.

34.4.3 Maintenance tasks performed through the access; the intricacy of tasks.

34.4.4 Time allotted to perform maintenance function.

34.4.5 Types of tools/accessories required.

34.4.6 Work space required.

34.4.7 Type of clothing the maintainer is likely to be wearing.

34.4.8 Necessary access reach (position of the human body; standing, squatting, lying prone, and so forth, must be considered in determining access reach).

34.4.9 Visual requirements; the intricacy of tasks.

34.5 *Visual Access with Physical Access*—If it is necessary for the technicians to see what they are doing, either access openings large enough to accommodate hand, arms, tools, and so forth, and still leave an adequate view, or an auxiliary viewing port shall be provided.

34.6 *Structural Members*—Structural members of units or chassis shall not prevent access to or removal of items. Replaceable items shall not be mounted in a manner that will make them difficult to remove. Where accessibility depends upon removal of panels, cases, and covers, measures shall be taken to ensure that such items are not blocked by structural members or other items.

34.7 *Large Items*—Large items that are difficult to remove shall be so mounted that they will not prevent convenient access to other items. Smaller, or more fragile, items shall be located so as not to be easily damaged during removal of the large items.

34.8 *Use of Tools and Test Equipment*—Check points, adjustment points, test points, cables, connectors, and labels shall be accessible and visible during maintenance. Sufficient space shall be provided for the use of test equipment and other required tools without difficulty or hazard.

34.9 *Rear Access*—Sliding, rotating, or hinged equipment to which rear access is required shall be free to open or rotate their full distance and remain in the open position without



TABLE 40 Upper Noise Limits Recommended for Military Facilities

Sound Level, dBA	Type of Activity	Communication Equivalent	Office Application
108	Maximum design limit for equipment (hearing protection required)	No direct communication	Not recommended
100	Armored vehicles (hearing protection required)	Electrically aided communication satisfactory with attenuating helmet or headset; limited shouted communication possible with difficulty	Not recommended
90	Material that is beyond the state of the art of meeting 85 dBA (hearing protection required)	Shouted communication possible at short distances (30–60 cm (1–2 ft))	Not recommended
85	Acceptable level for unprotected hearing for 8-h exposures	Shouted communication possible at several feet (90–120 cm (3–4 ft)); telephone use difficult	Not recommended
75	Maintenance shops and keypunch areas. Operation centers, computer rooms, word processing centers, galleys, and laundries	Occasional telephone use and occasional direct communication at up to 1.5 m (5 ft) is acceptable	Not recommended
65	Operation centers, computer rooms, word processing centers, galleys, and laundries	Frequent telephone use and frequent direct communication at up to 1.5 (5 ft) is acceptable	Business machine offices
55	Laboratories and conferences with two or three people	No difficulty with telephone use and occasional direct communication at up to 4.6 (15 ft)	Shop offices and general secretarial areas
45	Libraries, conference rooms, command and control centers, and sleeping areas	No difficulty with direct communication	General offices
35	Large conference rooms	Areas requiring unusually extreme quiet	Executive offices

TABLE 41 Comfort Limits for Noise by Octave Band

Octave band, Frequency, Hz	Comfort Criteria, DB	
	Normally Noisier Environment	Normally Quiet Environment
38–75	100	80
75–150	95	70
150–300	90	60
300–600	85	55
600–1200	75	50
1200– 2400	65	50
2400–4800	60	50
4800–9600	55	45

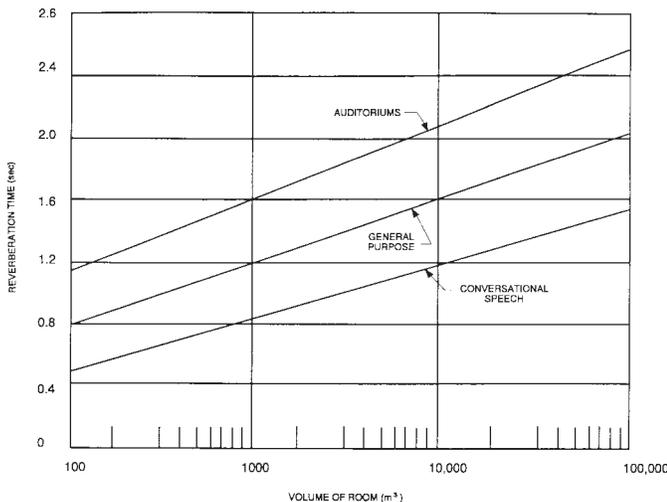


FIG. 96 Range of Acceptable Reverberation Time

being supported by hand. Rear access shall also be provided to plug connectors for test points, soldering, and pin removal where connectors require such operations.

34.10 Relative Accessibility—Items most critical to system operation and which require rapid maintenance shall be most accessible. When relative criticality is not a factor, items requiring most frequent access shall be most accessible.

34.11 High-Failure-Rate-Items—High-failure-rate items shall be accessible for replacement without moving nonfailed items. Mechanical replacement items shall be removable with common hand tools and simple handling equipment.

34.12 Skills—Access to items maintained by one technician shall not require removal of critical equipment maintained by another technician, particularly where highly specialized skills are involved.

34.13 Moving Parts—Maintenance tasks shall not be required on items for which the human must lean over or work directly around moving parts (belts, elevator cables, rotating shafts, and so forth), especially if it is necessary to have the moving parts active as a part of the maintenance procedure.

34.14 Elevated Positions—Items to be maintained from a ladder shall require only one hand and shall be located no more than 1219 mm (48 in.) from the ladder (see Fig. 40). Maintenance tasks performed at this maximum distance shall involve only adjustments or other similar tasks that can be performed with the bare hand or light tools.

34.15 Masts—Maintenance on antenna, lights, and so forth, mounted on a mast or other elevated structure, shall not require the person to be suspended from a safety harness, but rather shall be performed from a permanent or temporary work platform.

34.16 Strainers and Filters—Strainers and filters shall be located so that the person does not have to stand on valve handles, piping, wireway supports, and so forth to obtain access to the elements inside for removal for cleaning.

34.17 Rechargeable Containers—Compressed gas bottles for inert gases (nitrogen flasks in oil and water test labs), fire-extinguishing materials, and so forth, shall be located in a compartment or space to facilitate easy and quick removal.

34.18 Access Opening Covers—Where an access opening is provided the order of preference, as shown in Fig. 106, shall be followed regarding the provision of an access cover.

34.18.1 Securing of Covers—It shall be made obvious when a cover is not secured even though it may be in place.

34.18.2 Self-Supporting Covers—Hinged access covers that are not completely removable shall be self-supporting in the

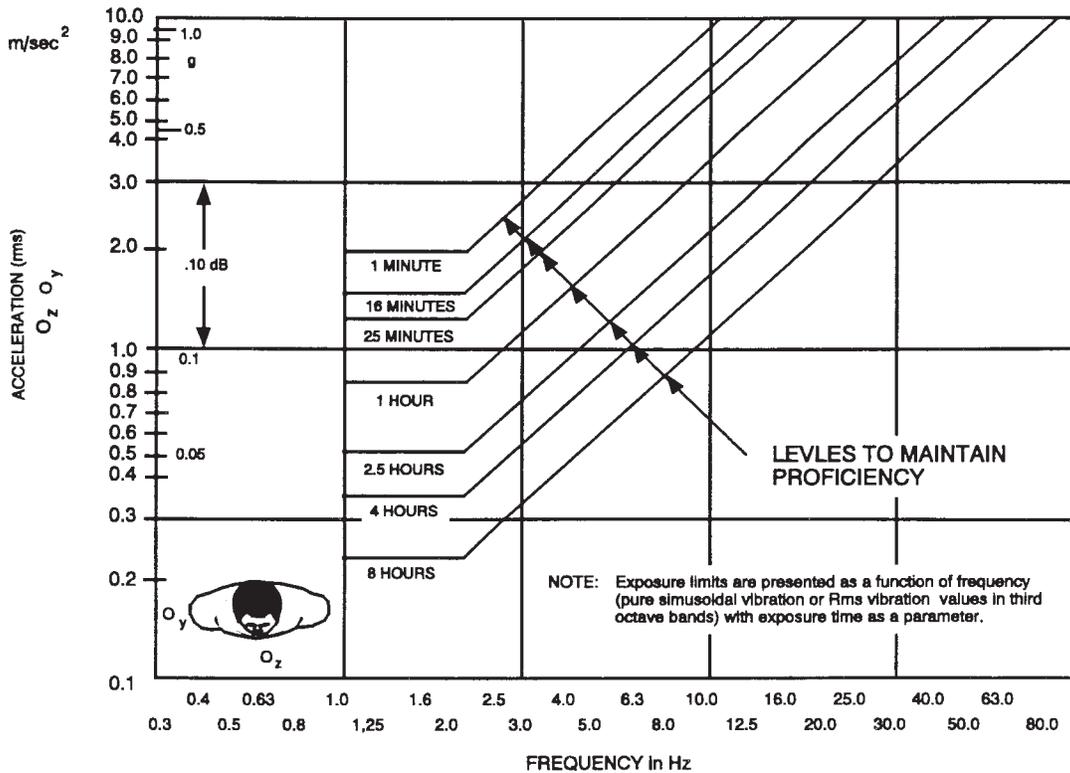
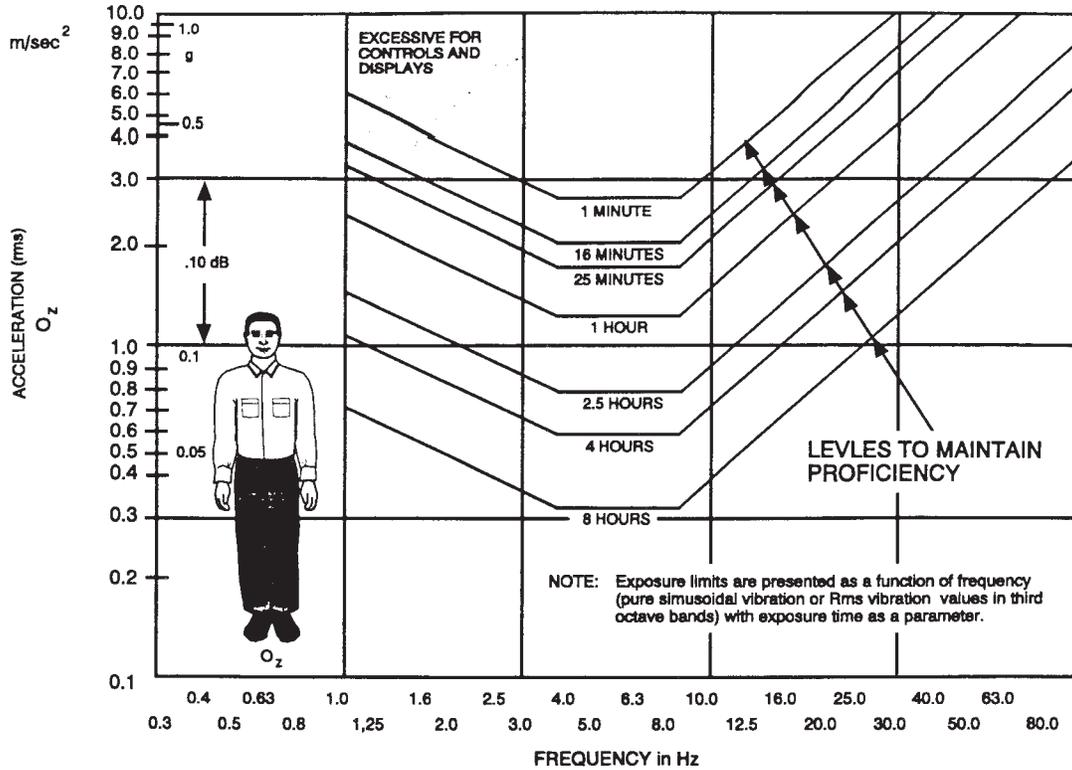


FIG. 97 Vibration Exposure Criteria for Longitudinal (Upper Figure) and Transverse (Lower Figure) Directions with Respect to Body Axis

open position. The cover in the open position shall not obstruct required visual or physical access to the equipment being

maintained or to related equipment during maintenance. Self-supporting covers shall be capable of being opened and closed

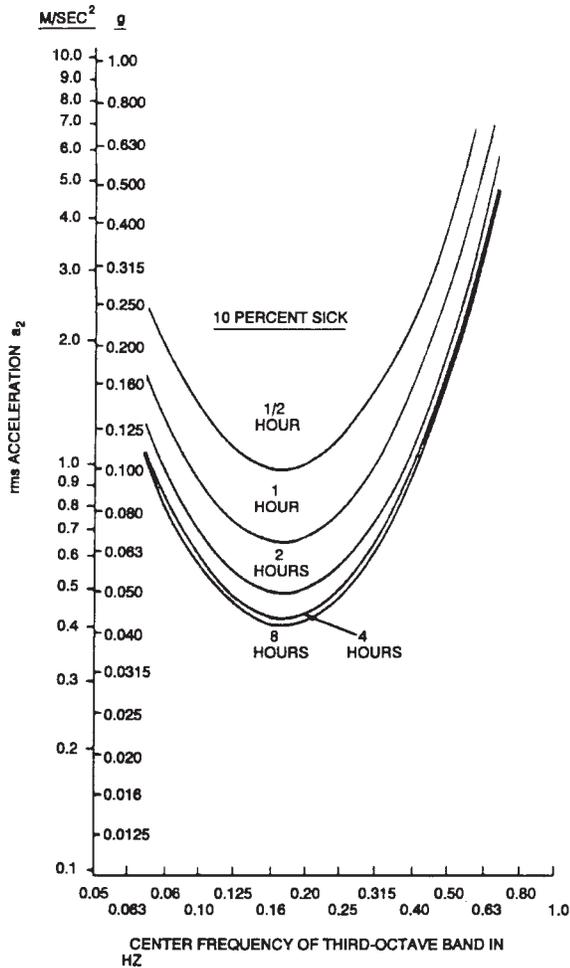


FIG. 98 The 90 % Motion Sickness Protection Limits for Human Exposure to Very Low Frequency Vibration

TABLE 42 Noxious Exhaust Products of Engine Fuels

Fuel	Exhaust Products			
	CO	CO ₂	N ₂ O ₄	SO ₂
Cite	X	X	X	X
JP4	X	X		
Kerosene	X	X		
Diesel	X	X	X	X
Gasoline	X	X	X	X

with one hand. Covers shall be secured to withstand windgusts, vibrations, or other environmental effects as specified by system requirements.

34.18.3 *Instructions*—If the method of opening a cover is not obvious from the construction of the cover itself, instructions shall be permanently displayed on the outside of the cover. Instructions shall consist of simple symbols such as arrows or simple words such as “push” or “push and turn.”

34.18.4 *Clearance*—Bulkheads, brackets, and other equipment shall not obstruct visual or physical access for removal or opening of covers on equipment within which work must be performed in the installed condition. Covers, doors, or panels that must be opened to perform onsite maintenance shall be visually and physically accessible to the maintainers.

TABLE 43 Design Weight Limits

Handling Function	Male and Female Population		Male Only Population	
	kg	(lb)	kg	(lb)
A Lift an object from the floor and place it on a surface not greater than 1.525 m (5 ft) above the floor.	16.8	(37)	25.4	(56)
B Lift an object from the floor and place it on a surface not greater than 915 mm (36 in.) above the floor.	20.0	(44)	39.5	(87)
C Carry an object 10 m (33 ft) or less.	19.0	(42)	37.2	(82)
D Carry an object more than 10 m (33 ft).				
E package carried at side with one hand (tool chest, container with handles, and so forth)	13.6	(30)	20.0	(45)
F package with irregular sides (electronic equipment chassis, and so forth)	11.4	(25)	14.0	(35)
G box or other item with two hands.	14.0	(35)	25.0	(55)

34.18.5 *Labeling*—Each access cover shall be labeled with nomenclature for items visible or accessible through it, nomenclature for auxiliary equipment to be used with it, and recommended procedures for accomplishing operations. Accesses shall be labeled with hazard signs advising of any hazards existing beyond the access. If instructions applying to a covered item are lettered on a hinged door, the lettering shall be properly oriented to be read when the door is open. Hazard notices shall be prepared in accordance with 29.2.

34.18.6 *Access Cover Attachment*—Covers shall be attached with the fewest number of simplest-to-operate fasteners practicable. Fasteners shall be operable by hand or by common hand tools in that order of preference. Small, removable covers shall be attached to structure or otherwise retained to prevent loss.

34.19 *Rounding*—Cover and access edges shall be rounded (see 51.7.4, Edge Rounding) to preclude hand injury or clothing damage.

34.20 *Operation*—Access covers shall be equipped with grasp areas or other means for opening them. If a hazardous condition, such as exposed conductors energized with dangerous voltages exists behind the access, the physical barrier over the access shall be equipped with an interlock that will deenergize the hazardous equipment when the barrier is opened or removed. Bulkheads, brackets, wireways, and other equipment shall not interfere with the removal or opening of covers, or restrict access to these openings, or interfere with the maintenance tasks that must be performed through the openings. Additional design criteria are as follows:

34.20.1 When hinged covers are adjacent, they shall open in the opposite directions to maximize accessibility.

34.20.2 Design hinged caps over service or test points so they will not interfere with inserting or attaching service or test equipment.

34.20.3 Use stops, retainers, and so forth, as necessary to keep covers from swinging into adjacent controls or fragile components, and so they will not spring their hinges.

	Percentiles, cm (in)				
	5th	25th	50th	75th	95th
A. Depth of reach	55.88 (22.00)	56.69 (23.50)	62.87 (24.75)	65.41 (25.75)	67.95 (26.75)
B. Breadth of aperture	25.40 (10.00)	25.40 (10.00)	25.40 (10.00)	25.40 (10.00)	25.40 (10.00)
C. Floor to top of aperture	154.31 (60.75)	160.66 (63.25)	163.20 (64.25)	167.64 (66.00)	174.63 (68.75)
D. Floor to bottom of aperture	132.72 (52.25)	139.07 (54.75)	142.24 (56.00)	145.42 (57.25)	149.86 (59.00)
E. Vertical dimension of aperture	41.91 (16.50)	41.91 (16.50)	41.91 (16.50)	41.91 (16.50)	41.91 (16.50)

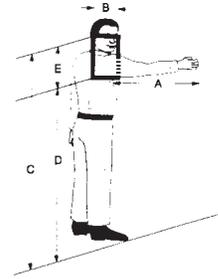


FIG. 99 Standing, Lateral Reach (Preferred Arm)

	Percentiles, cm (in)				
	5th	25th	50th	75th	95th
A. Depth of reach	38.10 (15.00)	41.91 (16.50)	45.09 (17.75)	49.53 (19.50)	56.52 (22.25)
B. Breadth of aperture	34.93 (13.75)	38.74 (15.25)	40.64 (16.00)	43.18 (17.00)	46.36 (18.25)
C. Floor to top of aperture	50.171 (19.75)	106.05 (41.75)	109.22 (43.00)	112.40 (44.25)	118.11 (46.50)
D. Floor to bottom of aperture	67.00 (34.25)	90.17 (35.50)	92.71 (36.50)	95.25 (37.50)	99.06 (39.00)
E. Vertical dimension of aperture	31.12 (12.25)	31.12 (12.25)	31.12 (12.25)	31.12 (12.25)	31.12 (12.25)

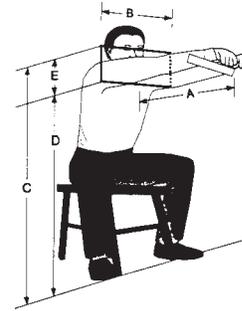


FIG. 100 Seated, Forward Reach (Both Arms)

	Percentiles, cm (in)				
	5th	25th	50th	75th	95th
A. Depth of reach	34.93 (13.75)	40.00 (15.75)	42.55 (16.75)	46.36 (18.25)	50.80 (20.00)
B. Breadth of aperture	34.93 (13.75)	37.47 (14.75)	40.64 (16.00)	42.55 (16.75)	45.09 (17.75)
C. Floor to top of aperture	57.79 (22.75)	61.80 (24.25)	64.14 (25.25)	66.68 (26.25)	71.12 (28.00)
D. Floor to bottom of aperture	43.18 (17.00)	46.99 (18.50)	48.90 (19.25)	50.80 (20.00)	53.98 (21.25)
E. Vertical dimension of aperture	27.94 (11.00)	27.94 (11.00)	27.94 (11.00)	27.94 (11.00)	27.94 (11.00)

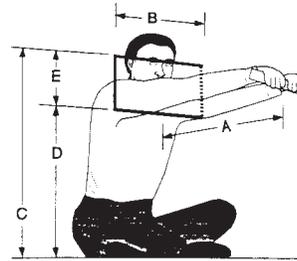


FIG. 101 Crosslegged Seated, Forward Reach (Both Arms)

	Percentiles, cm (in)				
	5th	25th	50th	75th	95th
A. Depth of reach	48.90 (19.25)	53.34 (21.00)	56.52 (22.25)	57.79 (22.75)	62.23 (24.50)
B. Breadth of aperture	39.37 (15.50)	43.18 (17.00)	45.09 (17.75)	46.99 (18.50)	49.53 (19.50)
C. Floor to top of aperture	154.90 (61.00)	161.29 (63.50)	165.74 (65.25)	168.91 (66.50)	175.26 (69.00)
D. Floor to bottom of aperture	132.72 (52.25)	139.07 (54.75)	142.24 (56.00)	145.42 (57.25)	149.80 (59.00)
E. Vertical dimension of aperture	42.55 (16.75)	42.55 (16.75)	42.55 (16.75)	42.55 (16.75)	42.55 (16.75)

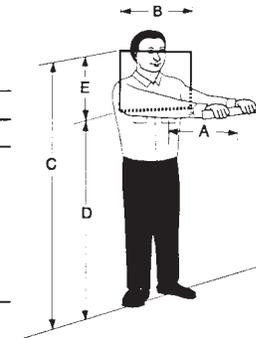


FIG. 102 Standing, Forward Reach (Both Arms)

34.20.4 Sliding covers or caps are particularly useful where swinging space is limited. Small sliding caps are useful for small accesses that do not require a tight seal. When sliding covers are used, the following shall be considered:

34.20.4.1 Sliding doors and caps shall lock positively.

34.20.4.2 They shall be designed so that they will not jam or stick.

34.20.4.3 They shall be easy to use, and personnel shall be able to use them without tools and with heavy gloves.

34.21 Removable covers, plates, or caps require little space for opening and, once removed, do not interfere with work space. However, handling them takes time and effort. When using removable covers, consider the following:

34.21.1 Use tongue-and-slot or similar catches wherever possible for small covers and caps to minimize the number of fasteners required.

34.21.1.1 If small covers and caps are likely to be misplaced or damaged, secure them with retainer chains.

	Percentiles, cm (in)				
	5th	25th	50th	75th	95th
A. Depth of reach	51.44 (20.25)	56.52 (22.25)	60.33 (23.75)	63.50 (25.00)	67.95 (26.75)
B. Breadth of aperture	30.45 (12.00)	30.45 (12.00)	30.45 (12.00)	30.45 (12.00)	30.45 (12.00)
C. Floor to top of aperture	154.94 (61.00)	160.66 (63.25)	165.10 (65.00)	169.28 (66.25)	175.26 (69.00)
D. Floor to bottom of aperture	132.75 (52.25)	139.07 (54.75)	142.24 (56.00)	145.42 (57.25)	149.86 (59.00)
E. Vertical dimension of aperture	42.55 (16.75)	42.55 (16.75)	42.55 (16.75)	42.55 (16.75)	42.55 (16.75)

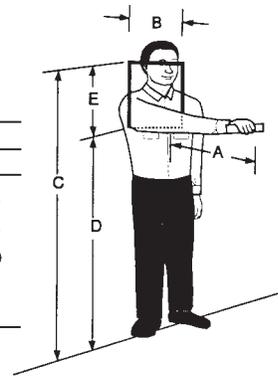


FIG. 103 Standing, Forward Reach (Preferred Arm)

34.21.1.2 If a removable cover must be attached in a certain way, design it so it cannot be attached improperly (use an asymmetric shape, locate mounting holes asymmetrically, or code both cover and structure with labels that will align when the plate is properly installed).

34.22 *Location of Access Covers*—Accesses shall be located only on equipment surfaces that are directly accessible when normally installed.

34.23 *Physical Access:*

34.23.1 *Arm and Hand Access*—Access openings provided for adjusting and handling interior equipment shall be sized to permit the required operations and shall provide an adequate view of the item being manipulated. All blind arm and hand access shall require approval of procuring authority.

34.23.2 *Opening Covers*—Access covers shall be equipped with grasp areas or other means for opening them. Where operations will require opening and closing the covers while wearing gloves or special clothing, opening provision shall accommodate the gloves or special clothing.

34.23.3 *Reach Access Dimensions*—The dimensions of access openings for arms, hands, and fingers shall be no less than those shown in Figs. 99-105. Allowance shall be made for the clearance of the operator’s gloved or mittened hand or special clothing as appropriate. Shape of access shall allow easy passage of equipment, body appendage, or tools as appropriate. Access shape shall permit passage of all equipment that must be replaced through the opening allowing for protuberances, attachments, and handles on the equipment.

34.23.4 *Tool Access Dimensions*—Access openings shall be large enough to operate tools required for maintenance of the equipment reached through the access.

34.23.5 *Remove and Replace Dimensions*—Opening size for removal and replacement of equipment shall allow for handling clearance for bare hand or gloved hand as appropriate.

34.23.6 *Guarding Hazardous Conditions*—If a hazardous condition, such as exposed conductors energized with dangerous voltages or currents, exist behind the access, the physical barrier over the access shall be equipped with an interlock that will deenergize the hazardous equipment when the barrier is open or removed. Both the presence of the hazard and the fact that an interlock exists shall be noted on the equipment case or cover such that it remains visible when the access is open.

34.23.7 *Type of Opening*—Where physical access is required, the following practices shall be followed in order of preference:

34.23.7.1 An opening with no cover unless this is likely to degrade system performance, safety, or NBC contamination survivability.

34.23.7.2 A hand-operated (latched, sliding, or hinged) cap or door where dirt, moisture, or other foreign materials might otherwise create a problem.

34.23.7.3 A quick-opening cover plate using ¼-turn captive fasteners if a cap will not meet stress requirements or space prevents a hinged cover.

34.23.7.4 When captive fasteners cannot be used because of stress, structure, or pressurization, screw down cover. Use minimum number of interchangeable screws to fasten door.

34.24 *Visual Access*—Where visual access is required, the opening shall provide a visual angle sufficient to view all required information at the normal operating or maintenance position. The maintainer shall be provided unrestricted visual access from the work station without bending. Where bending is required, frequency and time in the bent position shall not cause fatigue. Where visual access only is required, the following practices shall be followed in order of precedence:

34.24.1 An opening with no cover except where this might degrade system performance or NBC survivability.

34.24.2 A transparent window if dirt, moisture, or other foreign materials might otherwise create a problem.

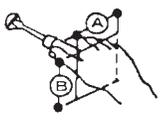
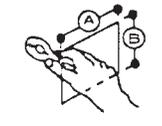
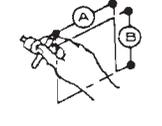
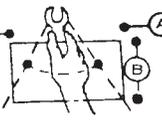
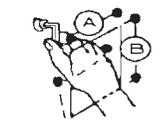
34.24.3 A break-resistant glass window if physical wear, heat, or contact with solvents would otherwise cause optical deterioration.

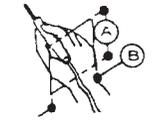
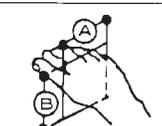
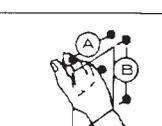
34.24.4 A quick-opening metal cover if glass will not meet stress or other requirements.

35. Cases

35.1 *Orientation*—The proper orientation of an item within its case shall be made obvious, either through design of the case or by means of appropriate labels.

35.2 *Removal*—When practical, cases shall be designed to be lifted from items rather than items lifted from cases (see Fig. 107). Equipment shall be protected from damage when cases are removed or replaced; cases shall not require manual support to remain in the open position during maintenance.

OPENING DIMENSIONS	DIMENSIONS mm (in)		TASK
	A	B	
	108 (4.25) 165 (6.5) 197 (7.75)	120 (4.75*) 178 (7.0) 205 (8.0)	USING COMMON SCREWDRIVER, WITH FREEDOM TO TURN HAND THROUGH 180°.
	127 (5.0) 185 (7.25) 216 (8.5)	115 (4.5) 171 (6.75) 197 (7.75)	USING PLIERS AND SIMILAR TOOLS.
	133 (5.25) 191 (7.5) 222 (8.25)	152 (6.0) 210 (8.25) 235 (9.25)	USING "T" HANDLE WRENCH, WITH FREEDOM TO TURN HAND THROUGH 180°.
	267 (10.5) 318 (12.5) 349 (13.75)	205 (8.0) 260 (10.25) 286 (11.25)	USING OPEN-END WRENCH, WITH FREEDOM TO TURN WRENCH THROUGH 60°.
	121 (4.75) 178 (7.0) 210 (8.25)	152 (6.0) 197 (7.75) 229 (9.00)	USING ALLEN-TYPE WRENCH, WITH FREEDOM TO TURN WRENCH THROUGH 60°.

OPENING DIMENSIONS	DIMENSIONS mm (in)		TASK
	A	B	
	89 (3.5) 146 (5.75) 178 (7.0)	89 (3.5) 146 (5.75) 178 (7.0)	USING TEST PROBE, ETC.
	127 (5.0) 152 (6.0) 215 (8.5)	95 (3.75) 115 (4.5) 178 (7.0)	EMPTY HAND CLINCHED FIST EXTENDED TO WRIST
	102 (4.0) 152 (6.0) 165 (6.5)	57 (2.25) 102 (4.0) 127 (5.0)	EMPTY HAND HAND FLAT EXTENDED TO WRIST

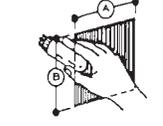
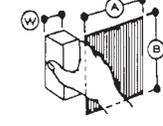
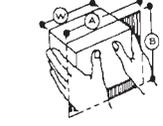
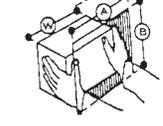
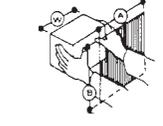
*Top measurement in each dimension is for bare hand. The second number is for a gloved hand and the third is for a hand wearing an arctic mitten. For dimensions required for an NBC suit, use the arctic dimensions.

FIG. 104 Access Opening Dimensions

35.3 *Size*—Cases shall be sufficiently larger than the items they cover to minimize the possibility of damaging wires or other parts when the cases are put on or taken off.

35.4 *Guides*—Guides, tracks, and stops shall be provided as necessary to help align the case to prevent damage to equipment or injury to personnel.

35.5 *Weight*—They shall be removable and transportable by one hand, by one person, or by two persons, in that order of preference.

OPENING DIMENSIONS	DIMENSIONS mm (in)		TASK
	A	B	
	114 (4.5) 171 (6.75) 205 (8.0)	121 (4.75) 178 (7.0) 210 (8.25)	GRASPING SMALL OBJECTS (UP TO 50 mm (2 in) OR MORE WIDE) WITH ONE HAND
	W + 45 (W + 1.75) W + 102 (W + 4.0) W + 159 (W + 6.25)	127 (5.0**) 178 (7.0**) 222 (8.75**)	GRASPING LARGE OBJECTS, 50 mm (2 in) OR MORE WIDE WITH ONE HAND
	W + 75 (W + 3.0) W + 5.25 W + 191 (W + 7.5)	127 (5.0**) 7.0** 222 (8.75**)	GRASPING LARGE OBJECTS WITH TWO HANDS, WITH ARMS EXTENDED THROUGH OPENINGS UP TO FINGERS
	W + 152 (W + 6.0) W + 279 (W + 11.0) W + 356 (W + 14.0)	127 (5.0**) 178 (7.0**) 222 (8.75**)	GRASPING LARGE OBJECTS WITH TWO HANDS, WITH ARMS EXTENDED THROUGH OPENINGS UP TO WRISTS
	W + 152 (W + 6.0) W + 279 (W + 11.0) W + 356 (W + 14.0)	127 (5.0**) 178 (7.0**) 222 (8.75**)	GRASPING LARGE OBJECTS WITH TWO HANDS, WITH ARMS EXTENDED THROUGH OPENINGS UP TO ELBOWS

**Or sufficient to clear part if part is larger than 125 mm

FIG. 104 Access Opening Dimensions (continued)

MINIMAL TWO-HAND ACCESS OPENINGS WITHOUT VISUAL ACCESS		
Reaching with both hands to depth of 152 to 489 mm (6 to 19.25 in):		
Light clothing:	Width: 205 mm (8 in) or the depth of reach* Height: 127 mm (5 in)	
Arctic clothing:	Width: 152 mm (6 in) plus 3/4 the depth of reach Height: 178 mm (7 in)	
Reaching full arm's length (to shoulders) with both arms: Width: 500 mm (195 in) Height: 127 mm (5 in)		
Inserting box grasped by handles on the front: 13 mm (1/2 in) clearance around box, assuming adequate clearance around handles		
Arm to elbow:		
Light clothing:	102 mm (4.0 in) x 115 mm (4.5 in) or 115 mm (4.5 in) dia.	
Arctic clothing:	178 mm (7.0 in) sq. or dia.	
With object:	Clearance as shown	
Arm to shoulder:		
Light clothing:	127 mm (6.0 in) sq. or dia.	
Arctic clothing:	216 mm (8.5 in) sq. or dia.	
With object:	Clearances as shown	
* Whichever is larger.		
MINIMAL FINGER ACCESS TO FIRST JOINT		
Push button access:	Bare hand:	32 mm (1.25 in) dia.
	Gloved hand:	38 mm (1.5 in) dia.
Two finger twist access:	Bare hand:	object plus 50 mm (2.0 in) dia.
	Gloved hand:	object plus 65 mm (2.5 in) dia.
		

FIG. 105 Minimal Two-Hand and Finger Access

35.6 *Handles*—Handles or tool grips, in accordance with 38.5, shall be provided if the case is heavy, difficult to open, or difficult to handle.

36. Lubrication

36.1 *General*—Configuration of equipment containing mechanical items requiring lubrication shall permit both lubrication and checking of lubricant levels without disassembly.

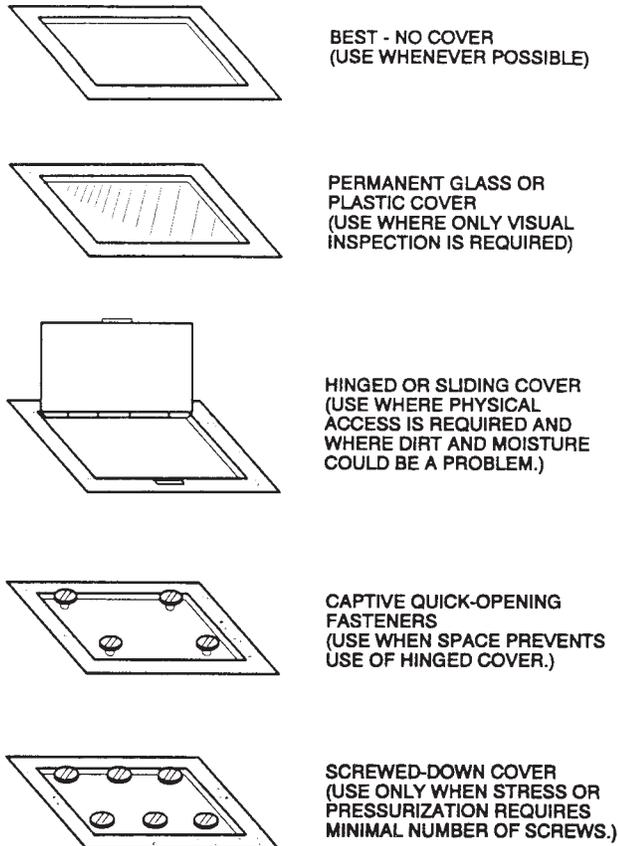


FIG. 106 Covers and Accesses

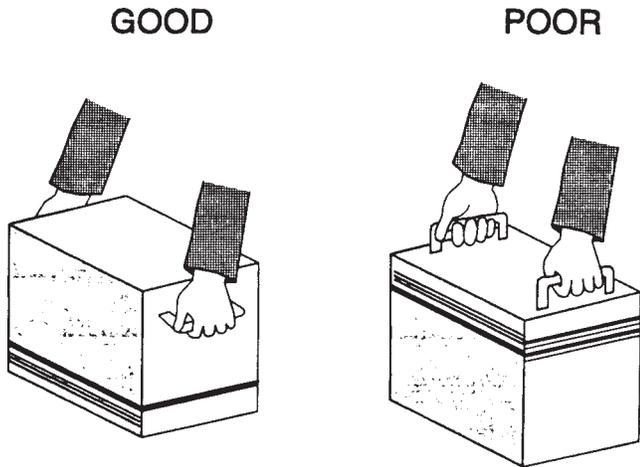


FIG. 107 Covers and Cases

Where fittings are not directly accessible (for example, around steering gear stocks and around inside vertical package conveyor trunks, and so forth), these fittings shall be extended via tubing to a location where they are directly accessible. Permanently lubricated items for which lubricant lasts for the life of the items are excluded.

36.2 *Labeling*—Where lubrication is required, the type of lubricant to be used and the frequency of lubrication may be specified via a lubrication chart of permanent construction mounted at or near the lube port or at the operator station of the equipment. A lubrication chart of permanent construction shall

be mounted at the operator station of the equipment; lubrication charts or individual labels shall not be required when the equipment has only one type of fitting and uses only one type of lubricant.

37. Fasteners

37.1 *General*—The number and diversity of fasteners used shall be minimized commensurate with stress, bonding, pressurization, shielding, thermal, and safety requirements. Finger- or hand-operated fasteners shall be used when consistent with these requirements, except where screws with heads flush with the case or fastening surface are required for NBC survivability. Fasteners requiring nonstandard tools shall not be used. Fasteners used on items requiring use by NBC-suited personnel shall be quick acting, with no sharp edges or protrusions that could puncture or tear the NBC suit.

37.2 *Hinges and Tongue-and-Slot Catches*—Optimum use shall be made of hinges and tongue-and-slot catches to minimize the number of fasteners required.

37.2.1 *Captive Fasteners*—Captive fasteners shall be used where dropping or loss of such items could cause damage to equipment or create a difficult or hazardous removal problem. Captive fasteners shall also be provided for access covers requiring frequent removal.

37.2.2 *Quantity*—If a hinged access panel or quick-opening fasteners will not meet stress, pressurization, shielding, or safety requirements, the minimum number consistent with these requirements shall be used.

37.2.3 *Fastener Head Type*:

37.3 *High-Torque Fasteners*—External hex or external double-hex wrenching elements shall be provided on all machine screws, bolts, or other fasteners requiring more than 14 N·m (10 ft·lb) of torque. When external wrenching fasteners cannot meet the mechanical function or personnel safety requirements, or in limited access situations, and where use is protected from accumulation of foreign material, internal wrenching fasteners may be used.

37.4 *Low-Torque Fasteners*—Hex-type internal grip head, hex-type external grip head, or combination head (hex or straight-slot internal grip and hex-type external-grip head), or torque-set fasteners shall be provided where less than 14 N·m (10 ft·lb) torque is required; however, internal-grip head fasteners shall be provided only where a straight or convex smooth surface is required for mechanical function or for personnel safety and where use is protected from accumulation of foreign material (such as ice or snow). Straight-slot or Phillips-type internal grip fasteners shall not be provided except as wood fasteners or where these type fasteners are provided on standard commercial items.

37.5 *Common Fasteners*—Identical screw and bolt heads shall be provided to allow various panels and components to be removed with one type of tool. Combination bolt heads such as the slotted hex head shall be selected whenever feasible.

37.6 *Accessibility*—The heads of mounting bolts and fasteners shall be located on surfaces directly accessible to the technician.

37.7 *Number of Turns*—Fasteners for mounting assemblies and subassemblies shall require only one complete turn,

provided that stress, alignment, positioning, and load considerations are not compromised. When machine screws or bolts are required, the number of turns and the amount of torque shall be no more than necessary to provide the required strength except when a common fastener is used.

37.8 Torque Labeling—When fastener torquing to meet EMI/RFI shielding, thermal conductance, or other constraints is required for organizational or intermediate-level maintenance actions, an instructional label or placard shall be provided in reasonable proximity to fasteners. Labels shall comply with requirements of Section 28.

37.9 Types of Fasteners (In Order of Preference):

37.9.1 Quick Connect-Disconnect Devices—These devices are fast and easy to use, do not require tools, may be operated with one hand, and are very good for securing plug-in components, small components, and covers. However, their power is low, and they cannot be used where a smooth surface is required. The following factors shall be considered in selecting quick connect-disconnect fasteners:

37.9.1.1 Use these fasteners wherever possible when components must be dismantled or removed frequently.

37.9.1.2 These fasteners must fasten and release easily, without requiring tools.

37.9.1.3 They shall fasten or unfasten with a single motion of the hand.

37.9.1.4 It shall be obvious when they are not correctly engaged.

37.9.1.5 When there are many of these fasteners, prevent misconnections by giving the female section a color or shape code, location, or size so it will be attached only to the correct male section.

37.9.2 Latches and Catches—These items are very fast and easy to use, do not require tools, and have good holding power; especially good for large units, panels, covers, and cases. They cannot be used where a smooth surface is required. The following factors shall be considered in selecting latches and catches:

37.9.2.1 Use long-latch catches to minimize inadvertent releasing of the latch.

37.9.2.2 Spring-load catches so they lock on contact, rather than requiring positive locking.

37.9.2.3 If the latch has a handle, locate the latch release on or near the handle so it can be operated with one hand.

37.9.2.4 Evaluate latches/catches for snap down/release forces that could be hazardous to hand during operation.

37.9.3 Captive Fasteners—Captive fasteners are slower and more difficult to use, depending upon type, and usually require using common hand tools; but they stay in place, saving time that would otherwise be wasted handling and looking for bolts and screws; can be operated with one hand. The following factors shall be considered in selecting captive fasteners:

37.9.3.1 Use captive fasteners when lost screws, bolts, or nuts might cause a malfunction or excessive maintenance time.

37.9.3.2 Use fasteners that can be operated by hand or with a common hand tool.

37.9.3.3 Use fasteners that can be replaced easily if they are damaged.

37.9.3.4 Captive fasteners of the quarter-turn style shall be self-locking and spring-loaded.

37.9.4 Regular Screws—Round, square, or flat-head screws take longer to use and are subject to loss, damage, stripping, and misapplication. Square-head screws are generally preferable to round or flat ones; they provide better tool contact, have sturdier slots, and can be removed with wrenches. If personnel must drive screws blindly, provide a guide in the assembly to help keep the screwdriver positioned properly. The following factors shall be considered in the selection of screws:

37.9.4.1 Screw heads shall have deep slots that will resist damage.

37.9.4.2 Use screws only when personnel can use screwdrivers in a straight-in fashion; do not require personnel to use offset screwdrivers.

37.9.5 Bolts and Nuts—Bolts are usually slow and difficult to use. Personnel must have access to both ends of the bolt, use both hands, and often use two tools. Also, starting nuts require precise movements. There are many loose parts to handle and lose (nuts, washers, and so forth). Design considerations shall include the following:

37.9.5.1 Keep bolts as short as possible, so they will not snag personnel or equipment.

37.9.5.2 Coarse threads are preferable to fine threads for low torques and reduce the possibility of cross threading.

37.9.5.3 Avoid left-hand threads unless system requirements demand them; then identify both bolts and nuts clearly by marking, shape, or color coding.

37.9.5.4 Use wing nuts (preferably) or knurled nuts for low-torque applications, because they do not require tools.

37.9.6 Combination-Head Bolts and Screws—Combination-head bolts and screws are preferable to other screws or bolts, because they can be operated with either a wrench or a screwdriver, whichever is more convenient, and there is less danger of damaged slots and stuck fasteners. In general, slotted hexagon heads are preferable to slotted knurled heads.

37.9.7 Internal-Wrenching Screws and Bolts—Internal-wrenching screws and bolts (socket heads) allow higher torque, better tool grip, and less wrenching space; but they require special tools, are easily damaged, and are difficult to remove if damaged. They also become filled with ice and frozen mud. The following factors shall be considered in selecting internal-wrenching fasteners:

37.9.7.1 Minimize the number of different sizes to minimize the number of special tools; preferably, use only one size.

37.9.7.2 Select fasteners with deep slots to reduce the danger of damaged fasteners.

37.9.8 Rivets—Rivets are very hard and time-consuming to remove. They shall not be used on any part that may require removal.

37.9.9 Cotter Key—Cotter key users shall consider the following:

37.9.9.1 Keys and pins shall fit snugly, but they shall not have to be driven in or out.

37.9.9.2 Cotter keys shall have large heads for easy removal.

37.9.10 *Safety Wire:*

37.9.10.1 Use safety wire only where self-locking fasteners cannot withstand the expected vibration or stress.

37.9.10.2 Attach safety wire so it is easy to remove and replace.

37.9.11 *Retainer Ring:*

37.9.11.1 Avoid rings that become difficult to remove and replace when they are worn.

37.9.11.2 Use rings that hold with a positive snap action when possible.

37.9.12 *Retainer Chains*—The following are uses and considerations for selection of retainer chains:

37.9.12.1 Keep hatches or doors from opening too far and springing their hinges.

37.9.12.2 Turn doors or covers into useful shelves for the technician.

37.9.12.3 Prevent small covers, plates, or caps from being misplaced.

37.9.12.4 Secure small, special tools where they will be used.

37.9.12.5 Secure objects that might fall and injure personnel.

37.9.12.6 Secure removable pins to prevent loss.

37.9.12.7 Use link, sash, or woven-mesh chains. Avoid bead-link chain, because it breaks more easily than other types.

37.9.12.8 Attach chains with screws or bolts; attach them strongly and positively, but so they can be disconnected easily when required.

37.9.12.9 Provide eyelets at both ends of the chain for attaching to the fasteners.

37.9.12.10 Chains shall not be longer than their function requires.

38. Unit Design for Efficient Manual Handling

38.1 *Rests and Stands*—When required to support operations or maintenance functions, rests or stands on which units can be placed, including space for test equipment, tools, technical orders, and manuals, shall be provided. When permitted by design requirements, such rests or stands shall be part of the basic unit, rack, or console chassis.

38.2 *Extensions*—Extensions and connected appurtenances, accessories, utilities, cables, wave guides, hoses, and similar items shall be designed for easy removal or disconnection from the equipment before handling.

38.3 *Weight Lifting and Carrying Limits:*

38.3.1 *Lifting Limits*—The weight limits in Table 43, Conditions A and B, shall be used as maximum values in determining the design weight of items requiring one person lifting with two hands. Double the weight limits in Table 43 shall be used as maximum values in determining the design weight of items requiring two-person lifting, provided the load is uniformly distributed between the two lifters. If the weight of the load is not uniformly distributed, the weight limit applies to the heavier lift point. Where three or more persons are lifting simultaneously, not more than 75 % of the one-person value may be added for each additional lifter, provided that the object lifted is sufficiently large that the lifters do not interfere with one another while lifting. Where it is not possible to define the height to which an object will be lifted in operational use, the limit wherein the object is lifted to shoulder height shall be

used rather than the more permissive bench height. The values in Table 43 are applicable to objects with or without handles.

38.3.2 *Lifting Frequency*—The equipment weight limits in Table 43 are not for repetitive lifting as found, for example, in loading or unloading transport vehicles. If the frequency of lift exceeds one lift in 5 min or 20 lifts per 8 h, the permissible weight limits shall be reduced by $(8.33 \times LF) \%$, where LF is the lift frequency in lifts per minute. For example, if the lift frequency is six lifts per minute, then the maximum permissible weight is reduced by 50 % ($8.33 \times 6 = 50$).

38.3.3 *Load Size*—The maximum permissible weight lift limits in Table 43 are applicable to an object with uniform mass distribution and a compact size not exceeding 460 mm (18 in.) high, 460 mm (18 in.) wide, 300 mm (12 in.) deep (away from the lifter). This places the hand holds at half the depth, or 150 mm (6 in.) away from the body. If the depth of the object exceeds 610 mm (24 in.), the permissible weight shall be reduced by 33 %. If the depth of the object exceeds 910 mm (36 in.), the permissible weight shall be reduced by 50 %. If the depth of the object exceeds 1.220 m (48 in.), the permissible weight shall be reduced by 66 %.

38.3.4 *Obstacles*—The values in Table 43 assume that there are no obstacles between the person lifting and the shelf, table, bench, or other surface on which the object is to be placed. Where there is a lower protruding shelf or other obstacle limiting the lifter's approach to the desired surface, the weight of the limit of the object shall be reduced by 33 % for an obstacle exceeding 300 mm (12 in.) in depth, 50 % for an obstacle exceeding 460 mm (18 in.), and 66 % for an obstacle of 610 mm (24 in.). If the allowable weight must be reduced by both oversize load considerations (38.3.3) and the obstacle considerations, only the more restrictive single value shall apply; two reductions shall not be applied.

38.3.5 *Carrying Limits*—The weight limit in Table 43 Condition C shall be used as the maximum value in determining the design weight of items requiring one person carrying objects a distance of up to 10 m (33 ft). The maximum permissible weight for carrying also applies to an object with a handle on top, such as a tool box, which usually is carried at the side with one hand. Double this weight-carrying limit shall be used as the maximum value in determining the design weight of items requiring two-person carrying, provided the load is uniformly distributed between the two carriers. Where three or more persons are carrying a load together, not more than 75 % of the one-person value may be added for each additional person and provided that the object is sufficiently large that the workers do not interfere with one another while carrying the load. In all cases involving carrying, it is assumed that the object is first lifted from the floor, carried a distance of 10 m (33 ft) or less and placed on the floor or on another surface not higher than 915 mm (36 in.). If the final lift is to a higher height, the 1.525-m (5-ft) lift height applies as the more limiting case.

38.3.6 *Carrying Frequency*—The reduction formula expressed in 38.3.2 shall be applied to repetitive carrying in the same manner as for repetitive lifting.

38.3.7 *User Population*—Unless otherwise specified by the procuring activity, the values in Table 43 for male and female

population shall apply to any object to be lifted or carried manually. Where the procuring activity specifies that the object is to be lifted or carried only in a combat environment, the male only population will be applied.

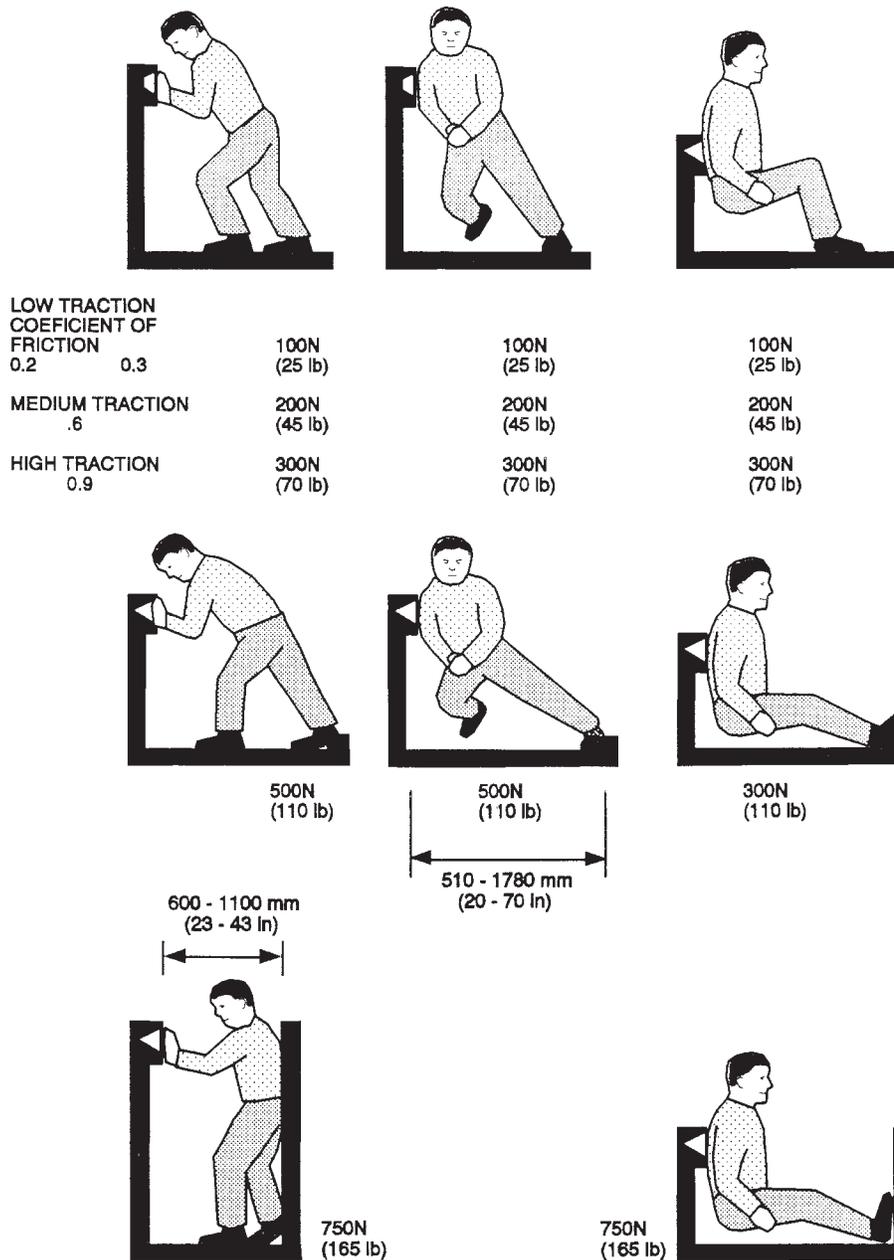
38.3.8 *Labeling*—Items weighing more than the one-person lift or carry values for male and female population of Table 43 shall be prominently labeled with weight of the object and lift limitation, that is, mechanical or two-person lift, three-person lift, and so forth. Where mechanical or power lift is required, hoist and lift points shall be provided and clearly labeled.

38.4 *Push-and-Pull Forces*:

38.4.1 *Horizontal*—Manual horizontal push-and-pull forces required to be applied initially to an object to set it in motion

or to be sustained over a short period of time, shall not exceed the values of Fig. 108, as applicable. The values shown in Fig. 108 apply to males only and shall be modified for females. (Two thirds of each value shown is considered to be a reasonable adjustment). Use of the maxima shown in Fig. 108 is predicted upon a suitable surface for force exertion, vertical with rough surface, and be approximately 400 mm (16 in.) wide and between 51 and 127 cm (20 and 50 in.) above the floor to allow force application with the hands, the shoulder, or the back.

38.4.2 *Vertical*—Manual vertical push-and-pull forces required shall not exceed the applicable fifty percentile peak or mean force values of Table 44.



MAY BE DOUBLED FOR TWO & TRIPLED FOR THREE PERSONS PUSHING SIMULTANEOUSLY. FOR THE FOURTH AND EACH ADDITIONAL OPERATOR, NOT MORE THAN 75% OF THEIR PUSH CAPABILITY SHOULD BE ADDED.

FIG. 108 Examples of Push-Pull Forces



TABLE 44 Static Muscle Strength Data

Strength Measurements	5th Percentile		95th Percentile	
	Men N (lbf)	Women N (lbf)	Men N (lbf)	Women N (lbf)
Standing two-handed pull: 38-cm (15-in.) level				
Mean force	738 (166)	331 (74)	1354 (304)	818 (184)
Peak force	845 (190)	397 (89)	1437 (323)	888 (200)
Standing two-handed pull: 50-cm (20-in.) level				
Mean force	758 (170)	326 (73)	1342 (302)	840 (187)
Peak force	831 (187)	374 (84)	1442 (324)	905 (203)
Standing two-handed pull: 100-cm (39-in.) level				
Mean force	444 (100)	185 (42)	931 (209)	443 (100)
Peak force	504 (113)	218 (49)	998 (224)	493 (111)
Standing two-handed push: 150-cm (59-in.) level				
Mean force	409 (92)	153 (34)	1017 (229)	380 (85)
Peak force	473 (106)	188 (42)	1094 (246)	430 (97)
Standing one-handed pull: 100-cm (39-in.) level				
Mean force	215 (48)	103 (23)	628 (141)	284 (64)
Peak force	259 (58)	132 (30)	724 (163)	322 (72)
Seated one-handed pull: Centerline, 45-cm (18-in.) level				
Mean force	227 (51)	106 (24)	678 (152)	392 (88)
Peak force	273 (61)	127 (29)	758 (170)	451 (101)
Seated one-handed pull: Side, 45-cm (18-in.) level				
Mean force	240 (54)	109 (25)	604 (136)	337 (76)
Peak force	273 (61)	134 (30)	659 (148)	395 (89)
Seated two-handed pull: Centerline, 38-cm (15-in.) level				
Mean force	595 (134)	242 (54)	1221 (274)	770 (173)
Peak force	699 (157)	285 (64)	1324 (298)	842 (189)
Seated two-handed pull: Centerline, 50-cm (20-in.) level				
Mean force	525 (118)	204 (46)	1052 (236)	632 (142)
Peak force	596 (134)	237 (53)	1189 (267)	697 (157)

38.5 Handles and Grasp Areas:

38.5.1 *General*—All removable or carried units designed to be removed and replaced shall be provided with handles or other suitable means for grasping, handling, and carrying (where appropriate, by gloved or mittened hand). Items requiring handling shall be provided with a minimum of two handles or one handle and one grasp area. Items weighing less than 4.5 kg (10 lbs) whose form factor permits them to be handled easily shall be exempt from this requirement unless specifically directed by the procuring activity.

38.5.2 *Location*—Whenever possible, handles or grasp areas shall be located relative to the center of gravity of the unit to preclude swinging or tilting when lifted. They shall be located to provide at least 65 mm (2.5 in.) of clearance from obstructions during handling.

38.5.3 *Nonfixed Handles*—Nonfixed handles (for example, hinged or foldout) shall have a stop position for holding the handle perpendicular to the surface on which it is mounted and shall be capable of being placed into carrying position by one hand (where appropriate, by gloved or mittened hand).

38.5.4 *Grasp Surface*—Where an item's installation requires that its bottom surface be used as a handhold during removal or installation, a nonslip grasp surface (for example, grooved or frictional) shall be provided.

38.5.5 *Handle Dimensions*—Handles that are to be used with mittened, gloved, or ungloved hands shall equal or exceed the minimum applicable dimensions shown in Fig. 109.

38.5.6 *Handle Grasp Area Force Requirements*—Force requirements to operate handle and grasp areas shall be in Section 21, Controls, General Information.

38.5.7 *Handle Material*—Handles or grasp areas used with bare hands shall have surfaces that are not thermally or electrically conductive. The surface shall be sufficiently hard to prevent imbedding of grit and grime during normal use.

38.5.8 *Shape*—Use hand-shape handles when items must be carried frequently or for long periods.

38.5.9 *Hoist Lugs*—Lifting eyes shall be provided on all equipment weighing more than 68 kg (150 lbs) with a minimum of 100 mm (4 in.) of space around the eye.

39. Handwheel Torque

39.1 *Handwheel Torque*—Fig. 110 contains information on desirable upper limits for handwheel torque. This data was from a very small male sample and the most conservative values were used. Female values were extrapolated and are 60 % of the male values. This information may be used for guidance in designing handwheels.

40. Equipment Mounting

40.1 *General*—Equipment items shall be designed so that they cannot be mounted improperly. Code, label, or key symmetrical components to indicate proper orientation for mounting or installation.

40.2 *Tools*—Field-removable items shall be replaceable by use of nothing more than common hand tools.

40.3 *Removal*—Replaceable items shall be removable along a straight or slightly curved line, rather than an angle.

40.4 *Alignment*—Guide pins or their equivalent shall be provided to assist in alignment during mounting, particularly on modules that are connectors themselves.

40.5 *Coding*—All replaceable items shall be coded (keyed) so that it will be physically impossible to insert a wrong item. Coding by such means as color or labels shall identify the correct item and its proper orientation or replacement.

40.6 *Rollout Racks, Slides, or Hinges*—Items that are frequently pulled out of their installed positions for checking shall be mounted on rollout racks, slides, or hinges. Rollout racks shall not shift the center of gravity to the extent that the entire rack or console falls. If this possibility exists, the console or rack shall be safely secured. The rollout racks shall operate with a force less than 178 N (4 lbs).

40.7 *Limit Stops*—Limit stops shall be provided on racks and drawers which are required to be pulled out of their installed positions for checking or maintenance. The limit stop design shall permit convenient overriding of stops for unit removal.

40.8 *Interlocks*—Where applicable, interlocks shall be provided to ensure disconnection of equipment that would otherwise be damaged by withdrawal of racks or drawers.

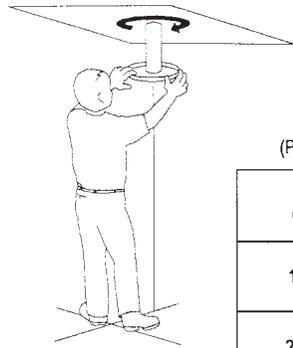
40.9 *Hinged Mounting*—Hinged items shall be provided with a brace or other means of support to hold equipment in the “out” position for maintenance it is not free to rotate and remain in the “out” position without support.

ILLUSTRATION	TYPE OF HANDLE	DIMENSIONS IN mm (inches)								
		(Bare Hand)			(Gloved Hand)			(Mittened Hand)		
		X	Y	Z	X	Y	Z	X	Y	Z
	Two-finger bar	32 (1 1/4)	65 (2 1/2)	75 (3)	38 (1 1/2)	75 (3)	75 (3)	Not applicable		
	One-hand bar	48 (1 7/8)	111 (4 3/8)	75 (3)	50 (2)	125 (5)	100 (4)	75 (3)	135 (5 1/4)	150 (6)
	Two-hand bar	48 (1 7/8)	215 (8 1/2)	75 (3)	50 (2)	270 (10 1/2)	100 (4)	75 (3)	280 (11)	150 (6)
	T-bar	38 (1 1/2)	100 (4)	75 (3)	50 (2)	115 (4 1/2)	100 (4)	Not applicable		
	J-bar	50 (2)	100 (4)	75 (3)	50 (2)	115 (4 1/2)	100 (4)	75 (3)	125 (5)	150 (6)
	Two-finger recess	32 (1 1/4)	65 (2 1/2)	50 (2)	38 (1 1/3)	75 (3)	50 (2)	Not applicable		
	One-hand recess	50 (2)	110 (4 1/4)	90 (3 1/2)	90 (3 1/2)	135 (5 1/4)	100 (4)	90 (3 1/2)	135 (5 1/4)	125 (5)
	Finger-tip recess	19 (3/4)	—	13 (1/2)	25 (1)	—	19 (3/4)	Not applicable		
	One-finger recess	32 (1 1/4)	—	50 (2)	38 (1 1/2)	—	5 (2)	Not applicable		
Curvature of Handle or Edge (DOES NOT PRECLUDE USE OF OVAL HANDLES)	Weight of item Up to 15 lbs (6.8 kg) 15 to 20 lbs (6.8 to 9.0 kg) 20 to 40 lbs (9.0 to 18 kg) Over 40 lbs (over 18 kg) T-bar Post	Minimum Diameter D - 6 mm (1/4 in.) D - 13 mm (1/2 in.) D - 19 mm (3/4 in.) D - 25 mm (1 in.) T - 13 mm (1/2 in.)			Gripping efficiency is best if finger can curl around handle or edge to any angle of $2/3 \pi$ rad 120° or more.					

FIG. 109 Minimum Handle Dimensions

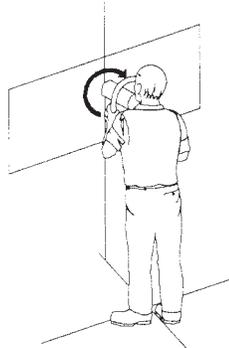
40.10 Braces—Hinged items shall be provided with a brace or other means to hold equipment in the out position during checking or maintenance.

40.11 Access—Sliding, rotating, or hinged equipment to which rear access is required shall be free to open or rotate their full distance and remain in the open position without



BOARD FACE HORIZONTAL (2 Hand Torque)

(Pounds/Feet)	WAIST HIGH		CHEST HIGH		OVER-HEAD	
	Male	Female	Male	Female	Male	Female
6" Wheel	20	12	20	12	16.7	10.02
12" Wheel	59	35.4	56	33.6	36	21.6
21" Wheel	85	51	80	48	55	33



BOARD FACE VERTICAL (2 Hand Torque)

(Pounds/Feet)	KNEE HIGH		WAIST HIGH		CHEST HIGH		OVER-HEAD	
	Male	Female	Male	Female	Male	Female	Male	Female
6" Wheel	18.9	11.3	18.7	11.2	18.2	10.9	15.2	9.1
12" Wheel	60	36	48	28.8	53	31.8	42	25.2
21" Wheel	106	63.6	86	51.6	92	55.2	77	46.2

FIG. 110 Desirable Upper Limits for Handwheel Torque

being supported by hand. If access panels are provided do not require opening more than one to remove any single unit and keep all panel removals to a minimum.

40.12 *Layout*—Units shall be laid out so that a minimum of place-to-place movements will be required during checkout. Position components so the heavier ones are the easiest to reach. Keep components under 13.6 kg (30 lbs) where possible, with removal items under 20.5 kg (45 lbs) max. Place the heavy units so they can be slid out rather than lifted out. Difficult to reach items shall weigh less than 11.3 kg (25 lbs) and the 20.4-kg (45-lbs) items shall be placed for two-person handling.

40.13 *Covers or Panels*—Removal of any replaceable item shall require opening or removing a minimum number of covers or panels.

41. Conductors

41.1 *Coding*—Cables containing individually insulated conductors with a common sheath shall be coded.

41.2 *Cable Clamps*—Long conductors, bundles, or cables, internal to equipment, shall be secured to the equipment chassis by means of clamps unless contained in wiring ducts or cable retractors.

41.3 *Length*—Cables shall be long enough so that each functional unit can be checked in a convenient place. Extension cables shall be provided where this is not feasible.

41.4 *Cable Routing*—Cable routing shall not obstruct visual or physical access to equipment for operation or maintenance.

41.5 *Location of Test Cables*—If it is essential that test cables terminate on control and display panels, the test receptacles shall be so located that the test cables will not interfere with controls and displays.

41.6 *Access*—Cables shall be routed so as to be directly accessible for inspection and repair.

41.7 *Susceptibility to Abuse*—Cables shall be routed or protected in such a way that they may not be pinched by doors, lids, and so forth, walked on, used for handholds, or bent or twisted sharply or repeatedly.

41.8 *Cable Protection*—If it is necessary to route cables and wires through holes in mental partitions, the conductors shall be protected from mechanical damage or wear by grommets or equivalent means. Where required for NBC survivability, cables shall be wrapped and sealed.

41.9 *Identification*—Cables shall be labeled to indicate the equipment to which they belong and the connectors with which they mate. All replaceable wires and cables shall be uniquely

identified with distinct color or number codes. Color-coded wires shall be color coded over their entire length. Number codes shall be repeated every 50 cm (20 in.) over the wire's entire length.

42. Connectors

42.1 *Use of Quick-Disconnect Plugs*—Plugs requiring no more than one turn, or other quick-disconnect plugs, shall be provided whenever feasible.

42.2 *Keying*—Plugs shall be designed so that it will be impossible to insert a wrong plug in a receptacle or to insert a plug into the correct receptacle the wrong way.

42.3 *Identification*—Electrical plugs and receptacles shall be identified by color, shape, labels, or equivalent means (see Fig. 111). If labels are used, they shall be placed on the

connector and receptacle, on plates attached to the connector and receptacle, or on tabs or tapes attached to the connector (in that order of preference).

42.4 *Alignment*—Plugs or receptacles shall be provided with aligning pins or equivalent devices to aid in alignment and to preclude inserting in other than the desired position.

42.5 *Aligning Pins*—Aligning pins shall extend beyond the plug's electrical pins to ensure that alignment is obtained before the electrical pins engage. All aligning pins for a given plug or series of plugs shall be oriented in the same direction, unless this conflicts with precautions against mismatching.

42.6 *Orientation*—Plugs and receptacles shall be arranged so that the aligning pins or equivalent devices are oriented in the same relative position.

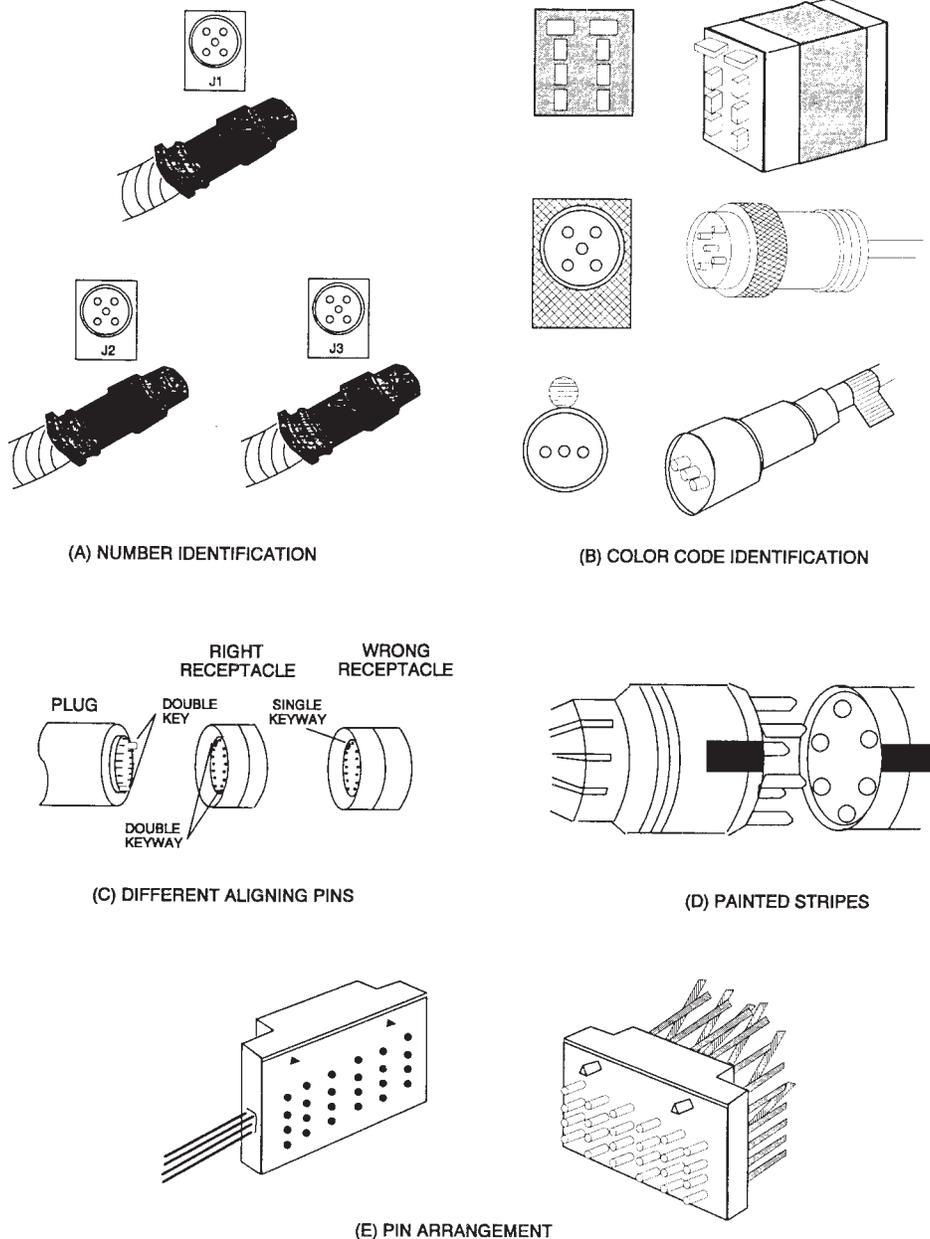


FIG. 111 Methods of Identifying Plugs and Receptacles to Prevent Mismatching

42.7 *Coding*—Plugs and receptacles shall have durable strips, arrows, or other indications to show the positions of aligning pins or equivalent devices for proper insertion.

42.8 *Spacing*—Connectors shall be spaced far enough apart so that they can be grasped firmly for connecting and disconnecting. Space between adjacent connectors, or between a connector and any adjacent obstructions, shall be compatible with the size and shape of the plugs, and the type of clothing worn by the maintainer (for example, cold weather handwear, NBC gloves), but shall be not less than 25 mm (1 in.), except where connectors are to be sequentially removed and replaced and 25-mm (1-in.) clearance is provided in a swept area of at least 4.71 rad (270°) around each connector at the start of its removal/replacement sequence. Spacing shall be measured from the outermost portion of the connector, that is, from the backshell, strain relief clamp, dust cover, or EMI/RFI shield. Where high torque is required to tighten or loosen the connector, space shall be provided for use of a connector wrench.

42.9 *Testing and Servicing*—The rear of plug connectors shall be accessible for testing and servicing, except where precluded by potting, sealing, or other requirements.

42.10 *Drawer Modules*—Drawer modules designed for remove-and-replace maintenance shall be provided with connectors mounted on the back of the drawer and mated with connectors in the cabinet to accomplish electrical interconnection between the drawer, other equipment in the rack, and external connectors, where feasible. Guide pins or equivalent devices shall be provided to aid in alignment.

42.10.1 *Electronic Modules*—Replacement electronic items (for example, modules and high-failure-rate components) should be provided with simple plug-in, rack-and-panel-type connectors.

42.11 *Simplicity*—In electronic equipment, replacement items (for example, modules and high-failure-rate components) shall normally be provided with simple plug-in connectors.

42.12 *Disassembly and Adapters*—Disassembly of connectors for reasons of changing pin connections shall be easily performed without special tools. When adapters are required, they shall be capable of being hand-tightened.

42.13 *Dust Covers*—If dust covers are required, captive types shall be used.

43. Electrical Wires and Cables

43.1 *Routing*—Wherever possible, cables should be routed over, rather than under pipes or fluid containers. Route cables so that they are not pinched by doors, lids, and slides; are not walked on or used for handholds; are accessible to the technician, that is, are not under floorboards, behind panels or components that are difficult to remove, or routed through congested areas, and need not be bent or unbent sharply when connected or disconnected (Fig. 112 and Fig. 113).

43.2 *Coding*—Each cable or wire shall be labeled or coded throughout its entire length. Labels installed at a bench preparatory site shall be placed so they will be visible, and in the proper orientation to the reader, once the wire or cable is installed.

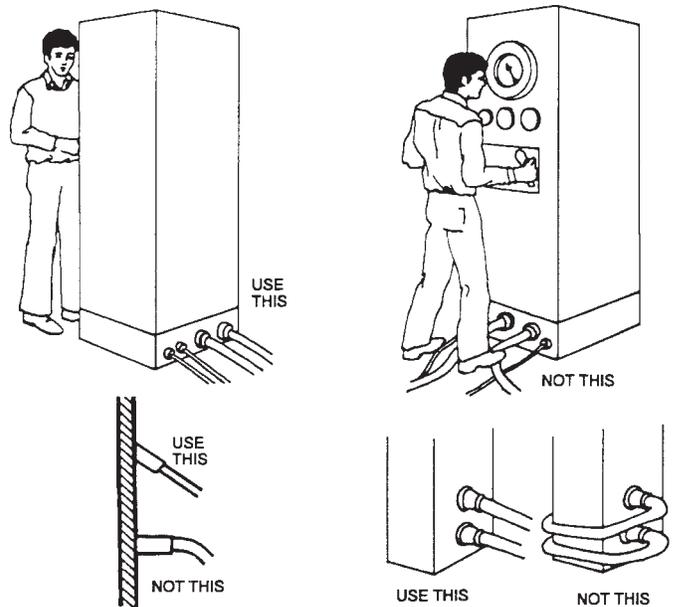


FIG. 112 Cable Arrangements

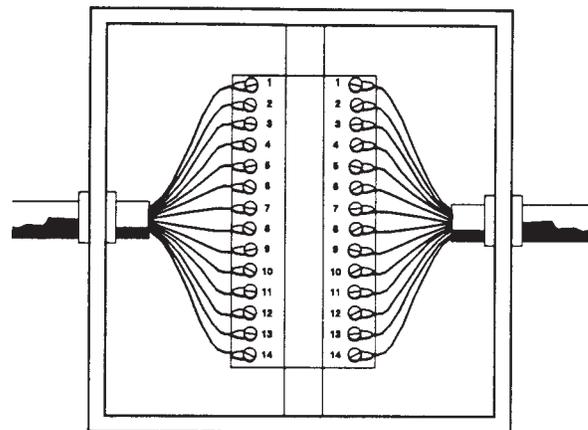


FIG. 113 Suggested Cable Arrangement in Junction Box for Easy Checking

43.3 *Leads*—Enough slack shall be provided so terminal fittings can be replaced at least twice and preferably three times.

43.4 *Fan Out in Junction Boxes*—Cables shall fan out in junction boxes for easy checking, especially if there are no other test points in the circuits (see Fig. 113). Each terminal in the junction box shall be clearly labeled and easy to reach with test probes.

43.5 *Location of Junction Boxes*—Junction boxes that contain many wires (for example, IC junction boxes) which will require continued access after installation shall not be located under false decks or other difficult places to reach.

43.6 *Preformed Cables*—Use preformed cables when possible (Fig. 114). They permit flexible, more efficient assembly methods and minimize the chances of making wiring errors. They also permit testing and coding of the entire cable before installation. Once the cable is placed in position on the chassis, the leads can be connected without interference and confusion caused by stray wires.

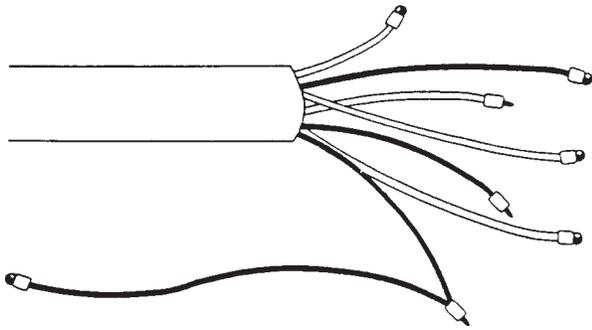


FIG. 114 Preformed Cables

44. Test Points

44.1 *Adjustment*—Test points used in adjusting a unit shall be located close to the controls and displays.

44.2 *Troubleshooting*—Sufficient test points shall be provided so that it will not be necessary to remove subassemblies from assemblies to accomplish troubleshooting.

44.3 *Location*—Test points and their associated labels and controls shall be located so they face the user in their test position.

44.4 *Design Considerations*—Test points shall be provided, designed, and located as follows:

44.4.1 So that there will be a minimum of disassembly or removal of other equipment or items.

44.4.2 On surfaces on or behind accesses that may be easily reached or readily operated when the equipment is fully assembled and installed.

44.4.3 So that adequate clearance is provided between connectors, probes, controls, and so forth, for easy grasping and manipulation. The following minimum clearances are recommended:

44.4.3.1 When only finger control is required, 19 mm (0.75 in.).

44.4.3.2 When the gloved hand must be used, 75 mm (3 in.).

44.4.4 With guards and shields to protect personnel and test or service equipment, particularly if the equipment must be serviced while operating.

44.4.5 To avoid locating a single test or service point in an isolated position; such points are most likely to be overlooked or neglected.

44.4.6 With windows to internal items requiring frequent visual inspections, such as gages, indicators, and so forth.

44.4.7 With tool guides and other design features to facilitate operation of test or service points that require blind operation.

44.4.8 Within easy functional reaching or seeing distance of related or corresponding controls, displays, fittings, switches, and so forth.

44.4.9 Away from dangerous electrical, mechanical, or other hazards. A hands-width separation of 115 mm (4.5 in.) shall be provided from the nearest hazard, along with guards and shields, to prevent injury.

44.5 *Adjustment Controls*—Where adjustment controls are associated with test and service points, they shall be designed and positioned so that:

44.5.1 They are capable of being quickly returned to the original settings to minimize realignment time if they are inadvertently moved.

44.5.2 Adjustments are independent of each other whenever possible.

44.5.3 Those that require sequential adjustment are located in the proper sequence and marked to designate the order of adjustment.

44.5.4 Knobs are used in preference to screwdriver adjustments except where inadvertent or unauthorized adjustments want to be avoided. In those cases, a screwdriver adjustment is preferred.

45. Test Equipment

45.1 *Storage*—Adequate storage space shall be provided within portable test equipment, its handling case, or lid to contain leads, probes, spares, manuals, and special tools, as required for operation.

45.2 *Instructions*—Instructions for operating portable test equipment shall be provided on the face of the test equipment, in a lid, or in a special compartment. Where applicable, the instructions shall include a reminder to calibrate the equipment before using it.

45.3 *Switches*—Selector switches shall be used instead of a number of plug in connections. Circuit breakers and fuses shall be used to safeguard against damage if the wrong switch or jack position is used.

45.4 *Portable Test Equipment Design:*

45.4.1 Rectangular or square shapes are recommended with dimensions to fit standard electrical racks if possible.

45.4.2 Stands or casters shall be provided for devices weighing more than 13.6 kg (30 lbs). Wheels, casters, or hoist-lifting shall be provided for devices weighing more than 40.8 kg (90 lbs).

45.4.3 Portable test equipment shall have rounded corners and edges.

45.4.4 Hinged, permanently attached covers are recommended.

45.4.5 The weight and dimensions of portable test equipment shall not exceed those listed in Table 45.

45.4.6 Instructions shall be written in a simple language and printed large enough to be seen in low light.

46. Failure Indications and Fuse Requirements

46.1 *Indication of Equipment Failure:*

TABLE 45 Weight and Dimensions of Portable Test Equipment

Dimensions	Operability, Hand-Held		Portability	
	Optimum	Maximum	One-Person Maximum	Two-Person Maximum
Weight, kg (lb)	1.4 (3)	2.3 (5)	11.3 (25)	40.8 (90)
Height, mm (in.)	50 (2)	100 (4)	460 (18)	485 (19)
Length, mm (in.)	200 (8)	255 (10)	460 (18)	...
Width, mm (in.)	100 (4)	125 (5)	255 (10)	...

46.1.1 *Power Failure*—An indication shall be provided to reveal when power failure occurs. All mission-essential electronic computer and peripheral components that are part of a system shall incorporate an automatic self-check diagnostic of software and hardware at power up and at the request of the operator to assure they are functioning properly.

46.1.2 *Out of Tolerance*—Displays shall be provided to indicate when equipment has failed or is not operating within tolerance limits.

46.1.3 *Critical Malfunctions*—If equipment is not regularly monitored, an auditory alarm shall be provided to indicate critical malfunctions.

46.2 Fuses and Circuit Breakers:

46.2.1 *General*—When required by the system, a positive indication shall be provided to reveal that a fuse or circuit breaker has opened a circuit.

46.2.2 *Replacement and Resetting*—Fuses shall be readily accessible for removal and replacement. No other components shall require removal to gain access to fuses. No special tools shall be required for fuse replacement unless required by safety considerations. When resetting of circuit breakers is permissible, and is required for system operation during a mission, the breakers shall be located within reach of crew members in their normal operating posture.

46.2.3 *Markings*—The area of equipment served by the fuse or circuit breaker shall be identified. The current rating of fuses shall be permanently marked adjacent to the fuse holder. In addition, SPARE shall be marked adjacent to each spare fuse holder. Fuse ratings shall be indicated either in whole numbers, common fractions (such as ¼), or whole number and common fractions (such as 2¼). Labeling of fuses and circuit breakers shall be legible in the anticipated ambient illumination range of the operator’s location.

46.2.4 *Circuit Breaker Controls*—Toggle bat and legend switch-actuated circuit breakers may be used to control electrical power. Push-pull-type breakers shall not be used as power switches.

46.2.5 *Printed Circuit Boards*—Printed circuit boards shall be designed and mounted for ease of removal and replacement, considering such factors as finger access, gripping aids, and resistance created by the mounting device. Appropriate feedback shall be provided to insure that the technician knows when the board is securely connected. Printed circuit boards shall be identified in accordance with MIL-STD-130 and reference designations for parts mounted on the printed circuit board shall be provided in accordance with MIL-STD-454, Requirement 67. These standards are applicable only to military vessels.

46.2.6 *Circuit Breaker Dimensions and Separations*—Dimensions and separation for toggle bat-actuated breakers shall comply with Fig. 42. Legend switch-actuated breakers shall comply with the dimension and separation criteria shown in Fig. 44. Push-pull-actuated circuit breaker separation shall comply with Fig. 47.

46.3 Other Design Considerations:

46.3.1 Fuses, or circuit breakers, shall be provided so that each unit of a system is separately fused and adequately protected from harmful powerline variations or transient voltages.

46.3.2 Fuses shall be located on the front or side panel of the unit where they can be seen and replaced without removing other parts. Fuses shall not be located inside the equipment.

46.3.3 Fuses shall be grouped in a minimum number of central, readily accessible locations and shall be replaceable by the equipment operator whenever possible, without the use of tools.

46.3.4 Caps or caps shall be the quick-disconnect, rather than the screw-in type; they shall be knurled and large enough to be removed easily by hand.

46.3.5 Fuse installations shall be designed so that only the cold terminal of the fuse can be touched by personnel.

46.3.6 When selecting fuses or circuit breakers, consider the suitability of each to perform a particular function (Table 46). There are two types of circuit breakers, thermal air and magnetic air. Thermal air circuit breakers are used primarily for overcurrent circuit protection. They are best adapted to dc circuits up to 250 V and to ac circuits up to 600 V in capacities up to 600 A. Magnetic air circuit breakers may be used to provide protection in event of overcurrent, undercurrent, reverse current, low voltage, reverse phase, and so forth.

46.4 *Printed Circuit Boards*—Printed circuit boards shall be designed and mounted for ease of removal and replacement, considering such factors as finger access, gripping aids, and resistance created by the mounting device. Appropriate feedback shall be provided to ensure that the technician knows when the board is securely connected.

47. Hydraulic Systems

47.1 Standardization:

47.1.1 Connectors in hydraulic systems shall be of standard design and handled with standard tools.

47.1.2 Standardize, where practical, valves and cylinders, hose assemblies, couplings, fittings, and filters.

47.1.3 Use standard hardware for mounting hydraulic components.

47.1.4 Ensure that all connectors are standardized by content of lines, and that the number of different sizes are held to a minimum. If there is a danger of mismatching connectors for adjacent lines carrying different fluids, specify physically incompatible connectors for the two lines.

47.2 Identification:

TABLE 46 General Comparison Fuses and Circuit Breakers

Function	Circuit Breaker		
	Fuse	Thermal Air	Magnetic Air
Instantaneous action	X		X
Time delay features	X	X	X
Resetting		X	X
Adjustable tripping range for other than maximum setting			X
Automatic resetting			X
Remote control resetting and tripping			X
Overcurrent protection low current, reverse current, reverse phase, and low-voltage protection	X	X	X

47.2.1 Use color coding for hydraulic lines, valves, and so forth, at each end of the line.

47.2.2 Provide permanent identification and instruction markings and indicate periodic inspection and drain schedules on them.

47.2.3 Inlets, outlets, and connecting lines in hydraulic systems shall be identified at least every 460 mm (18 in.), and at both ends, to facilitate maintenance.

47.3 *Drain Cocks*—All drain cocks shall be closed when the handle is in the down position. Those with a high rate drainage shall be fitted to all air receivers and oil reservoirs.

47.4 *Seals*—Seals that are visible externally after they are installed, since costly accidents result when seals are left out during assembly or repair, are preferred. However, O-ring seals

are permitted. Seals shall not protrude or extrude beyond the coupling since protruding seals are chipped and shredded by vibration or contact, and the damage spreads internally to destroy sealing power and deposit pieces in the line. For low-temperature operation, use special low-temperature materials.

47.4.1 Specify couplings that use permanent seals rather than those that must be removed and replaced when the seal wears out.

47.5 *Design Considerations*—Hydraulic systems design shall consider the following: (See Fig. 115.)

47.5.1 Provide mechanical stops for valve handles to prevent the valves from opening because of vibrations.

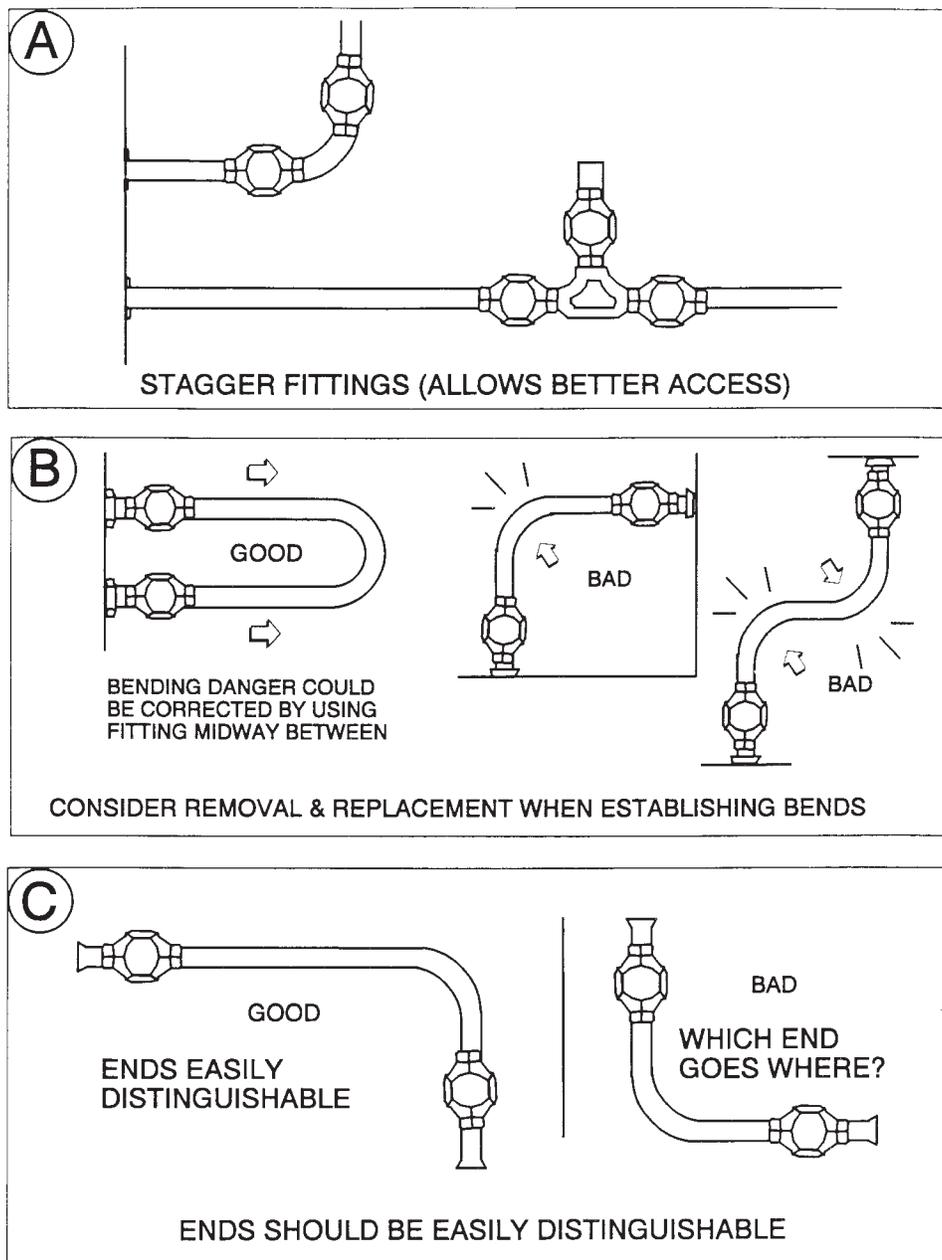


FIG. 115 Fluid Line Connector Recommendations



47.5.2 Self-sealing couplings shall be provided on complex hydraulic and pneumatic systems to simplify identification.

47.5.3 Consider the use of armor-covered flexible hose for hydraulic lines to facilitate replacement in the field from bulk stock.

47.5.4 Use aircraft-type safety fittings with built-in check valves in hydraulic lines to limit fluid loss in the event of a line rupture.

47.5.5 Design for automatic bleeding of hydraulic systems whenever possible.

48. Design of Equipment For Remote Handling

48.1 *Characteristics of Equipment to be Handled Remotely:*

48.1.1 *Alignment*—Self-alignment devices shall be provided for components that must be joined remotely.

48.1.2 *Disconnect*—Quick-disconnect devices shall be provided to reduce remote-handling difficulties.

48.1.3 *Fasteners*—All fasteners shall be captive and readily replaceable by remote-handling techniques.

48.1.4 *Lock and Latching Mechanisms*—Each lock or latching mechanism shall be operable from a single point, have a positive catch, and provide a clear visual indication of the latch position.

48.2 *Feedback*—Provision shall be made for transmitting information from remote work areas to the operator of the remote-handling system. Visual information shall be regarded as most critical, followed, in order, by kinesthetic, tactual, and auditory feedback.

48.3 *Manipulatory:*

48.3.1 *Safety*—Power manipulators shall be provided with positive stops to prevent accidents.

48.3.2 *Characteristics*—For tasks that require manipulative dexterity and load capacities of less than 10 kg (22 lbs), manipulators with the following characteristics shall be provided:

48.3.2.1 Position control (that is, zero-order control in which the operator's control output directly determines the machine output).

48.3.2.2 Mutual force reflection between control and effector.

48.3.2.3 Seven degrees of freedom in motion and force control (that is, three for translation, three for rotation, and one for gripping).

48.3.3 *Power Assist*—For tasks involving gross positioning of loads heavier than 10 kg (22 lbs), electrically or hydraulically powered manipulators with rate control shall be provided (that is, the operator's control output directly determines the rate of change of the machine output).

48.4 *Viewing Equipment:*

48.4.1 *General*—A viewing system shall be provided which gives the operator of a remote manipulator adequate information with respect to the three spatial coordinates of the workspace (that is, X, Y, and Z).

48.4.2 *Direct Viewing*—When permitted by shielding requirements, provision shall be made for the operator to view the work directly through shielding windows.

48.4.3 *Viewing Angle*—To avoid distortion, requirements shall be minimized for direct viewing of objects either near the viewing window or at line-of-sight angles at incidence greater than 105 rad (60°).

48.4.4 *Indirect Viewing*—Applicable viewing systems, such as closed-circuit television systems, periscopes, and microscopes, shall be provided to supplement direct viewing, where required by specific remote-handling situations.

48.4.5 *Coding*—Symbol or pattern coding shall be used in preference to color coding for television viewing.

48.4.6 *Lettering*—Letters, numbers, and important details that must be viewed by means of television shall be light whenever possible.

48.4.7 Use quick-release fastening devices on connections that require frequent disconnection. Provide self-sealing features to prevent leakage of fluid when disconnect is made.

48.4.8 Use valves with integral limit switches where practicable.

48.4.9 Use permanent or cartridge-type fasteners.

48.4.10 Provide, in case of electrical failure, a means for manually operating hydraulic systems.

48.4.11 Consider the connector recommendations shown in Fig. 114.

48.4.12 To prevent fluid spraying or draining on the technician or nearby objects when fluid lines are disconnected during maintenance, use the following design recommendations:

48.4.12.1 Provide line drains to ground or container at low-level access points.

48.4.12.2 Reposition line disconnects from sensitive components or shield the component.

48.4.12.3 Provide a high-visibility warning light at disconnect areas that are especially critical against a dark background. Glazed or reflecting surfaces shall be avoided.

48.4.13 *Stereo Viewing*—The two images produced by a stereoscopic periscope shall not differ more than 2 % in magnification or 0.50 prism diopter in vertical imbalance. Horizontal imbalance shall be no greater than 0.50 prism diopter so as not to be fatiguing. Light transmittance of the two optical paths shall be within 10 % of each other.

48.5 *Illumination:*

48.5.1 *Reflected Light*—Lighting provided in remote work areas shall be such that reflected light, as measured at the operator's work station (in direct viewing), will conform with the requirements of this standard, or as otherwise specified by the procuring activity.

48.5.2 *Threshold Viewing*—Monochromatic lighting shall be provided when viewing conditions are near threshold, when high magnification powers are required, or when the operator is required to view the work at high angles of incidence through refractive materials.

49. Small Systems and Equipment

49.1 *Portability and Load Carrying*—Individual portions of equipment shall be designed so that, when carried, the weight of the load will be distributed through as many muscle groups as possible. Pressure shall be avoided or minimized on sensitive areas, including large blood vessels, nerves, and areas lacking muscular padding. Design of load-carrying systems

shall consider the weight and distribution of individual items to be carried by the user. The weight of the items to be carried varies according to the climatic zone, mission to be performed, and occupational specialty. Load-carrying systems shall be provided with a quick-release capability.

49.1.1 Portability:

49.1.1.1 Weight—Individual portions of equipment may weigh up to 16 kg (35 lbs) if the load is balanced and is distributed over many muscle groups and it is not necessary for the individual carrying the load to maintain the pace of an infantry movement.

49.1.1.2 Lifting Aids—When necessary, lifting aids shall be provided to permit a second person to assist the porter in placing the load on the body.

49.1.1.3 Configuration—The load shall be designed to permit freedom of movement. The shape of the load shall be free of sharp edges or projections that may be harmful to the porter or snag on undergrowth. The shape and weight of the load shall not interfere with:

- (a) The length of step.
- (b) Movements of the head.
- (c) The ability to raise and lower the load when going over obstacles.
- (d) The ability to see where the feet are placed when walking.
- (e) The ability to squat.
- (f) Regulation of body temperature.
- (g) The maintenance of normal posture.

49.1.1.4 Carrying by Two Persons—Where the load is designed for carrying by two persons, a combination of stretcher-type handles and shoulder support shall be used, if feasible.

49.1.1.5 Standardization—Maximum use shall be made of standard load-carrying systems or components.

49.1.2 Transportability by Personnel—Systems that include a requirement for transportability by personnel shall conform to the following provisions:

49.1.2.1 Weight—Individual portions of equipment shall be designed to weigh as little as possible if the system is to be manually transported by an individual on foot while maintaining pace with an infantry movement.

49.1.2.2 Load Carrying—The total load carried by an individual, including clothing, weapons, and equipment for close combat operations shall not exceed 30 % of body weight and, for marching, 45 % of body weight. Where personnel with fifth percentile body weight must be accommodated, the total load shall not exceed 24.5 kg (54 lbs).

49.1.2.3 Lifting Aids—Units shall be equipped with handles suitable for two-handed lifting and carrying. The provisions of 38.5 shall apply.

49.2 Optical Instruments and Related Equipment:

49.2.1 General—This section pertains only to direct-view, visual optical systems. The information is presented so that human capabilities and limitations can be considered in the design, engineering, operation, and maintenance of optical equipment. Detailed instrument parameters, characteristics, and so forth, shall be a function of governing applications and user requirements.

49.2.2 Visual Accommodation—Any adjustment of the eyes beyond normal functional ability shall not be required.

49.2.3 Viewing Angle—Optical instruments shall be oriented so that they are presented to the operator at an angle comfortable for viewing.

49.2.4 Magnification:

49.2.4.1 General—Instrument magnification shall be sufficiently high to permit performance of the required application, such as detection, recognition, identification, laying, and so forth.

49.2.4.2 Unstabilized, Unsupported Handheld Sights—Because of hand tremors and body motion, magnification of unstabilized, unsupported handheld sights shall not exceed 8 power for monoculars or binoculars.

49.2.4.3 Multiple Magnification Requirements—If more than one magnification is required, two or more discrete magnifications shall be provided for optimum image quality and boresight integrity. Varifocal (zoom) systems shall be considered for use only in systems where sighting accuracy is relatively unimportant and it results in overall simplification.

49.2.5 Field of View—Field of view shall be compatible with intended use and optical-mechanical design limitations.

49.2.6 Entrance Pupil—The entrance pupil shall be equal to the product of the magnification and the exit pupil diameter and, therefore, defined by these parameters.

49.2.7 Exit Pupil:

49.2.7.1 General—The diameter of the exit pupil shall be consistent with intended use and size/weight limitations.

49.2.7.2 Daylight—For daylight application, the exit pupil diameter shall not be less than 3 mm (0.12 in.).

49.2.7.3 Low-Light Levels—For maximizing performance at twilight and lower light levels, the exit pupil shall be not less than 7 mm (0.28 in.).

49.2.8 Eye Relief—A long eye relief (for example, 25 mm (1 in.)), is ordinarily desirable for vehicular-mounted sights to observe on the move and to afford some field-of-view while wearing a protective mask. The required eye relief depends upon the particular application, but shall be at least 15 mm (0.6 in.) to permit use by observers wearing glasses.

49.2.9 Eyepiece Adjustments:

49.2.9.1 4-Power and Less—Fixed focus eyepieces set between -0.50 and -1.00 diopter may be used for instruments 4-power and less.

49.2.9.2 Over 4-Power—Eyepiece dioptric (focusing) adjustments (-4 to $+2$ diopters required, -6 to $+2$ diopters desired) shall be provided and marked in 0.5-diopter increments on all instruments over 4-power magnification.

49.2.10 Optical Quality:

49.2.10.1 Axial Resolution—Axial resolution shall be equal to or better than $300 \mu\text{rad}$ (1 min) divided by the magnification to provide an eye-limited instrument.

49.2.10.2 Luminous Transmission—Luminous transmission shall be as high as possible, preferably greater than 50 %.

49.2.11 Reticles:

49.2.11.1 Line Thickness—Reticule lines shall be thin enough so as not to obscure targets, but thick enough to be easily seen. Reticule lines shall subtend a minimum of $600 \mu\text{rad}$ (2 min) at the eye.

49.2.11.2 *Patterns*—Reticle patterns shall be as simple as possible and restricted to one main mission per reticle glass. Additional patterns shall be on separate reticle glasses if added complexity is warranted for the particular application.

49.2.11.3 *Format*—Line reticle shall be used in preference to reticle containing one, two, or three central spots. A small cross or very small circle shall be used in preference to a dot.

49.2.11.4 *Parallax*—The reticle shall be focused to the target range of primary interest to limit the parallax to an acceptable value throughout the usable range.

49.2.12 *Illuminated Sights and Reticles:*

49.2.12.1 *Night Operations*—Illuminated reticle shall be provided for sights to be used during twilight or night operations.

49.2.12.2 *Color*—Blue shall not be used as the color if illumination for reticle or sights.

49.2.12.3 *Dimming*—It shall be possible to gradually lower the luminance of a sight until it is extinguished.

49.2.12.4 *Illumination Level*—The illumination level of a sight (once an adjustment is made) shall remain fixed under all conditions of vibration.

49.2.12.5 *Uniformity*—Illuminated sights shall be evenly illuminated by means of an opal diffuser or similar device.

49.2.12.6 *Reticle Lines*—Reticle lines for illuminated sights shall be 150- μ rad (0.5-min) visual angle or more in thickness. They shall be thin enough so as not to obscure targets, but thick enough to be easily seen. In any case, their thickness shall not exceed 600 μ rad (2 min).

49.2.13 *Binoculars/Bioculars:*

49.2.13.1 *Biocular Viewing*—Where continuous use of a sight under low levels of illumination will exceed 1 min, the single optical train shall be provided with two eyepieces, if this does not lead to unacceptable light losses.

49.2.13.2 *Eyepiece Separation*—Binocular/biocular instruments shall have an eyepiece separation scaled from 50 to 73 mm with 1-mm interval markings.

49.2.13.3 *Magnification Differences*—Magnification differences of two barrels shall not exceed 2 %.

49.2.13.4 *Luminous Transmission Differences*—Luminous transmission differences of the two barrels shall not exceed 5 %.

49.2.13.5 *Matched Oculars*—To avoid size differences in the images supplied to the two eyes, hence eyestrain and headache or both, oculars shall be matched in focal length, that is, shall be matched pairs.

49.2.13.6 *Weight*—Weight of handheld binocular/bioculars shall not exceed 1 kg (2.2 lbs) and shall not exceed 1.5 kg (3.3 lbs).

49.2.13.7 *Size and Configuration*—Instrument size and configuration shall be compatible with anthropometric requirements of Section 30.

49.2.14 *Eyecups and Headrests*—Any optical instrument requiring steady orientation of the eyes shall be provided with a headrest or eyecups, or both.

49.2.14.1 *Eyecups*—Eyecups shall be provided to maintain proper eye relief, eliminate stray light, and, when required, to protect or cushion the eyes and orbital region against impact with the eyepieces. The radii of Fig. 116 defines a surface of revolution within which a satisfactory symmetrical eyepiece and cup must be designed if interferences with facial features are to be avoided. These shall be applied to cushion forms when they are compressed to the maximum.

49.2.14.2 *Headrests/Browpads*—A headrest or brow pad shall be used to absorb energy which would be injurious to the operator's head.

49.2.14.3 *Compatibility with Clothing and Personal Equipment*—Eyecups and headrests shall be compatible with helmets, protective masks, and other clothing and personal equipment.

49.2.15 *Accessories:*

49.2.15.1 *Filters:*

(a) *General*—Light filters, removable from the optical path, shall be provided to reduce glare, light intensity, or protect the observer's eyes against hazardous light levels. Provisions shall be made for filter stowage, where applicable.

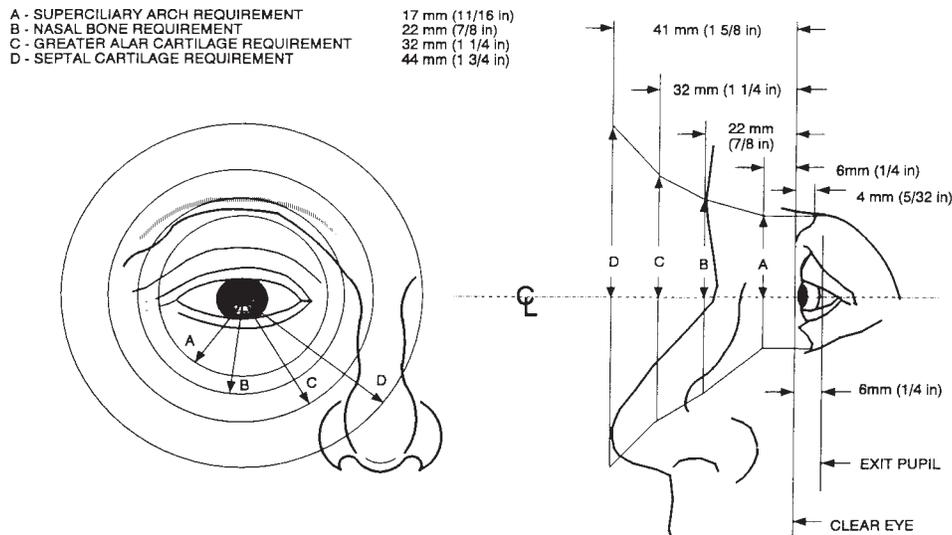


FIG. 116 Anatomical Limits on Axially Symmetrical Ocular Metal Part

(b) Use—Use of color or neutral density filters will depend upon the application. For use in observing bright light sources, neutral filters shall be considered for reducing overall brightness without affecting contrast. The use of polarizing filters shall be considered where it is necessary to reduce glare and increase apparent contrast from sun, snow, or water.

49.2.15.2 *Shutters*—Shutters having closure and reopening times appropriate for each application may be provided in lieu of fixed filters to protect the observer exposed to flashes from weapon systems, lasers, or nuclear devices. Shutters for protection from the observer’s own weapon system flash, which may be actuated just before the weapon is fired, shall not disturb the lay of the weapon before closing nor unnecessarily impede the observation of the projectile flight path or resultant impact.

49.2.15.3 *Positioning Aids*—Level vials, scales, pointers, and other devices required for positioning the instrument shall be readily visible and protected from damage of displacement.

49.2.16 *Environmental Conditions*—Carry/transport cases shall be provided for instruments to be hand-carried or mounted/dismounted separately. Instruments to be used under severe environmental conditions shall be designed to take into consideration the special clothing, headgear, protective masks, or other ancillary equipment required by the operator, affecting controls, eyepieces, eyecups, headrests, and other operator interfaces.

49.2.17 *Lighting*—Means shall be provided for illumination of internal and external scales, level vials, and so forth, under low-light-level conditions. Continuously variable control of illumination shall be provided as required by weapon system characteristics. Illumination under low-light-level conditions shall be designed to minimally affect the dark adaptation of the observer. Red illumination or red filters shall be used to maintain dark adaptation.

49.2.18 *Maintenance:*

49.2.18.1 *Modular Design*—When practical, optical equipment shall be developed using modular design to provide for interchangeability of optical subassemblies.

49.2.18.2 *Positioning Aids*—Built-in aligning devices and other aids shall be used whenever possible for ease of positioning optical assemblies within an instrument or optical modules that have multiple applications in equipment.

49.2.18.3 *Quick Release*—Quick-release methods of removing optical instruments shall be used wherever practical.

49.2.18.4 *Collimation*—Optical instruments shall be provided with built-in collimation features to allow field adjustment.

49.2.18.5 *Purging and Charging*—Where periodic purging and charging of optical instruments are required, an instruction plate, indicating time interval and pressure requirements, shall be provided on the instrument. Purging and charging fittings shall be accessible for required maintenance.

49.2.18.6 *Component Replacement*—Internal components such as light bulbs that require frequent replacement, checkout or maintenance shall be easily accessible, removable without special tools, and replaceable without removal or disassembly or other components. Components that require frequent replacement and frequently used special tools or equipment or

both shall be readily accessible. Provision shall be made for storage of such components and tools in or on the specific equipment. This particularly applies to items such as light bulbs whose failure could make the instrument inoperable.

50. Operational and Maintenance Vehicles

50.1 *General*—Handles, levers, pedals, knobs, and workspace dimensions shall be designed to enhance effective vehicle operation by suitably clothed and equipped users with relevant body dimensions varying between fifth and ninety-fifth percentiles (See Section 30).

50.2 *Seating:*

50.2.1 *Dimensions and Clearances*—Seating for vehicle operators shall follow the dimensions and clearances recommended in Fig. 54 and Fig. 55, and Table 47, as applicable.

50.2.2 *Vertical Adjustment*—If the seat’s height above the floor is variable, requirements for leg room and footrest will also vary. When the seat is adjusted higher, there will be more leg room and larger footrest angles.

50.2.3 *Horizontal Adjustment*—Seats shall adjust at least 150 mm (6 in.) in the fore-aft direction.

50.2.4 *Back Rest*—Back-rest angle shall be not more than 1920 mrad (110°) from horizontal. If only the lumbar area is supported, the backrest angle of tilt shall be 1660 to 1745 mrad (95 to 100°) for operators in an alert position.

50.2.5 *Seat Pan*—The seat pan shall be flat and made from a rigid material.

50.2.6 *Seat Padding*—Seat padding shall be kept to a minimum, but it shall be resilient enough to keep the operator’s body from contacting the seat bottom during severe vibration. Seat padding made of foam-type material shall be adequately ventilated.

50.2.7 *Seat Belts*—All administrative-type vehicles shall have safety seat belts. Seat belts shall be installed on other type vehicles except when they interfere with operational requirements.

50.3 *Controls:*

TABLE 47 Recommended Clearances Around Equipment Operator’s Station to Accommodate 95th Percentile Male Dressed in Arctic Clothing. Operator Seat in Rear Most Position

	mm (in.)
A. Elbow (dynamic)	910 (36)
B. Elbow (static)	710 (28)
C. Shoulder	580 (23)
D. Knee width (minimum)	460 (18)
E. Knee width (optimum)	610 (24)
F. Boot—provide adequate clearance to operate brake pedal without inadvertent acceleration operation	150 (6)
G. Pedals (minimum)	50 (2)
H. Boot—provide adequate clearance to operate accelerator without interference by brake pedal	150 (6)
1. Head (SRP to roof line)	1070 (42)
2. Abdominal (seat back to steering wheel)	410 (16)
3. Front of knee (seat back to manuals/controls on dash)	740 (29)
4. Seat depth (seat reference point to front edge of seat pan)	410 (16)
5. Thigh—under side of steering wheel to seat pan	240 (9.5)
6. Seat pan height	380 (15)
7. Boot (front of seat pan to heel point of accelerator)	360 (14)
8. Minimum mitten clearance around steering wheel	75 (3)
9. Knee—leg—thigh (brake—clutch pedal) to lower edge of steering wheel	660 (26)

50.3.1 *Design*—Controls shall be designed so as not to be adversely affected by distortion, shock, or vibration of the vehicle.

50.3.2 *Steering*—In case of power steering assist failure, the steering gear shall afford the operator sufficient mechanical advantage to guide the vehicle during an emergency stop or during low-speed operation (see Fig. 37 for quantitative data.)

50.3.3 *Pedals*—Foot pedals shall be designed to accept the weight of the operator's foot without initiating control action.

50.3.4 *Control of Hazardous Operations*—The operation of switches or controls that initiate hazardous operations shall require the prior operation of a locking control.

50.4 *Operating Instructions:*

50.4.1 *Provisions of Operating Instruction*—Operating instructions shall be provided for all vehicles and vehicle equipment, except where the mode of operation will be obvious to all potential operators.

50.4.2 *Format*—Information shall be presented in the form of diagrams whenever possible.

50.4.3 *Speed Notice*—Maximum permissible road speeds in each gear and range shall be indicated. On vehicles for which all road speeds are limited by engine speed, a red line on the tachometer (if so equipped), at maximum engine RPM, may be used in lieu of a speed placard.

50.4.4 *Shift Handle Position*—Operating positions of shift handles, such as transmission, power take-off, winch-control, and transfer case mechanisms shall be illustrated.

50.4.5 *Control Movements*—Control movements shall be shown in planes parallel to the movement of the actual controls.

50.4.6 *General Labeling Criteria*—Identification and instruction markings shall conform with the criteria for labeling contained in this standard.

50.5 *Visibility:*

50.5.1 *Night Operation*—Indicators required by the vehicle operator during night operation shall be illuminated. The display luminance shall be adjustable from 0.1 to 3.5 cd/m² (0.03 to 1.0 ft-L). Blackout lighting systems, if required, shall be designed to preclude accidental operation of external lights and signals.

50.5.2 *Visual Field*—The operator shall have forward visibility through a lateral visual field of at least π rad (180° preferably 3840 mrad (220°)).

50.5.3 *Glare*—Appropriate use shall be made of visors or other means to preclude performance degradation caused by glare from external sources such as sunlight or headlights except that windshields or other transparent areas through which high-acuity vision is required shall not be tinted or colored.

50.5.4 *Windshields and Windows*—Transparent materials selected for windshield and windows shall be shatterproof and shall neither distort nor obscure vision.

50.5.5 *Windshields Wipers and Washers*—Windshield wipers and washers shall be provided. Blades shall return to the stored position when turned OFF. Provisions shall be made for manual operation in event of power failure.

50.5.6 *Forklifts*—The configuration of fork lift mechanisms and forklift truck cabs shall permit the operator to have direct

view of the tips of the forks in all typical modes of material loading and in all likely operator positions.

50.6 *Heating and Ventilation:*

50.6.1 *Heating*—The crew compartments shall be provided with a heating system capable of maintaining temperatures above 20°C (68°F) during occupancy when personnel are not wearing arctic clothing and exposure is for extended duration (that is, more than 3 h). When arctic clothing is worn, cab heaters shall be capable of maintaining a reference temperature of not less than 5°C (41°F) at the minimum ambient design temperature with the vehicle moving at two-thirds maximum speed and the defrosters operating at maximum capacity. The reference temperature is measured 610 mm (24 in.) above the seat reference point of each operator/passenger position. Air temperatures around any part of the operator/passenger's body shall not vary more than $\pm 5^\circ\text{C}$ ($\pm 9^\circ\text{F}$). The heater shall achieve these requirements within 1 h after it is turned on.

50.6.2 *Ventilation*—Outside fresh air shall be supplied at minimum rate of 0.57 m³ (20 ft³)/min/person. Air flow rates for hot-climate operation (temperatures above 32°C (90°F)) shall be maintained between 4.2 and 5.7 m³ (150 and 200 ft³)/min/person, unless air conditioning or individual (microclimate) cooling is provided. Air velocity at each person's head location shall be adjustable either continuously or with not less than three settings (OFF, LOW, and HIGH) from near zero to at least 120 m (400 ft)/min.

50.6.3 *Visibility*—The heating-ventilating system shall be designed to minimize degradation of visibility as a result of frosting or misting of the wind shield.

50.7 *Cranes, Materials, Handling, and Construction:*

50.7.1 *General*—Positioning of equipment and loads shall be facilitated through use of center-of-gravity identification, matching guidelines, identification of attaching points, detachable probes, and so forth. Latches on control levers shall not cause delay in operation.

50.7.2 *Control Labels*—All controls used with lifting equipment shall be labeled as to function and direction of movement.

50.7.3 *Control Placement*—The placement of controls shall be within easy reach of the operator and shall afford optimum visibility of the load at all times.

50.7.4 *Foot-Operated Controls*—Foot-operated controls shall not be selected for precise adjustments or movements. Foot-operated brake pedals that require locking shall lock by foot action alone. For ease of operation, the pedals shall rise from the depressed position in a backward as well as vertical movement.

50.7.5 *Load Capacity*—The load capacity shall be indicated on the equipment, and audible warning devices shall be provided where necessary to indicate that the allowable load is being exceeded.

50.7.6 *Visibility*—Maximum, unobstructed view of the work, including the point sheaves of the basic boom of a revolving crane at a 3-m (10-ft) radius shall be visible to suitably clothed and equipped users with relevant body dimensions varying between fifth and ninety-fifth percentiles.

50.7.7 *Handholds and Footholds*—Suitable handholds and footholds shall be provided to facilitate personnel access and movement.

51. Hazards and Safety

51.1 *General*—As a part of system equipment design, safety factors shall be given major consideration, including, as a minimum, the effective application of the human engineering criteria in other sections of this practice, together with the representative safety criteria herein.

51.1.1 *Principles of Human Behavior Related to Safety*—There are principles of human behavior that are of importance to the designer striving to design safe equipment. Armed with this knowledge the designer can design out many of the accidents that occur with shipboard equipment.

51.1.1.1 If the equipment is insufficient, it will be modified by the user, usually at the job site and often with built-in hazards.

51.1.1.2 The operational/maintenance procedures must be clean, definite, and comprehensive, otherwise they will be ignored.

51.1.1.3 Equipment design must be such that it encourages safe use, that is, do not provide hardware that can be used in an unsafe manner.

51.1.1.4 If the equipment or system is not designed to operate as the user's cultural expectancies and stereotypes lead him or her to think it will operate, he or she will eventually make a mistake.

51.1.1.5 If an unsafe design is allowed in the equipment, no warning note in a technical manual can eliminate it completely. Neither can regular or even special training prevent accidents, even if it mandatory.

51.1.1.6 Equipment users tend to be unimaginative; they do not visualize the consequences of unsafe acts. Therefore, do not expect that an obviously dangerous task will be recognized by the user.

51.1.1.7 Designers shall consider the possibilities for errors and design equipment so incorrect use (deliberate or accidental) will do as little harm as possible.

51.1.1.8 People make guesses as to what a label, instruction, operational chart, and so forth, says if it is not complete, legible, and readable. Be sure that they are complete and legible.

51.1.1.9 If procedures for safe operation or maintenance seem needlessly difficult or burdensome, people avoid doing what is necessary for safety. So, make it easier to use safely than to use it unsafely.

51.1.1.10 Equipment develops a reputation among users and maintainers regarding its difficulty or hazardous use that can significantly affect the way it is used and serviced.

51.1.1.11 Abbreviated checklists tend to cause mistakes so make job procedures detailed enough so the user does not have to fill in the blanks.

51.1.1.12 People must be protected against themselves. Designers cannot create an unsafe piece of equipment or system and expect the user to look out for himself or herself.

51.1.1.13 An operator's care in using and maintaining an item tends to increase in relation to the item's cost and complexity. Thus, complicated and costly pieces of equipment, with safety hazards, will usually produce fewer accidents as a result of poor maintenance than will the simpler and less expensive equipment.

51.1.1.14 Ease of maintenance affects the equipment's reliability.

51.1.1.15 Equipment is particularly susceptible to misuse if operators must communicate with each other to use it.

51.2 *Safety Labels and Placards:*

51.2.1 *Hazard-Identifying Plates*—All hazard plates (that is, danger, caution) shall comply with Section 28 and shall be mounted adjacent to any equipment that presents a hazard to personnel (from high voltage, heat, toxic vapors, explosion, ionizing radiation, and so forth) or equipment.

51.2.2 *Center of Gravity and Weight*—Where applicable, the center of gravity and the weight of equipment shall be distinctly marked.

51.2.3 *Weight Capacity*—The weight capacity shall be indicated on stands, hoists, lifts, jacks, and similar weight-bearing equipment, to prevent overloading.

51.2.4 *Identification of Protective Areas*—Areas of operation or maintenance in which special protective clothing, tools, or equipment are necessary (insulated shoes, gloves, suits, and so forth) shall be specifically identified.

51.2.5 *NO-STEP Markings*—NO-STEP markings shall be provided when necessary to prevent injury to personnel or damage to equipment.

51.2.6 *Electrical Labels*—All receptacles shall be marked with their voltage, phase, and frequency characteristics, as appropriate.

51.2.7 *Hand Grasp Areas*—Hand grasp areas shall be conspicuously and unambiguously identified on the equipment.

51.3 *Pipe, Hose, and Tube Line Identification*—Pipe, hose, and tube lines for liquids, gas, steam, and so forth, shall be clearly and unambiguously labeled or coded as to contents, pressure, heat, cold, or other specific hazardous properties.

51.4 *General Workspace Hazards:*

51.4.1 *Alerting Device*—A hazard-alerting device shall be provided to warn personnel of impending danger or existing hazards. Normally, a flashing red light and siren (if an auditory signal is used) are used for the worst condition (DANGER) while a horn and amber light are used for the CAUTION condition.

51.4.2 *Emergency Doors and Exits*—Emergency doors and exits shall be constructed so that they:

51.4.2.1 Are simple to operate,

51.4.2.2 Are directly accessible,

51.4.2.3 Are unobstructed,

51.4.2.4 Are simple to locate and operate in the dark,

51.4.2.5 Are quick opening in 3 s or less,

51.4.2.6 Require 44 to 133 N (10 to 30 lbs) of operating force to open, and

51.4.2.7 Do not themselves, or in operation, constitute a safety hazard. Two exits, doors, or kickout panel, shall be provided in any manned space where fuel, chemicals, or other flammable materials are used.

51.4.3 *Stairs*—Stairs, including incline, step risers, and treads, shall conform with standard safe design practice. Incline ladders shall have a maximum angle of 60°, 50° preferred. Skid-proof flooring, stair, and step treads shall be

provided. Where conditions warrant special precaution, surfaces shall be covered with a nonslip coating. Incline ladders shall run fore and aft.

51.4.4 *Obstructions*—Workspace around areas where heavy manual maintenance is performed shall be free of obstructions that could cause injury to personnel, either through accidental contact with the obstruction or because the obstruction requires an awkward or dangerous body position.

51.4.4.1 *Pipe Hangers*—Pipe hangers shall not protrude from the overhead into the minimum head room. Hangers used to support pipe mounted on bulkheads or other locations where they can be struck by passing crew members shall be of the U type and installed, as close as possible, to that shown in Fig. 89 (lower drawing).

51.4.4.2 *Storage Racks*—Storage racks located in passageways for gas bottles, casualty cables, fire-fighting equipment, and so forth, shall not impede traffic flow and shall not have securing nut studs or other sharp objects protruding into the passageway.

51.4.4.3 *Door Swing*—Hinges for doors on lockers, electrical cabinets, storage bins, and so forth, shall be located so that a partial or fully opened door will not interfere with personnel and equipment flow.

51.5 *Illumination*—Adequate illumination shall be provided in all areas. Hazard-identifying plates, stairways, and all hazardous areas shall be illuminated in accordance with the recommended levels of Table 32.

51.6 *Thermal Contact Hazards*—Equipment that, in normal operation, exposes personnel to surface temperatures greater or less than those shown in Table 48, shall be appropriately guarded. Surface temperatures induced by climatic environment are exempt from this requirement. Cryogenic systems shall also be appropriately guarded.

51.7 *General Equipment-Related Hazards:*

51.7.1 *Interlocks and Alarms*—The operation of switches or controls that initiate hazardous operations (ignition, movement of a crane, and so forth) shall require the prior operation of a related or locking control. Where practicable, the critical position of such a control shall activate a visual and auditory warning device in the affected work area.

51.7.2 *Access*—Units shall be so located and mounted that access to them can be achieved without danger to personnel from electrical charge, heat, moving parts, chemical contami-

nation, radiation, or other hazards. Mounting heights for common electrical fixtures shall be in accordance with Fig. 117.

51.7.3 *Hazardous Access*—Where access areas must be located over dangerous mechanical or electrical components, the access door or cover shall be designed to actuate an internal light when opened, and a highly visible warning label shall be provided on the outside of the door or cover.

51.7.4 *Edge Rounding*—Where applicable, all exposed edges and corners shall be rounded to a minimum of 0.76-mm (0.03-in.) radius. Sharp edges and corners that present a personal safety hazard or potential damage to equipment during usage shall be suitably protected or rounded to a minimum radius of 13 mm (0.5 in.).

51.7.5 *Storeroom Shelves*—Shelves in storerooms over 203 mm (80 in.) above the deck shall be equipped with foot supports (lower shelves are acceptable) designed to support a 113-kg (250-lbs) load. Where lower shelves are used as a foot support, they shall be designed to support whatever may be stored on the shelf plus a 113-kg (250-lbs) load.

51.7.6 *Eyewash Fountains*—A minimum clearance of 30 cm (12 in.), and 48 cm (15 in.) preferred, shall be provided on either side of an eyewash fountain as measured from the fountain centerline.

51.8 *Platforms:*

51.8.1 *Locks*—Self-locking or other fail-safe devices shall be incorporated on elevating stands, work platforms, and drawbridges to prevent accidental or inadvertent collapsing or falling.

51.8.2 *Handrails, Safety Bars, and Chains*—Handrails, safety bars, or chains shall be installed around platforms and across stair or step openings in platforms, ledges, catwalks, and so forth. Such guards shall be placed 107 cm (42 in.) above the standing surface. An intermediate guard rail shall be provided. Chains shall only be used where it is not feasible to install handrails or safety bars. Kickboards, at least 152 mm (6 in.) high, shall be installed. When platforms are raised and located near a railing (for example, signal lights on the bridge wings), the railing around the platform must also be raised to maintain the 107-cm (42-in.) height.

51.8.3 *Safety Mesh*—Screen or safety mesh shall be installed on the underside of open gratings, platforms, or flooring surfaces where there is a possibility that small tools, parts, or debris may fall through the grating on workers or equipment beneath the platform.

51.8.4 *Elevated Work Platforms*—Elevated work platforms raised by electric or hydraulic motors shall fail safe so that in the event power or hydraulic failure occurs the platform will lock in the up position. All platforms shall have their lifting capacity clearly marked on the platform.

51.9 *Electrical Hazards:*

51.9.1 *Shock*—The principle electrical hazard is shock. All electrical potentials of 30-V rms or more are potential shock hazards. Most shock deaths result from contacting relatively low potentials, ranging from 70 to 500 V. Table 49 summarizes typical effects of various currents.

51.9.2 *Shock Prevention*—One or more of the following shall be used to minimize the chance of inadvertent contact

TABLE 48 Temperature Limits

Exposure	Metal	Glass	Plastic or Wood
	°C (°F)		
Momentary contact	60 (140)	68 (154)	85 (185)
Prolonged contact	49	59	69
or handling	(120)	(138)	(156)
Momentary contact	0 (32)	0 (32)	0 (32)
Prolonged contact	0	0	0
or handling	(32)	(32)	(32)

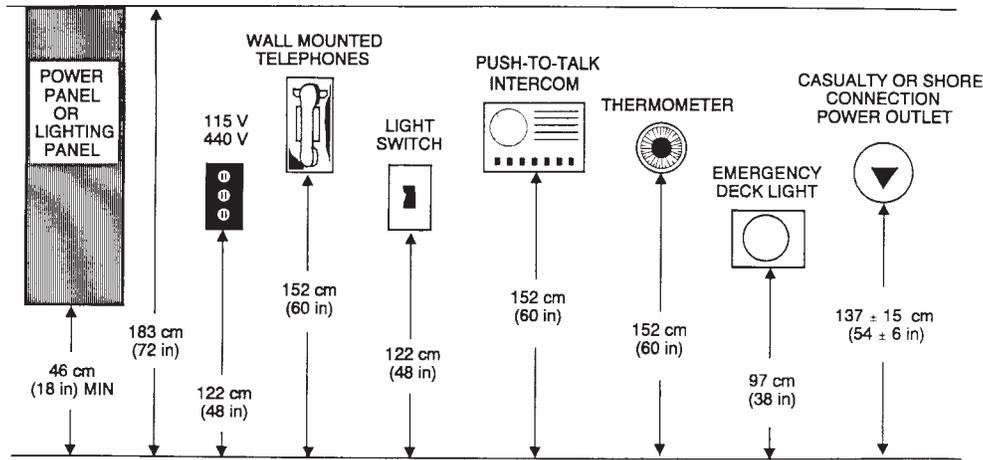


FIG. 117 Mounting Heights for Common Electrical Fixtures

TABLE 49 Shock Current Intensities and Their Probable Effects

Current, milliamperes AC (60 Hz)	DC	Effects
0-1	0-4	perception
1-4	4-15	surprise
4-21	15-80	reflex action
21-40	80-160	muscular inhibition
40-100	160-300	respiratory block
Over 100	over 300	usually fatal

with live electrical wires, potentials, exposed contacts, charged capacitors, and so forth.

51.9.2.1 Guards.

51.9.2.2 Grounding.

51.9.2.3 Interlock Switches—Every door or access part that provides access to high-voltage potentials shall have an interlock.

51.9.2.4 Warning Signs.

51.9.2.5 Capacitor Discharge Devices (Bleeders) shall discharge the capacitor fully in 1 min or less.

51.9.2.6 Fuses.

51.9.3 Insulation of Tools—Tools and test leads to be used near high voltages shall be adequately insulated.

51.9.4 Plugs and Receptacles—Plugs and receptacles shall be designed so that a plug of one voltage rating cannot be inserted into a receptacle of another rating.

51.9.5 Voltage Exposure—Equipment shall be designed so that all hot contacts will be socket contacts.

51.9.5.1 Dangerous Voltage or Current—Guards, grounding, interlocks, and warning placards shall be provided to minimize the possibility of exposing personnel to dangerous voltages or currents.

51.9.6 Ground Potential—Equipment shall be designed so that all external parts, with the exception of antenna and transmission line terminals, will be at ground potential.

51.9.7 Electrically Operated Hand Tools—Electrically operated hand-held power tools shall be designed with three-wire power cords with one wire at ground potential and shall have exposed surfaces that are either nonconducting or are electrically connected to the ground wire. Exposed surfaces include cases, grips, handles, switches, triggers, chucks, and other

surfaces that are capable of being contacted during operation. Portable tools, protected by an approved system of double insulation or its equivalent, may be used without a ground wire when approved by the procuring activity. Hand tools with the potential for injury to personnel (for example, deck sanders, large drills, and so forth) shall be equipped with a dead man power switch.

51.9.8 Vehicle Batteries—All batteries that have a rating greater than 25 amp hours shall have terminal guarding to prevent inadvertent short-circuit. Such guarding shall also prevent short-circuiting of the battery in spite of clearly improper but possible acts by personnel, such as placing of tools across terminals, resting a heavy object on the battery cover, and standing on a battery cover.

51.9.9 Main Power Switch—Every item of equipment shall have a clearly labeled main-power switch that turns off all power to the item.

51.10 Mechanical Hazards:

51.10.1 Guards—A guard shall be provided on all moving parts of machinery and transmission equipment, including pulleys, belts, gears, blades, and so forth, on which personnel may become injured or entangled. Where perforations are provided in guards for air circulation, none shall be larger than a 13-mm (0.5-in.) round or square hole.

51.10.2 Steps and Ladders—Adequate clearance for fingers shall be provided in the design of telescoping steps or ladders.

51.11 Fluid Hazards:

51.11.1 Connectors—Each connector used in the handling or control of hazardous fluids, including propellants, solvents, toxics, hypergolics, asphyxiants, and so forth, shall be incompatible with other connectors within the access area of that conductor.

51.11.2 Fluid and Fuel-Servicing Equipment—Automatic shutoff devices shall be provided on fluid and fuel service equipment to prevent overflow and spillage.

51.11.3 Flammable Liquid Lockers—Flammable liquid lockers shall not be installed nearer than 1.8 m (6 ft) to a door or exit if it is the only means of egress from the space or compartment.

51.12 Barriers—Barriers may be used to protect a person from contacting a hazard (for example rotating machinery,

electrical contact, hot pipe). The required height of the barrier and the distance separating the barrier from the hazard depends on the height of the hazard as shown in Fig. 118.

51.13 Toxic Hazards:

51.13.1 Toxic Fumes:

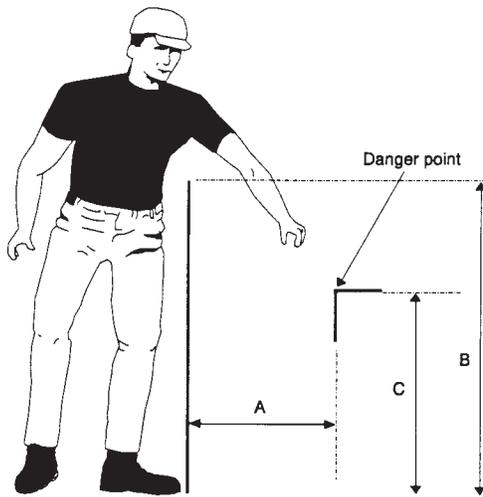
51.13.1.1 General—All reasonable precautions shall be taken to eliminate toxic fume hazards. From the standpoint of practical health-hazard control, the most important constituents are carbon monoxide from gasoline engines, aldehydes, nitrogen oxides from diesel engines, and sulfur dioxide from marine turbine engines.

(a) Carbon Monoxide—Carbon monoxide in personnel areas shall be reduced to the lowest level feasible. Personnel

shall not be exposed to concentrations of carbon monoxide (CO) in excess of values which will result in carboxyhemoglobin (COHb) levels in their blood greater than the following percentages: 5 % COHb (all system design objectives and aviation system performance limits) and 10 % COHb (all other systems performance limits).

51.13.1.2 Allowable Limits—Allowable limits for some of the toxic gases described above are shown in Table 50.

51.13.2 Toxic Material—Place all storage bins containing toxic material (for example, soaps, bleach, and so forth, in the laundry) in a vertical position if possible. If mounted horizontally, the bins shall be no higher than 151 cm (60 in.) above the deck.



There should be no interpolation of the values in the table, see the following examples:

Example 1

The height of the danger point, "A", is 1500 mm (59.1 in) and its horizontal distance, "C", from the proposed barrier is 700 mm (27.6 in). Using the table, the height of the barrier, "B", should be 1800 mm (71.1 in).

Example 2

The height of the barrier, "B" is 1300 mm (51.3 in) and the height of the danger point, "A", is 2300 mm (90.6 in). Using the table, the barrier should be positioned 600 mm (23.7 in) from the danger point.

Example 3

The height of the barrier, "B", is 1700 mm (66.9 in) and the horizontal distance, "C", from the danger point is 550 mm (21.7 in). Using the table, the danger point should not be between 1200 and 2200 mm (47.4 and 86.8 in)

Distance of danger point from floor "A" mm (in)	Height of edge of barrier "B" mm (in)							
	2400 (94.7)	2200 (86.8)	2000 (78.9)	1800 (71.1)	1600 (63.2)	1400 (55.3)	1200 (47.4)	1000 (39.5)
	Horizontal distance "C" from danger point mm (in)							
2400 (94.7)	—	100 (3.9)	100 (3.9)	100 (3.9)	100 (3.9)	100 (3.9)	100 (3.9)	100 (3.9)
2200 (86.8)	—	250 (9.9)	350 (13.8)	400 (15.8)	500 (19.7)	500 (19.7)	600 (23.7)	600 (23.7)
2000 (78.9)	—	—	350 (13.8)	500 (19.7)	600 (23.7)	700 (27.6)	900 (35.5)	1100 (43.4)
1800 (71.1)	—	—	—	600 (23.7)	900 (35.5)	900 (35.5)	1000 (39.5)	1100 (43.4)
1600 (63.2)	—	—	—	500 (19.7)	900 (35.5)	900 (35.5)	1000 (39.5)	1300 (51.3)
1400 (55.3)	—	—	—	100 (3.9)	800 (31.6)	900 (35.5)	1000 (39.5)	1300 (51.3)
1200 (47.4)	—	—	—	—	500 (19.7)	900 (35.5)	1000 (39.5)	1400 (55.3)
1000 (39.5)	—	—	—	—	300 (11.8)	900 (35.5)	1000 (39.5)	1400 (55.3)
800 (31.6)	—	—	—	—	—	600 (23.7)	900 (35.5)	1300 (51.3)
600 (23.7)	—	—	—	—	—	—	500 (19.7)	1200 (47.4)
400 (15.8)	—	—	—	—	—	—	300 (11.8)	1200 (47.4)
200 (7.9)	—	—	—	—	—	—	200 (7.9)	1100 (43.4)

FIG. 118 Required Distance Between Hazard and Barrier



TABLE 50 Allowable Exposure Limits to Some Toxic Gases

Emission	8-h Time One Weighted Average, ppm	15-min Short Two-Term Exposure, ppm
Carbon monoxide (CO)	50	500
Carbon dioxide (CO ₂)	5000	15 000
Oxides of nitrogen ^A	5	5
Sulfur dioxide (SO ₂)	2 ^B	2

^AOxides of nitrogen consist predominately of nitric oxide.

^BSome references allow 5 ppm for an 8-h exposure to SO₂.

51.14 *Radiation*—Radiation-emitting systems and equipment require special consideration to minimize hazards to operators and maintenance personnel. Ionizing radiation exposure rates produced by any device shall not exceed 0.5 mR/h at a distance of 50 mm (2 in.) from any point on the external surface.

52. User-Computer Interface

52.1 *General*—Computer programs and equipment interfaces shall provide a functional interface between the system for which they are designed and users (operators/maintainers) of that system. This interface shall optimize compatibility with personnel and shall minimize conditions that can degrade human performance or contribute to human error.

52.1.1 *Standard Procedures*—Users shall be provided standard procedures for similar, logically related transactions.

52.1.2 *Computer Response*—Every input by a user shall consistently produce some perceptible response output from the computer.

52.1.3 *On-Line Guidance*—Users shall be provided on-line data and command indices and dictionaries to guide selection and composition for data and command entries. Definitions of allowable options, system capabilities, procedures, and ranges of values shall be displayable at the user's request.

52.1.4 *System Status*—Users shall be provided information at all times on system status regarding operational modes, availability, and loads, either automatically or by request.

52.1.5 *Log-On Procedures*—In applications in which users must log on to the system, log on shall be a separate procedure that must be completed before a user is required to select among any operational options.

52.1.5.1 *Automatic Log-On Display*—Appropriate prompts for log on shall be automatically displayed on the user's terminal with no special action required other than turning on the terminal.

52.1.5.2 *Log-On Feedback*—Users shall be provided feedback relevant to the log-on procedure that indicates the status of the inputs.

52.1.5.3 *Log-On Delay*—If a user cannot log on to a system, a prompt shall be provided to explain the reason for this inability. Log-on processes shall require minimum input from the user consistent with the requirements prohibiting illegal entry.

52.1.6 *Log-Off Procedures*—When a user signals for log off, the system shall check pending transactions to determine if data loss seems probable. If so, the computer shall prompt for confirmation before the log-off command is executed.

52.1.7 *Computer Failure*—In the event of partial hardware/software failure, the program shall allow for orderly shutdown

and establishment of a checkpoint so restoration can be accomplished without loss of computing performed to date.

52.1.8 *Interaction*—Where two or more users must have simultaneous read access to the computer program or data processing results from multiple personnel-equipment interfaces, the operation by one person shall not interfere with the operations of another person unless mission survival may be contingent upon the preemption. Provisions shall be made so that the preempted user can resume operations at the point of interference without information loss.

52.2 Data Entry:

52.2.1 *General*—Data entry functions shall be designed to establish consistency of data entry transactions, minimize input actions and memory load on the user, ensure compatibility of data entry with data display, and provide flexibility of user control of data entry.

52.2.2 *User Pacing Manual*—Data entry shall be paced by the user, depending on the user's application, criticality of the operation and attention span, rather than by the system.

52.2.3 *Positive Feedback*—The system shall provide a positive feedback to the user of the acceptance or rejection of a data entry.

52.2.4 *Processing Delay*—Where system overload or other system conditions will result in a processing delay, the system shall acknowledge the data entry and provide an indication of the delay to the user.

52.2.5 *Explicit Action*—Data entry shall require an explicit completion action, such as the depression of an ENTRY key.

52.2.6 *Validation*—Data entries shall be validated by the system for correct format, legal value, or range of values. Where repetitive entry of data sets is required, data validation for each set shall be completed before another transaction can begin.

52.2.7 *Software Available Data*—The user shall not be required to enter data already available to the software.

52.2.8 *Input Units*—Data shall be entered in units that are familiar to the user.

52.2.9 Cursors:

52.2.9.1 *Control*—Systems using cursors shall provide cursor control capability consistent with user speed and accuracy requirements.

52.2.9.2 *Display*—A movable cursor within the display shall have a distinctive visual attribute that does not obscure other displayed entities. When fine positioning accuracy is required, as in some forms of graphic and image-processing applications, the displayed cursor shall include an appropriate point designation feature (such as crosshairs).

52.2.9.3 *Home Position*—The home position for the cursor shall be consistent across similar types of displays.

52.2.9.4 *Explicit Actuation*—A separate, explicit action, distinct from cursor position, shall be required for the actual entry (for example, enabling, actuation) of a designated position.

52.2.9.5 *Consistent Positioning*—Where cursor positioning is incremental by discrete steps, the step size of cursor movement shall be consistent horizontally (that is, in both right and left directions) and vertically (in both up and down directions).



52.2.9.6 *Keyboard Cursor Control*—When position designation is required in a task emphasizing keyed data entry, cursor control shall be by some device integral to the keyboard. If cursor movement is accomplished by depressing keys, the keys shall be located on the main keyboard.

52.2.9.7 *Movement Relationships*—The response of a cursor to control movements shall be consistent, predictable, and compatible with the user's expectations. For cursor control by key action, a key labeled with a left-pointing arrow shall move the cursor leftward on the display; for cursor control by joystick, leftward movement of the control shall result in leftward movement of the cursor.

52.2.9.8 *Abbreviations, Mnemonics, and Codes*—When abbreviations, mnemonics, or codes are used to shorten data entry, they shall be distinctive and have a relationship or association to normal language or specific job-related terminology.

52.2.9.9 *Explicit Delete Action*—Data deletion or cancellation shall require an explicit action, such as the depression of a DELETE key.

52.2.9.10 *Change of Data*—Where a user requests change (or deletion) of a data item that is not currently being displayed, the option of displaying the old value before confirming the change shall be presented.

52.2.9.11 *Single Method of Data Entry*—Data entry methods and data displays shall not require the user to shift between entry methods.

52.2.9.12 *Data Entry Display*—Where data entry on an electronic display is permitted only in prescribed areas, a clear visual definition of the entry fields shall be provided.

52.3 *Keyboard:*

52.3.1 *Use*—A keyboard shall be used to enter alphabetic, numeric, and other special characters into the system.

52.3.2 *Timely Display*—Keyed inputs, except security items such as passwords, shall be echoed on the display within 0.1 s.

52.3.3 *Length*—Except for extended text, the length of individual data items shall be minimized.

52.3.4 *Justification*—When entering tabular data, the user shall not be required to right- or left-justify tabular data entries. The system shall automatically justify columnar data with respect to decimal point, left margin, and right margin.

52.3.5 *Numeric Keypads*—Keyboards used in systems requiring substantial numeric input shall be equipped with a numeric keypad.

52.3.6 *Minimization of Keying*—The amount of keying required shall be minimized by using numbered lists and abbreviations.

52.3.7 *Minimization of Shift Keying*—The use of key-shifting functions shall be minimized during data entry transactions.

52.3.8 *Data Change*—In keyed data entry, means shall be provided to allow users to change previous entries, if necessary, by DELETE and INSERT actions.

52.4 *Fixed Function (Dedicated) Keys:*

52.4.1 *Use*—Fixed function keys (for example, ENTER) shall be used for time-critical, error-critical, or frequently used control inputs.

52.4.2 *Standardization*—Fixed function keys shall be common throughout the system.

52.4.3 *Functional Consistency*—Once a key has been assigned a given function, it shall not be reassigned to a different function for a given user.

52.4.4 *Availability*—Fixed function keys shall be selected to control functions that are continuously available; lockout of fixed function keys shall be minimized.

52.4.5 *Nonactive Keys*—Nonactive fixed function keys shall be replaced by a blank key on the keyboard.

52.4.6 *Grouping*—Fixed function keys shall be logically grouped and shall be placed in distinctive locations on the keyboard.

52.4.7 *Activation*—A fixed function key shall require only a single actuation to accomplish its function.

52.4.8 *Feedback*—When fixed function key activation does not result in an immediately observable natural response, the user shall be given an indication of system acknowledgement.

52.4.9 *Function Labels*—Key assignments shall be displayed at all times, preferably through direct marking. Where abbreviations are necessary, they shall be in accordance with Section 28.

52.5 *Variable Action Keys:*

52.5.1 *Use*—Variable action keys may be used for programmable menu selection and entry of control functions.

52.5.2 *Status Display*—When the effect of an action key varies, the status of the key shall be displayed.

52.5.3 *Reprogrammable or Inactive Default Action*—When keys with labeled default functions are reprogrammed or turned off, a visual warning shall alert the user that the standard action is not currently accessible via that key.

52.5.4 *Relabeling*—Provision shall be made for easily relabeling variable action keys. Labels for variable function keys, located along the perimeter of a display, may be generated on the display face.

52.5.5 *Shifted Characters*—Variable function keys shall not be shifted character keys that require the depression of a shift key before each actuation of the variable key.

52.5.6 *Easy Return to Base-Level Functions*—Where the functions assigned to a set of function keys change as a result of user selection, the user shall be given an easy means to return to the initial, base-level functions. For example, in cockpit design, where multifunction keys may be used for various purposes such as navigation or weapons control, the aircrew should be able to take a single action to restore those keys quickly to their basic flight control functions.

52.5.7 *Minimization of Keying*—Operational sequences using variable action keys shall be minimized with respect to the number of key functions required.

52.6 *Lightpen:*

52.6.1 *Use*—A lightpen may be used when noncritical, imprecise input functions are required. Such direct-pointing controls shall be used when item selection is the primary type of data entry.

52.6.2 *Dimensions and Mounting*—See 26.6.3.



52.6.3 *Actuation*—Lightpens shall be equipped with a discrete actuating/deactuating mechanism. For most applications, a push-tip switch, requiring 0.5 N (2 to 5 oz) of force to actuate, is preferred.

52.6.4 *Feedback*—Two forms of feedback shall be provided to the user when using a lightpen:

52.6.4.1 Feedback concerning lightpen placement, preferably in the form of an illuminated circle projected from the lightpen onto the display screen, and

52.6.4.2 Feedback that the lightpen has actuated and the input has been received by the system.

52.7 *Joystick/Trackball*:

52.7.1 *Use*—A joystick, trackball, or similar device may be used when precise input functions are required. These devices shall conform to 26.2, 26.3, 26.4, 26.5, and 26.6.

52.7.2 *Actuation/Deactuation*—A discrete mechanism shall be provided to allow the user to actuate/deactuate the device.

52.8 *Touch Screen*—See 26.8 for information on touch screens.

53. Data Display

53.1 *Display Format*:

53.1.1 *Consistency*—Display formats shall be consistent within a system.

53.1.1.1 When appropriate for users, the same format shall be used for input and output.

53.1.1.2 Data entry formats shall match the source document formats.

53.1.1.3 Essential data, text, and formats shall be under computer, not user, control.

53.1.2 *Criticality*—Only data essential to the user's needs shall be displayed.

53.1.3 *Readily Usable Form*—Data presented to the user shall be in a readily usable and readable form that the user does not have to transpose, compute, interpolate, or mentally translate into other units, number bases, or languages.

53.1.4 *Order and Sequences*—When data fields have a naturally occurring order (such as chronological), such order shall be reflected in the format organization of the fields.

53.1.4.1 *Data Grouped by Importance*—Where some displayed data items are of significant importance or require immediate user response, those items shall be grouped at the top of the display.

53.1.4.2 *Data Grouped by Function*—Where sets of data are associated with particular questions or related to particular functions, each set may be grouped together to help illustrate those functional relationships.

53.1.4.3 *Data Grouped by Frequency*—Where some data items are used more frequently than others, those items may be grouped at the top of the display.

53.1.5 *Data Separation*—Separation of groups of information shall be accomplished by blanks, spacing, lines, color coding, or other means consistent with the application.

53.1.6 *Recurring Data Fields*—Recurring data fields within a system shall have consistent names and shall have consistent relative position within displays.

53.1.7 *Extended Alphanumerics*—When five or more alphanumeric characters within natural organization are displayed, the characters shall be grouped in blocks of three to five

characters within each group separated by a minimum of one blank space or other separating character such as a hyphen or slash.

53.1.8 *Comparative Data Fields*—Data fields to be compared on a character-by-character basis shall be positioned one above the other.

53.1.9 *Labels and Titles*—Each display shall be labeled with a title or label that is unique within the system. To make the display as meaningful as possible and to reduce user memory requirements, every field or column heading shall be labeled.

53.1.9.1 *Display Title*—Every display shall begin with a title or header at the top, describing briefly the contents or purpose of the display. There shall be at least one blank line between the title and the body of the display.

53.1.9.2 *Command Entry, Prompts, Messages at Bottom*—The last several lines at the bottom of every display shall be reserved for status and error messages, prompts, and command entry.

53.1.10 *Data Group Labels*—Each individual data group or message shall contain a descriptive title, phrase, word, or similar device to designate the content of the group or message. Labels shall perform the following:

53.1.10.1 Be located in a consistent fashion adjacent to the data group or message they describe. The relationship of the label to the group, field, or message being described shall be unambiguous.

53.1.10.2 Be highlighted or otherwise accentuated to facilitate operator scanning and recognition. The technique used to accentuate labels shall be different from, and easily distinguished from, that used to highlight or code emergency or critical messages.

53.1.10.3 Be unique and meaningful to distinguish them from data, error messages, or other alphanumerics.

53.1.10.4 Be displayed in uppercase only, while text may be displayed in uppercase and lowercase.

53.1.10.5 Reflect the question or decision being posed to the user, when presenting a list of user options.

53.1.11 *Scrolling*—Items continued on the next page (scrolled) shall be numbered relative to the last item on the previous page.

53.1.12 *Page Numbering*—Each page of a multiple-page display shall be labeled to identify the currently displayed page and the total number of pages, for example, Page 2 of 5.

53.1.13 *Frame Identification*—Every display frame shall have a unique identification to provide a reference for use in requesting the display of that frame. The frame identification shall be an alphanumeric code or an abbreviation which is prominently displayed in a consistent location. It shall be short enough (three to seven characters) and meaningful enough to be learned and remembered easily.

53.2 *Display Content*:

53.2.1 *Standardization*—The content of displays within a system shall be presented in a consistent, standardized manner.

53.2.2 *Information Density*—Information density shall be held to a minimum in displays used for critical task sequences. A minimum of one-character space shall be left blank vertically

above and below critical information, with a minimum of two-character spaces left blank horizontally before and after.

53.2.2.1 *Crowded Displays*—When a display contains too much data for presentation in a single frame, the data shall be partitioned into separately displayable pages.

53.2.2.2 *Related Data on Same Page*—When partitioning displays into multiple pages, functionally related data items shall be displayed together on one page.

53.2.2.3 *Page Labeling*—In a multipage display, each page shall be labeled to show its relation to the others.

53.2.3 *Abbreviations and Acronyms*—Information shall be displayed in plain concise text wherever possible. Abbreviations and acronyms shall conform to Section 28. Abbreviations shall be distinctive to avoid confusion. Words shall have only one consistent abbreviation. No punctuation shall be used in abbreviations. Definitions of all abbreviations, mnemonics, and codes shall be provided at the user's request.

53.2.3.1 *Data Entry and Display Consistency*—Data display word choice, format, and style shall be consistent with the requirements for data entry and control.

53.2.3.2 *Context for Displayed Data*—The user shall not have to rely on memory to interpret new data; each data display shall provide needed context, including recapitulating prior data from prior displays as necessary.

53.3 *Display Coding:*

53.3.1 *Use*—Coding shall be used to differentiate between items of information and to call the user's attention to changes in the state of the system. Coding shall be used for critical information, unusual values, changed items, items to be changed, high priority messages, special areas of the display, errors in entry, criticality of command entry, and targets. Consistent, meaningful codes shall be used. Coding shall not reduce legibility or increase transmission time.

53.3.2 *Flash*—Flash coding shall be used to call the user's attention to mission critical events only. No more than two flash rates shall be used. Where one rate is used, the rate shall be between three and five flashes per second. Where two rates are used, the second rate shall be less than two per second.

53.3.3 *Brightness*—Brightness intensity coding shall be used only to differentiate between an item of information and adjacent information. No more than three levels of brightness shall be used. Each level shall be separated from the nearest by at least a 2:1 ratio.

53.3.4 *Pattern and Location*—Pattern and location coding shall be used to reduce user search time by restricting the area to be searched to prescribed segments.

53.3.5 *Underlining*—Underlining may be used to indicate unusual values, errors in entry, changed items, or items to be changed.

53.3.6 *Symbol*—Symbol coding may be used to enhance information assimilation from data displays. Symbols shall be analogs of the event or system element they represent or be in general use and well known to the expected users. Where size difference between symbols is used, the major dimensions of the larger shall be at least 150 % of the major dimension of the smaller with a maximum of three size levels permitted.

53.3.6.1 *Special Symbols*—When special symbols are used to signal critical conditions, they shall be used for only that purpose.

53.3.6.2 *Markers Close to Words Marked*—When a special symbol is used to mark a word, the symbol shall be separated from the beginning of the word by one space.

53.3.7 *Color*—Color coding may be used to differentiate between classes of information in complex, dense, or critical displays. Information shall not be coded solely by color if the data must be accessed from monochromatic as well as color terminals or printed in hardcopy versions.

53.3.8 *Shape*—Shape coding may be used for search and identification tasks.

53.3.9 *Brightness Inversion*—When a capability for brightness inversion is available (so-called "reverse video," where dark characters on a bright background can be changed under computer control to bright on dark or vice versa), it may be used for highlighting critical items that require user attention. When used for alerting purposes, brightness inversion shall be reserved consistently for that purpose and not be used for general highlighting.

53.4 *Dynamic Displays:*

53.4.1 *Changing Values*—Changing alphanumeric values that the operator must reliably read shall not be updated more than once per second. Changing values that the viewer uses to identify rate of change or to read gross values shall not be updated faster than five times per second, nor slower than two per second, when the display is to be considered as real time.

53.4.2 *Update Rate*—The rate of update shall be controllable by the user and shall be determined by the use to be made of the information.

53.4.3 *Display Freeze*—A display freeze mode shall be provided to allow close scrutiny of any selected frame that is updated or advanced automatically by the system. For frozen display frames, an option shall be provided to allow resumption at the point of stoppage or at the current real-time point.

53.4.4 *Freeze Feedback*—An appropriate label shall be provided to remind the operator when the display is in the freeze mode.

53.5 *Tabular Data:*

53.5.1 *Use*—Tabular data displays shall be used to present row-column data.

53.5.2 *Standard Formats*—Location of recurring data shall be similar among all tabular data displayed and common throughout the system.

53.5.3 *Arrangement*—Tabular data shall be displayed in a left-to-right, top-to-bottom array. Alphanumeric data shall be left justified; numeric data shall be right justified with decimal points, if any, aligned vertically.

53.5.4 *Titles*—When tabular data are divided into classifications, the classification titles shall be displayed and subclassification shall be identified. When tabular data extend over more than one page vertically, the columns shall be titled identically on each page.

53.5.5 *Horizontal Extension*—Tabular displays shall not extend over more than one page horizontally.

53.5.6 *Lists*—Items in lists shall be arranged in a recognizable order, such as chronological, alphabetical, sequential, functional, or importance.

53.5.6.1 *List Lines*—Each item in a list shall start on a new line.

53.5.6.2 *Vertical Extension*—Where lists extend over more than one display page, the last line of one page shall be the first line of the succeeding page.

53.5.6.3 *Marking Multiline Items in a List*—Where a single item in a two separate word list continues for more than one line, such items shall be marked in some way (for example, blank line, indentation) so that the continuation of the item is obvious.

53.5.6.4 *Arabic Numerals*—When listed items will be numbered, Arabic numerals shall be used rather than Roman.

53.5.6.5 *Vertical Ordering in Multiple Columns*—Where items in a list are displayed in multiple columns, items shall be ordered vertically within each column.

53.5.6.6 *Hierarchic Structure for Long Lists*—Where lists are long and must extend beyond more than one displayed page, a hierarchic structure shall be used to permit the logical partitioning into related shorter lists.

53.5.7 *Numeric Punctuation*—Long numeric fields shall not be punctuated with spaces, commas, or slashes. Conventional punctuation schemes shall be used if in common usage. Where none exist, a space shall be used after every third or fourth digit. Leading zeros shall not be used in numerical data except where needed for clarity.

53.5.8 *Alphanumeric Grouping*—Strings of alphanumerics shall be grouped into sets of three to five characters or grouped at natural breaks. When a code consists of both letters and digits, common character types shall be grouped for ease of location.

53.5.9 *Distinctive and Informative Labels*—Rows and columns shall be labeled distinctively to guide data entry.

53.5.10 *Justification of Numeric Entry*—Users shall be allowed to make numeric entries in tables without concern for justification; the computer shall right justify integers or else justify with respect to a decimal point if present.

53.5.11 *Labeling Units of Measurement*—In tabular display, the units of displayed data shall be consistently included in the column labels.

53.5.12 *Consistent Column Spacing*—Column spacing within a table from one table to another shall be uniform and consistent.

53.5.13 *Column Scanning Cues*—A column separation of at least three spaces shall be maintained.

53.5.14 *Row Scanning Cues*—In dense tables with many rows, a blank line shall be inserted after a group of rows at regular intervals. No more than five lines shall be displayed without a blank line being inserted.

53.6 *Graphic Displays:*

53.6.1 *Use*—Graphic data displays may be used to present assessment of trend information, spatially structured data, time critical information, or relatively imprecise information.

53.6.2 *Recurring Data*—See 53.1.6.

53.6.3 *Refresh Rates*—Graphic displays that require user visual integration of changing patterns shall be updated at the maximum refresh rate of the display device consistent with the user's information handling rates.

53.6.4 *Graph Axes*—The axes of graphs shall be labeled and shall be graduated in accordance with 10.5.

53.6.5 *Trend Lines*—When trend lines are to be compared, multiple lines shall be used on a single graph.

53.6.6 *Pointing*—Where graphic data entry involves frequent pointing on a display surface, the user interface shall provide display control and sequence control by pointing to minimize shifts from one entry device to another. For example, in drawing a flow chart, a user shall be able to link elements or points directly by pointing at them or drawing lines between rather than by separately keyed entries.

53.6.7 *Distinctive Cursor*—The current cursor position on graphic display shall be indicated by displaying some distinctive cursor symbol at that point, for example, a plus sign, representing abbreviated crosshairs whose intersection can mark a position with reasonable precision.

53.6.8 *Precise Positioning*—Where data entry requires exact placement of graphic elements, users shall be provided the capability for expansion of the critical display area (for example, zooming and panning) to make the positioning task easier and more precise.

53.6.9 *Confirming Cursor Position*—For most graphics data entry, pointing shall be a dual action, with the first action positioning the cursor at a desired position and the second action confirming that position to the computer. An exception may be a design allowing “freehand” drawing of continuous lines where the computer must store and display a series of cursor positions as they are entered by the user.

53.6.10 *Selecting Graphic Elements*—Users shall be provided some means for designating and selecting displayed graphic elements for manipulation. Normally this function is performed by pointing where a pointing device is provided for line-drawing purposes.

53.6.11 *Selecting from Displayed Attributes*—During graphic data entry, users shall be allowed to specify attributes for displayed elements (for example, text font, plotting symbol, line type) by selecting from displayed samples illustrating the available options.

53.6.12 *Displaying Current Attributes*—During graphic data entry/editing, the selected attributes that will affect current actions shall be displayed for ready reference as a reminder of current selections in effect.

53.6.13 *Easy Storage and Retrieval*—An easy and convenient means shall be provided for saving and retrieving graphic displays for their possible reuse. The user shall be allowed to designate filenames of his or her choice for the stored graphic data.

53.6.14 *Automatic Data Registration*—The computer shall provide automatic registration or alignment of computer-generated graphic data, so that variable data are shown properly with respect to fixed background or data map at any display scale.

53.6.15 *Predefined Graphic Formats*—Where graphic data must be plotted in predefined standard formats (for example,



target areas on maps, flight plans), templates or skeletal displays shall be provided for those formats to aid data entry.

53.6.16 *Computer Deviation of Graphic Data*—When graphic data can be derived from data already available in the computer, machine aids for that purpose shall be provided.

53.6.17 *Drawing Lines*—When line drawing is required, users shall be provided with aids for drawing straight line segments. When line segments must join or intersect, computer aids shall be provided to aid in such connection.

53.6.18 *Drawing Figures*—When a user must draw figures, computer aids shall be provided for that purpose (for example, templates, tracing techniques, stored forms).

53.6.19 *Changing Size*—When editing graphic data, users shall be provided with the capability to change the size (scale) of any selected element on the display, rather than delete and recreate the element in a different size.

53.6.20 *Highlighting Critical Data*—When a user's attention must be directed to a portion of a graphic display showing critical or abnormal data, that feature shall be highlighted with some distinctive means of data coding.

53.6.21 *Reference Index*—When a user must compare graphic data to some significant level or critical value, a reference index or baseline shall be included in the display.

53.6.22 *Data Annotation*—When precise reading of a graphic display may be required, the capability shall be provided to supplement the graphic representation with the actual numeric values.

53.6.23 *Normal Orientation for Labels*—The labels on dynamic graphic displays shall remain with the top of the label up when the displayed image rotates.

53.6.24 *Pictorial Symbols*—Pictorial symbols (for example, icons, pictograms) shall look like the objects, features, or processes they represent.

53.6.25 *Display of Scale*—When a map or other graphic display has been expanded from its normal presentation, an indicator of the scale expansion shall be provided.

53.6.26 *Consistent Scaling*—When users must compare graphic data across a series of charts, the same scale shall be used for each chart.

53.6.27 *Single Scale Only*—Where graphs are presented, only a single scale shall be shown in each axis, rather than including different scales for different curves in the graph. If interpolation must be made or where accuracy of reading graphic data is required, computer aids shall be provided the user.

53.6.28 *Unobtrusive Grids*—When grid lines are displayed, they shall be unobtrusive and shall not obscure data elements. Grid lines shall be displayed or suppressed at the option of the user.

53.6.29 *Direct Display of Differences*—Where users must evaluate the difference between two sets of data, that difference shall be plotted directly as a curve in its own right, rather than requiring user to compare visually the curves that represent the original data sets.

53.6.30 *Bar Graphs*—Bar graphs shall be used for comparing a single measure across a set of several entities or for a variable sampled at discrete intervals.

53.6.30.1 *Bar Spacing*—Adjacent bars shall be spaced closely enough, normally not more than one bar width, so that a direct visual comparison can be made without eye movement.

53.6.30.2 *Histograms (Step Charts)*—Histograms (bar graphs without spaces between the bars) shall be used where bar graphs are required and where a great many intervals must be plotted.

53.7 *Textual Data Displays*:

53.7.1 *Use*—Information, such as abstracts or reports, that cannot be presented in any other format, may be presented in text format.

53.7.2 *Formats*—Textual data formats shall conform to the practices established for the particular type of textual data displayed.

53.7.3 *Paragraph Separation*—Text paragraphs shall be separated by at least one blank line. Paragraphs shall be numbered.

53.7.4 *Brevity*—Short simple sentences shall be used and shall be displayed in normal upper/lowercase font.

53.7.5 *Abbreviations*—See 52.2.9.8.

54. Text/Program Editing

54.1 *Buffer*—When inserting characters, words, or phrases (editing), items to be inserted shall be collected in a buffer area and displayed in the prescribed insert area of the screen for subsequent insertion by user command.

54.2 *Presentation Mode*—Display mode rather than line mode shall be used for text editing.

54.3 *Display Window*—ROLL and SCROLL commands shall refer to the display window not the text/data, that is, the display window shall appear to the user to be an aperture moving over stationary text.

54.4 *Editing Commands*—Easy-to-use, special editing commands, such as MOVE, COPY, and DELETE, for adding, inserting, or deleting text/program segments shall be provided.

54.4.1 *Text Edit Commands*—In text editing, the special commands shall be based on sentences, paragraphs, or higher-order segments.

54.4.2 *Program Edit Commands*—In program editing, the special commands shall be used on lines or subprograms. Program lines shall reflect a numbering scheme for ease in editing and error correction. When available, line-by-line syntax checking shall be under user control.

54.4.3 *Tab Controls*—For editing programs or tabular data, cursor tab controls or other provisions for establishing and moving readily from field to field shall be provided.

54.5 *Editing Commands*—Where editing commands are made by keying onto the display, the editing commands shall be readily distinguishable from the displayed textual material.

54.6 *Highlighted Text*—Where text has been specified to become the subject of control entries (for example, for underlining, bolding, moving, copying, or deleting), the affected segment of text shall be highlighted to indicate its boundaries.

54.7 *String Search*—The capability shall be provided to allow the user to specify a string of text (words, phrases, or numbers) and request the computer to advance (or back up) the cursor automatically to the next occurrence of that string.



54.8 *Automatic Line Break*—An automatic line break (carriage return) shall be provided when the text reaches the right margin for entry/editing of unformatted text. User override shall be provided.

54.9 *Format Control*—An easy means shall be provided for users to specify required format control features during text entry/editing, for example, to specify margins, tab settings, line spacing, and so forth.

54.10 *Predefined Formats*—When text formats must follow predefined standards, the required format shall be provided automatically. Where text formats are a user option, a convenient means shall be provided to allow the user to specify and store for future use the formats that have been generated for particular applications.

54.11 *Frequently Used Text*—The capability shall be provided to label and store frequently used text segments (for example, signature blocks, organizational names, call signs, coordinates) and later to recall (copy into current text) stored segments identified by their assigned labels.

54.12 *Text Displayed as Printed*—Users shall have the option of displaying text as it will be printed, including underlining, boldface, subscript, superscript, special characters, special symbols, and different styles and sizes of type. Where display of all possible features (for example, special fonts) is impractical, format codes shall be highlighted and displayed within the text to mark the text that will be affected by the code.

54.13 *Control Annotations*—Where special formatting features are indicated in the text by use of special codes or annotation, the insertion of the special annotation shall not disturb the spacing of the displayed text and shall not disturb formatting of graphs and tables or alignment of rows and columns.

54.14 *Flexible Printing Options*—In printing text, users shall be allowed to select among available output formats (for example, line spacing, character size, margin size, heading, and footing) and to specify the pages of a document to be printed.

54.15 *Head and Foot of File*—The means shall be provided to readily move the cursor to the head or the foot (end) of the file.

55. Audio Displays, Interface

55.1 *Uses*—Audio displays (signals), used as part of the user-computer interface, have application where:

55.1.1 The common mode of visual display is restricted by overburdening or user mobility needs and it is desirable to cue, alert, or warn the user, or

55.1.2 The user shall be provided feedback after control actuation, data entry, or completion of timing cycles and sequences.

55.2 *Other Requirements*—Other audio design criteria apply. See Sections 14, 15.1 and 15.3.

55.3 *Supportive Function, Audio*—Audio signals used in conjunction with visual displays shall be supplementary to the visual signals and shall be used to alert and direct the user's attention to the appropriate visual display.

55.4 *Signal Characteristics*—The intensity, duration, and source location of the signal shall be compatible with the acoustical environment of the intended receiver as well as the

requirements of other personnel in the signal area. Signals shall be intermittent, allowing the user sufficient time to respond. Signals shall be automatically terminated by operator response action or by manual control.

55.5 *Frequency*—See Section 16.

55.6 *Alarm Settings*—When alarm signals are established on the basis of user-defined logic, users shall be permitted to obtain status information concerning current alarm settings, in terms of dimensions (variables) covered and values (categories) established as critical. Alarm status information is particularly necessary in monitoring situations in which responsibility may be shifted from one user to another as in changes of shift.

56. Interactive Control

56.1 *General*—System response times shall be consistent with operational requirements. Required user response times shall be compatible with required system response time. Required user response times shall be within the limits imposed by total user tasking expected in the operational environment.

56.2 *Response Time*—System response times shall be consistent with operational requirements. Required user response times shall be compatible with required system response time. Required user response times shall be within the limits imposed by total user tasking expected in the operational environment. See Section 56.27, Error Management/Data Protection.

56.2.1 *Response Time Induced Keyboard Lockout*—If computer processing time requires delay of concurrent user inputs and no keyboard buffer is available, keyboard lockout shall occur until the computer can accept the next transaction. An alert shall be displayed to indicate to the user that lockout has occurred.

56.2.2 *Keyboard Restoration*—When the computer is ready to continue, following response time-induced keyboard lockout, a signal to so indicate shall be presented, for example, cursor changes back to normal shape.

56.2.3 *Interrupt to End Keyboard Lockout*—When keyboard lockout has occurred, the user shall be provided with a capability to abort a transaction that has resulted in an extended lockout. Such capability shall act like an UNDO command that stops ongoing processing and does not RESET the computer thereby losing prior processing.

56.3 *Simplicity*—Control/display relationships shall be straightforward and explicit. Control actions shall be simple and direct.

56.4 *Accidental Actuation*—Provision shall be made to prevent accidental actuation of potentially destructive control actions, including the possibility of accidental erasure or memory dump.

56.5 *Compatibility with User Skill*—Controls shall be compatible with the lowest anticipated user skill levels.

56.6 *Availability of Information*—Information necessary to select or enter a specific control action shall be available to the user when selection of that control action is appropriate.

56.7 *Concurrent Display*—Control actions to be selected from a discrete set of alternatives shall have those alternatives displayed before the time of selection. The current value of any

parameter or variable with which the user is interacting shall be displayed. User control inputs shall result in a positive feedback response displayed to indicate performance of requested actions.

56.8 *Hierarchical Process*—When hierarchical levels are used to control a process or sequence, the number of levels shall be minimized. Display and input formats shall be similar within levels and the system shall indicate the current positions within the sequence at all times.

56.9 *User Memorization*—The requirement to learn mnemonics, codes, special or long sequences, or special instructions shall be minimized.

56.10 *Dialogue Type*—The choice of dialogue type (for example, form filling, menus, command language) for interactive control shall be compatible with user characteristics and task requirements.

56.11 *Number System*—When numeric data is displayed or required for control input, such data shall be in the decimal, rather than binary, octal, hexadecimal, or other number system.

56.12 *Data Manipulation*—The user shall be able to manipulate data without concern for internal storage and retrieval mechanisms of the system.

56.13 *Computer-Processing Constraints*—The sequence of transaction selection shall generally be dictated by user choices and not by internal computer-processing constraints.

56.14 *Feedback for Correct Input*—Control feedback responses to correct user input shall consist of changes in state or value of those elements of the displays that are being controlled in an expected and logically natural form. An acknowledgement message shall be used only in those cases in which the more conventional mechanism is not appropriate or feedback response time must exceed 1 s.

56.15 *Feedback for Erroneous Input*—Where control input errors are detected by the system, error messages shall be available, and error recovery procedures shall be provided.

56.16 *Control Input Data Display*—The presence and location of control input data entered by the user shall be clearly and appropriately indicated. Data displayed shall not mislead the user with regard to nomenclature, units of measure, sequence of task steps, or time phasing.

56.17 *Originator Identification*—Except for broadcast communication systems, the transmitter of each message in inter-user communications shall be identified—automatically, if possible.

56.18 *Menu Selection:*

56.18.1 *Use*—Menu selection interactive control shall be used for tasks that involve little or no entry of arbitrary data and where users may have relatively little training. It shall also be used when a command set is so large that users are not likely to be able to commit all of the commands to memory.

56.18.2 *Selection Devices*—Lightpens or other pointing devices shall be used for menu selection. Where design constraints do not permit pointing devices, a standard window shall be provided for the user to key the selected option code.

56.18.3 *Titles*—Each page of options (menu) shall have a title that clarifies the purpose of that menu.

56.18.4 *Series Entry*—Users shall be provided the capability to stack menu selections, that is, to make several menu selections without having each menu displayed.

56.18.5 *Sequences*—A menu shall not consist of a long list of multipage options, but shall be logically segmented to allow several sequential selections among a few alternatives.

56.18.6 *Active Option Presentation*—The system shall present only menu selections for actions that are currently available.

56.18.7 *Format Consistency*—Menus shall be presented in a consistent format throughout the system and shall be readily available at all times.

56.18.8 *Option Sequence*—Menu selections shall be listed in a logical order, or, if no logical order exists, in the order of frequency of use.

56.18.9 *Simple Menus*—When the number of selections can fit on one page in two columns, a simple menu shall be used. If the selection options exceed two columns, hierarchical menus may be used.

56.18.10 *Option Presentation*—Selection codes and associated descriptors shall be presented on single lines.

56.18.11 *Direct Function Call*—If several levels of hierarchical menus are provided, a direct function call capability shall be provided such that the experienced user does not have to step through multiple menu levels.

56.18.12 *Consistency With Command Language*—When menu selection is used to train in the use of a command language, the wording and order shall be consistent with the command language.

56.18.13 *Option Coding*—When selections are indicated by coded entry, the code associated with each option shall be included on the display in some consistent manner.

56.18.14 *Keyed Codes*—If menu selections must be made by keyed codes, the options shall be coded by the first several letters of their displayed labels rather than by more arbitrary numeric codes.

56.18.15 *Position in Structure*—When menu traversal can be accomplished by clearly defined hierarchical paths, the user shall be given some indication of the displayed menu's current position in the overall or relevant structure, such as by having an optional display of "path" information. A menu tree showing the menu hierarchy shall be included in the user manual.

56.18.16 *Back Menu*—When using hierarchical menus, the user shall be able to return to the next higher level by using single key action until the initial, top-level menu or display is reached.

56.18.17 *Return to Top Level*—A function shall be provided to directly recall the initial, top-level menu or display without stepping through the menu or display hierarchy.

56.19 *Form Filling:*

56.19.1 *Use*—Form-filling interactive control may be used when some flexibility in data to be entered is needed and where the users will have moderate training.

56.19.2 *Grouping*—Displayed forms shall be arranged such that related items are grouped together.

56.19.3 *Format and Content Consistency*—The format and content of displayed forms shall be perceptually related to that

of paper forms, if paper forms are used to guide data entry. A standard input form shall be used.

56.19.4 *Distinctiveness of Fields*—Fields or groups of fields shall be separated by lines or other delineation cues. Required fields shall be distinguished from optional fields.

56.19.5 *Field Labels*—Field labels shall be distinctively presented such that they can be distinguished from data entry. Labels for data entry fields shall incorporate additional cueing of data format where the entry is made up of multiple inputs, for example, DATE (M/D/Y): / / .

56.19.6 *Cursor*—A displayed cursor shall be positioned by the system at the first data entry field when the form is displayed. The cursor shall be advanced by a tab key to the next data entry field when the user has completed entry of the current field.

56.19.7 *Entry Length Indication*—The maximum acceptable length for variable length fields shall be indicated.

56.19.8 *Overwriting*—Data entry by overwriting a set of characters in a field (such as a default) shall not be used.

56.19.9 *Unused Underscores*—When an item length is variable, the user shall not have to remove unused underscores.

56.19.10 *Dimensional Units*—When a consistent dimensional unit is used in a given entry field, the dimensional unit shall be provided by the computer. When the dimensional unit varies for a given field, it shall be provided, or selected, by the user.

56.19.11 *User Omissions*—When required data entries have not been input, the omission shall be indicated to the user and either immediate or delayed input of the missing items shall be allowed. For delayed entry, the user shall be required to enter a special symbol in the field to indicate that the missing item is delayed, not overlooked.

56.19.12 *Nonentry Areas*—Nonentry (protected) areas of the display shall be designated and made inaccessible to the user via the cursor.

56.19.13 *Flexible Data Entry*—When multiple data items are entered as a single transaction, the user shall be allowed to reenter, change, or cancel any item before taking a final ENTER action.

56.19.14 *Information Labels*—Descriptive wording shall be used when labeling data fields; use of arbitrary codes shall be avoided.

56.19.15 *Logical Order*—Where no source document or external information is involved, forms shall be designed so that data items are ordered in a logical sequence for input.

56.19.16 *Form Filling for Control Entry*—Form filling shall be considered as an aid for composing complex control entries. For example, for a print request, a displayed form might help a user invoke the various format controls that are available.

56.19.17 *Fixed Function Keys*—Fixed function key interactive control may be used for tasks requiring only a limited number of control inputs or in conjunction with other dialogue types.

56.20 *Command Language:*

56.20.1 *Use*—Command language interactive control may be used for tasks involving a wide range of user inputs and where user familiarity with the system can take advantage of the flexibility and speed of the control technique.

56.20.2 *User Viewpoint*—A command language shall reflect the user's point of view such that the commands are logically related to the user's conception of what is being done.

56.20.3 *Distinctiveness*—Commands shall be distinctive from one another.

56.20.4 *Punctuation*—The command language shall contain a minimum of punctuation or other special characters.

56.20.5 *Abbreviations*—The user shall be permitted to enter the full command name or an abbreviation for any command of more than five characters.

56.20.6 *Standardization*—All commands and their abbreviations, if any, shall be standardized and consistent with Section 28.

56.20.7 *Displayed Location*—Commands shall be entered and displayed in a standard location on the display.

56.20.8 *Command Prompts*—The user shall be able to request prompts, as necessary, to determine required parameters in a command entry.

56.20.9 *Complexity*—The command language shall be programmed in layers of complexity such that the basic layer will allow the inexperienced user to control a transaction. As this person's skill increases, the command language shall allow skipping from basic to more advanced layers to meet the user's current needs.

56.20.10 *User Definition of Macro Commands*—The programming shall not accept a user designated macro name that is the same as an existing command name.

56.20.11 *Standard Techniques for Command Editing*—Users shall be allowed to edit erroneous command entries with the same techniques that are used to edit data entries since consistent editing techniques will speed learning and reduce errors.

56.20.12 *Destructive Commands*—Where a command entry may have disruptive consequences, the user shall be required to review and confirm a displayed interpretation of the command before it is executed.

56.21 *Questions and Answers:*

56.21.1 *Use*—Question-and-answer dialogues shall be considered for routine data entry tasks in which data items are known and their ordering can be constrained, users will have little or no training, and the computer is expected to have medium response speed.

56.21.2 *Questions Displayed Separately*—Each question shall be displayed separately in question-and-answer dialogues; users shall not be required to answer several questions at once.

56.21.3 *Recapitulating Prior Answers*—When a series of computer-posed questions are interrelated, answers to previous questions shall be displayed when those will provide context to help a user answer the current questions.

56.21.4 *Source Document Capability*—When questions prompt entry of data from a source document, the question sequence shall match the data sequence in the source document.

56.22 *Query Language:*



56.22.1 *Use*—Query language dialogue shall be used for tasks emphasizing unpredictable information retrieval (as in many analysis and planning tasks), with moderately trained users.

56.22.2 *Natural Organization of Data*—Query languages shall reflect a data structure or organization perceived by users to be natural. For example, if a user supposes that all data about a particular topic are stored in one place, then the query language shall permit such data to be retrieved by a single query, even though actual computer storage might carry the various data in different files.

56.22.3 *Coherent Representation of Data Organization*—A single representation of the data organization for use in query formulation shall be established, for example, if different queries will access different databases over different routes, the user shall not necessarily need to know this.

56.22.4 *Task-Oriented Wording*—The wording of a query shall simply specify what data are requested; a user shall not have to tell the computer how to find the data.

56.22.5 *Logic to Link Queries*—The query language shall be designed to include logic elements that permit users to link (for example, “and,” “or”) sequential queries as a single entry.

56.22.6 *Confirming Large-Scale Retrieval*—If a query will result in a large-scale data retrieval, the user shall be required to confirm the transaction or else take further action to narrow the query before processing.

56.23 *Graphic Interaction:*

56.23.1 *Use*—Graphic interaction as a dialogue may be considered for use by casual users to provide graphic aids as a supplement to other types of interactive control.

56.23.2 *Iconic Menus*—When system users have different linguistic backgrounds, graphic menus may be used which display icons to represent the control options.

56.23.3 *Supplementary Verbal Labels*—Where icons are used to represent control actions in menus, verbal labels shall be displayed with each icon to help assure that its intended meaning will be understood.

56.24 *Feedback:*

56.24.1 *Use*—Feedback shall be provided which presents status information, confirmation, and verification throughout the interaction.

56.24.2 *Standby*—When system functioning requires the user to standby, WORKING, BUSY, or WAIT messages shall be displayed until user interaction is again possible. Where the delay is likely to exceed 15 s, the user shall be informed. For delays exceeding 60 s, a countdown display shall show delay time remaining. (See 56.27).

56.24.3 *Process Outcome*—When a control process or sequence is completed or aborted by the system, positive indication shall be presented to the user concerning the outcome of the process and the requirements for subsequent user action.

56.24.4 *Input Confirmation*—Confirmation shall not cause displayed data removal.

56.24.5 *Current Modes*—When multiple modes of operation exist, a means shall be provided to remind the user of the current mode.

56.24.6 *Highlighted Option Selected*—When a displayed message or datum is selected as an option or input to the system, the subject item shall be highlighted to indicate acknowledgment by the system.

56.24.7 *User Input Rejection*—If the system rejects a user input, feedback shall be provided to indicate the reason for rejection and the required corrective action. Feedback shall be self explanatory.

56.24.8 *Feedback Message Content*—Users shall not be required to translate feedback messages by use of reference system or code sheets. Abbreviations shall not be used unless necessary.

56.24.9 *Time-Consuming Processes*—The system shall give warning information when a command is invoked which will be time consuming or expensive to process.

56.25 *Prompts:*

56.25.1 *Use*—Prompts and help instructions shall be used to explain commands, error messages, system capabilities, display formats, procedures, and sequences and to provide data. Prompting shall conform to the following:

56.25.1.1 When operating in special modes, the system shall display the mode designation and file(s) being processed.

56.25.1.2 Before processing any user requests that would result in extensive or final changes to existing data, the system shall require user confirmation.

56.25.1.3 When missing data are detected, the system shall prompt the user.

56.25.1.4 When data entries or changes will be nullified by an abort action, the user shall be requested to confirm the abort.

56.25.1.5 Neither humor nor admonishment shall be used in structuring messages; the dialog shall be strictly factual and informative for the user.

56.25.1.6 Error messages shall appear as close as possible to the user entry that caused the message.

56.25.1.7 If a user repeats an entry error, the second error message shall be revised to include a noticeable change so that the user may be certain that the computer has processed the attempted correction.

56.25.2 *Standard Display*—Prompting messages shall be displayed in a standardized area of the displays.

56.25.3 *Explicit Prompts*—Prompts and help instructions for system-controlled dialogue shall be explicit, and the user shall not be required to memorize lengthy sequences or refer to secondary written procedural references.

56.25.4 *Prompt Clarity*—Prompts shall be clear and understandable. They shall not require reference to coding schemes or conventions which may be unfamiliar to occasional users.

56.25.5 *Definitions*—A dictionary of abbreviations and codes shall be available on-line. Definitions of allowable options and ranges of values shall be displayable at the user's request.

56.25.6 *Consistent Terminology*—On-line documentation, off-line documentation, and help instructions shall use consistent terminology.

56.25.7 *User Confirmation*—User acceptance of stored data or defaults shall be possible by a single confirming keystroke.

56.26 *Default:*



56.26.1 *Workload Reduction*—Default values shall be used to reduce user workload. Currently defined default values shall be displayed automatically in their appropriate data fields with the initiation of a data entry transaction and the user shall indicate acceptance of the default.

56.26.2 *User Selection*—The user shall have the option of generating default values based on operational experience if the systems designer cannot predefine appropriate values.

56.26.3 *Default Substitution*—The user shall be able to replace any default value during a given transaction without changing the default definition.

56.26.4 *Defaults for Sequential Entries*—Where a series of default values have been defined for a data entry sequence, the user shall be allowed to default all entries or to default until the next required entry. The experienced user may not wish to accept each default value for each data field individually.

56.27 *Error Management/Data Protection:*

56.27.1 *Error Correction*—Where users are required to make entries into a system, an easy means shall be provided for correcting erroneous entries. The system shall permit correction of individual errors without requiring reentry of correctly entered commands or data elements.

56.27.2 *Early Detection*—A capability shall be provided to facilitate detection and correction of errors after keying in but before entering into the system. While it is desirable that errors be detected early, error checking shall occur at logical data entry breaks, for example, at the end of data fields rather than character by character to avoid disrupting the user.

56.27.3 *Internal Software Checks*—User errors shall be minimized by use of internal software checks of user entries for validity of item, sequence of entry, completeness of entry, and range of value.

56.27.4 *Critical Entries*—The system shall require the user to acknowledge critical entries before their being implemented by the system. An explicitly labeled CONFIRM function key, different from the ENTER key, shall be provided for user confirmation of control and data entries that have been questioned by the computer.

56.27.5 *Error Message Content*—Error message shall be constructive and neutral in tone, avoiding phrases that suggest a judgment of the user's behavior. The error messages shall reflect the user's view, not that of the programmer. Error messages shall be appropriate to the user's level of training, be as specific as possible to the user's particular application, and describe a way to remedy, recover, or escape from the error situation.

56.27.6 *Error Recovery and Process Change*—The user shall be able to stop the control process at any point in a sequence as a result of indicated error or as an option. The user shall be able to return easily to previous levels in multistep processes to nullify an error or to effect a desired change.

56.27.7 *Diagnostic Information*—Error messages shall explicitly provide as much diagnostic information and remedial direction as can be inferred reliably from the error condition. Where clear inference is not possible, probable helpful inference(s) may be offered.

56.27.8 *Correction Entry and Confirmation*—When the user enters correction of an error, such corrections shall be

implemented by an explicit action by the user (for example, actuation of an ENTER key.) All error corrections by the user shall be acknowledged by the systems either by indicating a correct entry has been made or by another error message.

56.27.9 *Spelling Errors*—Spelling and other common errors shall not produce valid system commands or initiate transactions different from those intended. When possible, the system shall recognize common misspellings of commands and execute the commands as if spelling had been correct. Computer-corrected commands, values, and spellings shall be displayed and highlighted for user confirmation.

56.27.10 *Errors in Stacked Commands*—To prompt for corrections of an error in stacked commands, the system shall display the stacked sequence with the error highlighted. Where possible, a procedure shall be provided to correct the error and salvage the stack.

56.27.11 *Display of Erroneous Entries*—A computer-detected error, as well as the error message, shall be continuously display until the error is corrected.

56.27.12 *Help*—In addition to explicit error management aids, (labels, prompts, advisory messages) and implicit aids (cuing), users shall be able to obtain further on-line guidance by requesting HELP. Following the output of a simple error message, users shall be permitted to request a more detailed discussion at levels of increasing detail.

56.27.12.1 *Standard Action to Request HELP*—A simple, standard action that is always available shall be provided to request HELP.

56.27.12.2 *Multilevel HELP*—When an initial HELP display provides only summary information, more detailed explanations shall be provided in response to repeated user requests for HELP.

56.27.12.3 *Browsing Help*—Users shall be permitted to browse through on-line HELP displays, just as they would through a printed manual, to gain familiarity with system functions and operating procedures.

56.27.13 *Data Security*—Data shall be protected from unauthorized use, potential loss from equipment failure, and user errors.

56.27.13.1 *Automated Security Measures*—Automated measures shall be provided to minimize data loss from intruders in a system or from errors by legitimate users.

56.27.13.2 *Warning of Threats to Security*—Computer logic shall be provided that will generate messages or alarm signals or both to warn users of attempted intrusion by unauthorized users.

56.27.13.3 *Segregating Real from Simulated Data*—When simulated data and system functions are provided (perhaps for user training), real data shall be protected and real system use shall be clearly distinguished from all simulated operations.

56.27.13.4 *Display of Simulated Data*—In applications in which either real or simulated data can be displayed, a clear indication of simulated data shall be included as part of the classification label.

56.27.13.5 *Displayed Security Classification*—When displayed data are classified for security purposes, a prominent indication of security classification level shall be labeled in each display.

56.27.13.6 *User Identification*—User identification procedures shall be as simple as possible, consistent with adequate data protection. For protection of the password, the password shall not be echoed on the display. Audio feedback, rather than visual, shall be provided when imputing secure passwords during log on.

56.27.13.7 *Choice of Passwords*—When passwords are required, users shall be allowed to choose their own passwords since a password chosen by a user will generally be easier for that individual to remember. Guidelines for password selection shall be given so that users will not choose easily guessable ones.

56.27.13.8 *Changing Passwords*—Users shall be allowed to change passwords whenever they choose; all passwords shall be changed at periodic intervals.

56.28 *System Response Time*—Maximum system response times for real-time systems (for example, fire-control systems, command and control systems) shall not exceed the values of Table 51. Non-real-time systems may permit relaxed response times. If computer response time will exceed 15 s, the user shall be given a message indicating that the system is responding.

56.29 *Other Requirements:*

56.29.1 *Overlays*—Mechanical overlays, such as coverings over the keyboard or transparent sheet placed on the display, shall be avoided.

56.29.2 *Hard Copy*—The user shall have the capability to obtain a paper copy of the exact contents of the alphanumeric or digital graphic display in those systems where:

56.29.2.1 Mass storage is restricted.

56.29.2.2 Mass stored data can be lost by power interruption or

56.29.2.3 Record keeping is required.

56.29.3 *Display Print*—The user shall be able to print a display by simple request (for example, PRINT-SCREEN) without having to take a series of other actions first, such as calling for the display to be filed, specifying a filename, then calling for a print of that named file.

56.29.4 *Print Page*—The user shall have the capability to request printing of a single page, or sequence of pages, by specifying the page numbers.

56.29.5 *Functional Integration*—Data transmission functions shall be integrated with other information-handling functions within a system. A user shall be able to transmit data using the same computer system and procedures used for general entry, display, and other processing of data.

56.29.6 *Consistent Procedures*—Procedures for preparing, sending, and receiving data and messages shall be consistent from one transaction to another and consistent with procedures for other information-handling tasks.

56.29.7 *Minimal Memory Load on Users*—The data transmission procedures shall minimize memory load on the users by providing computer aids for automatic insertion of standard information, such as headers and distribution lists.

56.29.8 *Interrupt*—Users shall be allowed to interrupt message preparation, review, or disposition and then resume any of those tasks from the point of interruption.

56.29.9 *Stored Message Forms*—Where formats conform to a defined standard or are predictable in other ways, prestored forms shall be provided to aid users in message preparation.

56.29.10 *Incorporate Existing Files*—Users shall be allowed to incorporate an existing data file in a message or to combine several files into a single message for transmission and to combine stored data with new data when preparing messages for transmission. It shall not be necessary to reenter any data already entered for other purposes.

56.29.11 *Addresses:*

56.29.11.1 *Prompting Address Entry*—When users must specify the address for messages, prompting shall be provided to guide the user in the process.

56.29.11.2 *Address Directory*—Users shall be provided with an on-line directory showing all acceptable forms of message addressing for each destination in the system and for links to external systems.

56.29.11.3 *Aids for Director Search*—Computer aids shall be provided so that a user can search an address directory by specifying a complete or partial name. It shall also be possible to extract selected addresses from a directory for direct insertion into a header to specify the destination(s) for a message.

56.30 *Software:*

56.30.1 *General*—The design of computer program shall provide adequate information and respond within required time

TABLE 51 System Response Times

System Interpretation	Response Time Definition	Maximum Acceptable Response Time (s)
Key response	Key depression until positive response; for example "click"	0.1
Key print	Key depression until appearance of character	0.2
Page turn	End of request until first few lines are visible	1.0
Page scan	End of request until text begins to scroll	0.5
XY entry	From selection of field until visual verification	0.2
Function	From selection of command until response	2.0
Pointing	From input of point to display point	0.2
Sketching	From input of point to display of line	0.2
Local update	Change to image using local database; for example, new menu list from display buffer	0.5
Host update	Change where data is at host in readily accessible form: for example, a scale change of existing image	2.0
File update	Image update requires an access to a host file	10.0
Inquiry (simple)	From command until display of a commonly used message	2.0
Inquiry (complex)	Response message requires selection-used calculations in graphic form	10.0
Error feedback	From entry of input until error message appears	2.0

limits with sufficient detail and precision to ensure mission accomplishment while minimizing physical and mental stress on the users.

56.30.2 Information and System Response—The information displayed to the user, such as symbols, display codes, prompts, alerts, and alarms shall be limited to that which is necessary to perform specific actions or to make decisions.

56.30.3 Computer Failure—In the event of computer failure, the program shall allow for orderly shutdown and establishment of a checkpoint so restoration can be accomplished without loss of computing performed to date.

56.30.4 Task Complexity—Software shall minimize user task complexity. Control inputs shall be simplified to the extent

possible, particularly for tasks requiring real-time responses, and shall permit logical task sequences with a minimum number of control manipulations to achieve task completion.

56.30.5 Interaction—Where two or more users must have simultaneous read access to the computer program or data-processing results from multiple personnel-equipment interfaces, the operation by one person shall not interfere with the operations of another person unless mission survival may be contingent upon the preemption. Provisions shall be made so that the preempted user can resume operations at the point of interference without information loss.

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