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MILITARY **STANDARD**

HUMAN ENGINEERING DESIGN CRITERIA FOR MILITARY **SYSTEMS, EQUIPMENT AND** FACILITIES

AMSC N/A
AREA HFAC

Distribution Statement A. Approved for public release; distribution is unlimited.

FOREWORD

1. This Military Standard has been approved for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, US Army Missile Command, ATTN: AMSMI-RD-SE-TD-ST, Redstone Arsenal, Al. 35898-5270, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

3. This standard establishes general human engineering criteria for design and development of Military systems, equipment and facilities. Its purpose is to present human engineering design criteria, principles and practices to be applied in the design of systems, equipment and facilities SO as to:

a. Achieve required performance by operator, control and maintenance personnel.

b. Minimize skill and personnel requirements and training time.

c. Achieve required reliability of personnel-equipment combinations.

d. Foster design standardization within and among systems.

4. This standard does not alter requirements for system development participation of human engineering specialists to interpret and implement these practices and to provide solutions to human engineering problems which arise and which are not specifically covered herein.

5. The use of the words "shall," "should," "may," and "will" in this standard is in accordance with MIL-STD-962, wherein "shall" expresses a provision that is binding, "should" and "may" express nonmandatory provisions,, and "will" expresses a declaration of purpose or simple futurity.

6. Requirements herein are expressed in the International System of units (SI). As a convenience, the metric units are accompanied by their approximate customary system equivalents (in parentheses). Angular measure is expressed in radians or milliradians, except for 45°, 90°, 180°, 360°, etc., which are shown as multiples or divisions of π radians.

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HUMAN ENGINEERING DESIGN CRITERIA FOR MILITARY SYSTEMS, EQUIPMENT AND FACILITIES

1. SCOPE

1.1 Scope. This standard establishes general human engineering design criteria for military systems, subsystems, equipment and facilities.

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

1.3 Application. This standard shall be applied to the design of all systems, subsystems, equipment and facilities. Nothing in this standard 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 standard is applicable to design of systems, subsystems, equipment and facilities for use by both men and women. This standard is not intended to be a criterion for limiting use of materiel already in the field in areas such as lift repetition or temperature exposure time. Where the procuring activity establishes use by male personnel exclusively, the following paragraphs are changed as noted below:

Paragraph	Line	From	To
3.1	9	female	(delete)
5.2.1.4.11	3	635 mm (25 in)	700 mm (28 in)
5.4.4.2	4&5	which . ..adjustment)	(delete)
5.4.4.3	5-7	The,...adjustment)	(d e l e t e)
5.6.1	4	female, male	(delete)
5.7.2.2	3	1.780 m (70 inches)	1.880 m (74 inches)
5.7.2.3	3&4	1.650 m (65 inches)	1.750 m (69 inches)
5.7.2.4	3	1.780 m (70 inches)	1.880 m (74 inches)
5.7.2.5	2&3	1.350 m (53 inches)	1.450 m (57 inches)
5.7.2.5	3&4	530 mm (21 inches)	560 mm (22 inches)
5.7.3.4.2	2	380 mm (15 inches)	400 mm (16 inches)
5.7.3.6	3	1.170 m (46 inches)	1.220 m (48 inches)
5.7.3.7	2&3	890 mm (35 inches)	940 mm (37 inches)
5.7.3.7	3	530 mm (21 inches)	560 mm (22 Inches)
5.7.3.9	3	860 mm (34 inches)	890 mm (35 inches)
5.7.3.10	2	740 mm (29 inches)	760 mm (30 inches)
5.7.6.1.4	2&3	685 mm (27 inches)	750 mm (29.5 inches)

Table XX	Al	1.170 m (46.0 in)	1.210 m (47.5 in)
		1.335 m (52.5 in)	1.370 m (54.0 in)
		1.435 m (56.5 in)	1.470 m (58.0 in)
	A3&4	1.535 m (60.5 in)	1.570 m (62.0 in)
	B1	520 mm (20.5 in)	560 mm (22.0 in)
	B3&4	620 mm (24.5 in)	660 mm (26.0 in)
Figure 30	G	150 mm (6 in)	125 mm (5 in)
	H	190 mm (7.5 in)	165 mm (6.5 in)
Figure 36	B-Max	380 mm (15 inches)	410 mm (16 inches)
5.7.7.1.2	5	13 kg (29 lbs)	18 kg (40 lbs)
5.9.11.4.1	5-7	(Delete second and third sentences)	

1.4 Force limits. If it is known that an item is to be used by an already established military occupational specialty, for which physical qualification requirements for entry into that specialty are also established, any discrepancy between the force criteria of this standard 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. If such physical qualification requirements for entry into a specialty do not cover the task addressed by the criteria herein, the criteria herein shall govern.

1.5 Manufacturing tolerances. When manufacturing tolerances are not perceptible to the user, this standard 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.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solication (see 6.2).

SPECIFICATIONS

MILITARY

MIL-W-5044	Walkway Compound, Nonslip, and Walkway Matting, Nonslip
HIL-W-5050	Walkway Coating and Matting, Nonslip, Aircraft Application of
MIL-L-5667	Lighting Equipment, Aircraft Instrument Panel, General Specification for Installation of
MIL-P-7788	Panels, Information, Integrally Illuminated
MIL-A-8806	Acoustical Noise Level in Aircraft, General Specification for
MIL-S-008806	Sound Pressure Levels in Aircraft, General Specification for
MIL-S-9479	Seat System, Upward Ejection, Aircraft, General Specification for
MIL-M-18012	Markings for Aircrew Station Displays, Design and Configuration of
MIL-S-18471	System, Aircrew Automated Escape, Ejection Seat Type: General Specification for
MIL-A-23121	Aircraft Environmental, Escape and Survival Cockpit Capsule System, General Specification for
MIL-T-23991	Training Devices, Military, General Specification for
MIL-C-25050	Colors, Aeronautical Lights and Lighting Equipment, General Requirements for

MIL-L-25467 Lighting, Integral, Red, Aircraft Instrument, General Specification for

MIL-C-25969 Capsule, Emergency Escape System, General Specification for

STANDARDS

FEDERAL

FED-STD-515/17 Outside Rearview Mirror(s) for Automotive Vehicles

FED-STD-595 Colors

MILITARY

MIL-STD-I2 Abbreviation for Use on Drawings, Specifications, Standards, and in Technical Documents

MIL-STD.129 Marking for Shipment and Storage

MIL-STD-130 Identification Markings of U.S. Military Property

MIL-STD.195 Marking of Connections for Electric Assemblies

MI L-STD-203 Aircrew Station Controls and Displays for Fixed Wing Aircraft

MIL-STD-250 Aircrew Station Controls and Displays for Rotary Wing Aircraft

MIL-STD-280 Definitions of Item Levels, Item Interchangeability, Models and other related Terms

MIL-STD-411 Aircrew Station Signals

MIL-STD-415 Test Provisions for Electronic Systems and Associated Equipment, Design Criteria for

MIL-STD.454 Standard General Requirements for Electronic Equipment

MIL-STD.490 Specification Practices

MIL-STD-681 Identification Coding and Application of Hookup and Lead Wire

MIL-STD-740-1 Airborne Sound Measurements and Acceptance Criteria of Shipboard Equipment

MIL-STD-783	Legends for Use in Aircrew Stations and on Airborne Equipment
MIL-STD-850	Aircrew Station Vision Requirements for Military Aircraft
MIL-STD-1179	Lamp, Reflectors and Associated Signal1 ing Equipment for Military Vehicles
MIL-STD-1180	Safety Standards for Military Ground Vehicles
MIL-STD-1247	Markings, Functions and Hazard Designations of Hose, Pipe, and Tube lines for Aircraft, Missile and Space Systems
MXL-STD-1280	Keyboard Arrangements
MIL-STD-1294	Acoustical Noise Limits in Helicopters
MIL-STD-1333	Aircrew Station Geometry for Military Aircraft
MIL-STD-1348	Knobs, Control, Selection of
MIL-STD-1473	Standard General Requirements for Color and Marking of Army Materiel
MIL-STD-1474	Noise Limits for Army Materiel
MIL-STD-1787	Aircraft Display Symbology

HANDBOOKS

MILITARY

DOD-HDBK-743	Anthropometry of US Military Personnel
MIL-HDBK-759	Human Factors Engineering Design for Army Materiel

(Unless otherwise indicated, copies of federal and military specifications, standards and handbooks are available from the Naval Publications and Forms Center (ATTN: NPODS), 5801 Tabor Avenue, Philadelphia, PA 191204099.)

2.1.2 Other Government documents, drawings, and publications. The following other government documents, drawings and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

PUBLICATIONS

NAVY

OPNAVINST 5100.236 Hearing Conservation Program

AIR FORCE

AFR 161-35 Hazardous Noise Exposure (Regulation)

FEDERAL REGULATION

29 CFR 1910 Occupational Safety and Health Standards

(Copies of other government documents, 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.)

2.2 Non-Government publications. The following document(s) form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 6.2).

Human Engineering Guide to Equipment Design, 1972 Edition

(Application for copies should be addressed to the Superintendent of Documents, US Government Printing Office, Washington, DC 20402)

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH)

Threshold Limit Values

(Application for copies should be addressed to the ACGIH, 1014 Broadway, Cincinnati, OH 45202.)

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI S1.1 1960	Acoustical Terminology
ANSI 51.4	Sound Level Meters
ANSI S1.6 1967	Preferred Frequencies and Band Numbers for Acoustical Measurements
ANSI S3.2 1960	Monosyllabic Word Intelligibility, Method for Measurement of

ANSI $3.5 1969 Articulation Index, Methods for the Calculation of

(Application for copies should be addressed to the American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM E 380-84 Metric Practice, Standard for

ASTM F 1166-88 Standard Practice for Human Engineering design Criteria for Marine systems equipment and facilities

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

INTERNATIONAL STANDARDIZATION ORGANIZATION (ISO)

ISO DIS 2631 Guide to the Evaluation of Human Exposure to Whole Body Vibration

(Application for copies should be addressed to the American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.)

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

SAE 5925 Minimum Access Dimensions for Construction and Industrial Machinery

(Application for copies should be addressed to the Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096-0001.)

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

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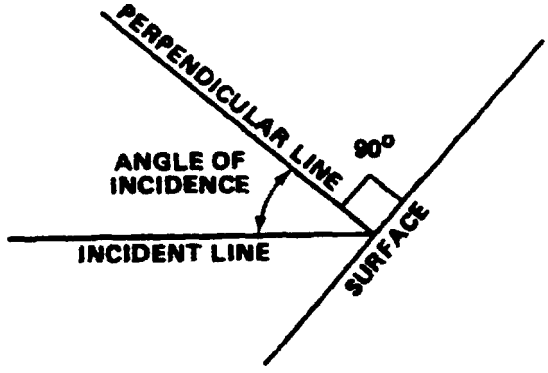
3. DEFINITIONS

3.1 Abort. A capability that cancels all user entries in a defined transaction sequence.

3.2 Accessible. Except where stated to the contrary 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 5th and 95th percentile body dimensions. Applicable body dimensions are those dimensions which are design-critical to the operation, manipulation, removal or replacement task. (For example, an adjustment control behind an aperture should be located sufficiently close to the aperture to enable a suitably clothed and equipped user with a 5th percentile female depth of reach to grasp and manipulate the adjustment control, while the opening should be sufficently large to enable passage of similarly clothed and equipped 95th percentile male hand and arm dimensions. See 5.6.1.)

3.3 Advisory signal. A signal to indicate safe or normal configuration, condition of performance, operation of essential equipment, or to attract attention and impart information for routine action purposes.

3.4 Angle of incidence. The angle-between the line of direction of anything (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.



3.5 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.

3.6 Cancel. A capability that regenerates or re-initializes the current display without processing or retaining any changes made by the user.

3.7 Caution signal. A signal which alerts the operator to an impending dangerous condition requiring attention, but not necessarily immediate action.

3.8 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.

3.9 Command language. A type of dialogue in which a user composes control entries with minimal prompting by the computer.

3.10 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.

3.11 Control entry User input for sequence control, such as function key actuation, menu selection, command entry, etc.

3.12 Data. The raw materials from which a user extracts information. Data may includenumbers, words, pictures, etc.

3.13 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 an "auditory display."

3.14 Data entry. User input of data for computer processing and computer responses to such inputs.

3.15 Data field. An area of the display screen reserved for user entry of a data item.

3.16 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.

3.17 Data protection. Functional capabilities that guard against unauthorized data access and tampering, user errors, and computer failure.

3.18 dB(A). The unit used to express sound level measured through the A-weighting network of a sound level meter.

3.19 Decibel (dB). See para 3.58.

3.20 De-emphasis The inverse of pre-emphasis, employed for the purpose of restoring original vowel-consonant amplitude relationships in pre-emphasized speech; primarily useful in maintaining the "natural" sound quality. (See pre-emphasis.)

3.21 Default value. A predetermined, frequently used value for a data field or control entry, intended to reduce required user entry actions.

3.22 Dialogue. A structured series of interchanges between a user and a computer terminal. Dialogues can be computer initiated, e.g., question and answer, or user initiated, e.g., command languages.

3.23 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.

3.24 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, etc.

3.25 Effective temperature. An arbitrary index which combines into a single value 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 which would induce an identical sensation.

3.26 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 data base, subject to data validation.

3.27 Equipment. General term designating any item or group of items.

3.28 Equipment failure. An equipment failure is 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.

3.29 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 standard apply are those in which personnel perform system operational or maintenance duties.

3.30 Fail-safe design. Fail-safe design is one in which a failure will not adversely affect the safe operation of the system, equipment, or facility.

3.31 Field. See "Data Field."

3.32 File. A collection of data, treated as a single unit, that is stored in a computer.

3.33 Function key. A key whose actuation will effect a control entry.

3.34 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.

3.35 Highlighting. Emphasizing displayed data or format features in some way, e.g., through the use of underlining, bolding, or inverse video.

3.36 Human engineering design criteria. The summation of available knowledge which defines the nature and limits of human capabilities as they relate to the checkout, operation, maintenance or control of systems or equipment, and which may be applied during engineering design to achieve optimum compatibility between equipment and human performance.

3.37, Information. Organized data that users need to successfully perform their tasks. 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.

3.38 Interrupt. Stopping an ongoing transaction in order to redirect the course of the processing. Examples of interrupt options are ABORT, BACKUP, CANCEL, and RESTART.

3.39 Luminance contrast. The contrast between the background and a figure equals the difference between the higher luminance (LI) and the lower luminance (L2) divided by the lower luminance (L_2); i.e.,

$$C = \frac{L_1 - L_2}{L2}$$

Conversions to the other contrast formulae are as follows:

L1 (brighter)	L2 (dimmer)	$\frac{L1-L2}{L2}$	$\frac{L1-L2}{L1}$	$\frac{L1-L2}{L1+L2}$	$\frac{L1}{L2}$
100	50	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

3.40 Luminance ratio (LR). The ratio of luminance between the target or 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 (nonimage or background); i.e.,

$$LR = \frac{L}{L_n}$$, where: L = Image or subject luminance
L_n = Nonimage or background luminance

3.41 Macro. The capability to allow the user to assign a single name or function-to a defined series of commands for use with subsequent command entry. Sometimes called "smart key." Examples of use are storage of addresses or signature blocks that are frequently used.

3.42. Maintainability, design for. Design considerations directed toward achieving those combined characteristics of equipment and facilities which

3.43 Master caution (warning) signal. A signal which indicates that one or more caution (warning) lights has been actuated.

3.44 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.

3.45 Metric equivalents, abbreviations and prefixes. Table I has been used herein in accordance with paragraph 4 of the Foreword.

TABLE I METRIC EQUIVALENTS, ABBREVIATIONS AN0 PREFIXES

TO CONVERT FROM:	TO:	MULTIPLY BY:
DEGREE (ANGLE) (deg)	RADIAN (rad)	1.745 329 E-02
FOOT (ft)	METER (m)	3.048 000 E-01
FOOT^2 (ft^2)	METER^2 (m^2)	-9.260 304 E42
FOOT^3 (ft^3)	METER^3 (m^3)	2.831 685 E-02
FOOTCANDLE (ft-C)	LUX (lx)	1.076 391E+01
FOOTLAMBERT (ft-L)	CANDELA PER METER^2 (cd/m^2)	2.426 259 E+00
INCH (in. OR ")	METER	2.540 000 E-02
INCH^2 (in.^{2})	METER^2 (m^2)	6.451 600 E-01
INCH^3 (in.^{3})	METER^3 (m^3)	1.638 706 E-05
MINUTE (ANGLE) (min)	RADIAN (rad)	2.606 662 E-or
OUNCE-FORCE (ozf)	NEWTON (N)	2.780 139 E-01
OUNCE-INCH (ozf · in.)	NEWTON METER (N · m)	7.061 552 E-03
POUND (lb) AVOIRDUPOIS	KILOGRAM (kg)	4.535 924 E-01
POUND-FORCE (lbf)	NEWTON (N)	4.446 222 E+00
POUND-INCH (lbf · in.)	NEWTON METER (N · m)	1.126 848 E-01
SECONO (ANGLE) (sec)	RADIAN (rad)	4.848 137 E-06

PREFIXES					
NANO	n	10^{-9}	CENTI	c	10^{-2}
MICRO	μ	104	KILO	k	10^{3}
MILLI	m	10^{-3}	MEGA	M	10^{6}

TEMPERATURE CONVERSION

$^{\circ}C = \frac{5}{9} (^{\circ}F - 32)$

$^{\circ}F = \frac{9}{5} {}^{\circ}C + 32$

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 x 10^{-1} = 0.3048000
OR; 1.076 391 E+01 = 1.076 391 x 10^{1} = 10.76391

EXAMPLES OF USE OF TABLE:
TO CONVERT 2 ft^3 TO m^3, MULTIPLY 2 BY 2.831 685 E-02
2 x 0.028 316 85 = 0.056 634 m^3
(TO CONVERT 2 m^3 TO ft^3, DIVIDE 2 BY 2.831 685 E-02)
(2/0.028 316 85 = 70.629 325 ft^3)

A MORE COMPLETE LISTING AND DISCUSSION MAY BE FOUNO IN ASTM E 380-76

3.46 Noise-cancelling (microphone). A feature which 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 adiaphragm 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 so are transmitted more favorably than if both ambient noise and speech fell simultaneously upon one face of the diaphragm.

3.47 Nuclear, biological, chemical (NBC) survivability. NBC survivability includes both the instantaneous, cumulative and residual effects of NBC weapons upon a system including its personnel. NBC 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 an NBC contaminated battlefield, it must have at least three essential characteristics: Decontaminability, hardness, and compatibility.

(1) Decontaminability is the ability of a system to be rapidly decontaminated to reduce the hazard to personnel operating, maintaining and resupplying it.

(2) Hardness is the ability of a system to withstand the materiel damaging effects of NBC contamination and any decontamination agents and procedures required to remove it.

(3) Compatibility is the ability of a system to be effectively operated, maintained, and resupplied by persons wearing the full NBC protective ensemble.

3.48 Page. The data appearing at one time on a single display screen.

3.49 Panel. The front face of an assembly, normally used for mounting controls and displays.

3.50 Panning. An orientation for display framing in which a user conceives of the display frame as moving over a fixed array of data. The opposite of scrolling.

3.51 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.

3.52 Pre-emphasis. 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).

3.53 Prompt. An indicator provided by the computer that alerts the user that the computer is ready, data should be entered, etc.

3.54 Query language. A type of dialogue in which users compose control enteries for displaying specified data from a data base.

3.55 Question and answer. A type of dialogue in which the computer displays questions, one at a time, for a user to answer.

3.56 Scrolling. An orientation for display framing in which the user conceives of data as moving behind a fixed display frame. The opposite of panning.

3.57 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. (See MIL-STD-1333 for Army and Navy aircraft definition.)

3.58 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, i.e.,

$$SPL = 20 \log_{10} \frac{P}{20\mu Pa}$$

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

3.59 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, etc.

3.60 Special tools. Tools not listed in the Federal Supply Catalog.

3.61 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 canplying with this standard, by either the Phonetically Balanced (PB) Monosyllabic Word Intelligibility Test or the Modified Rhyme Test (MRT). The former consists of a list of 1,000 words in which each word is spoken from a source and written down by a listener at a destination. The latter consists of a list of 300 words in which a word is spoken from a source and the listener at a destination responds on a prepared multiple format selecting one of six words as the item heard. Speech intelligibility may also be predicted by the Articulation Index (AI) in which calculation is performed of the peak speech-to-root-mean-square noise ratio obtafned in selected frequency bands from 200 to 7,000 Hertz (Hz), i.e., peak amplitude of speech in relation to the root-mean-square amplitude of the background noise.

3.62 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 20μPa) in the four octave bands centered on the frequencies 500, 1000, 2000, and 4000 Hz, respectively. The unit of speech-interference is the decibel.

3.63 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.

3.64 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.

3.65 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.

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

3.67 String. In the user's context, a word, phrase, or number (string of characters) in the test or file. Normally employed in the context of causing the computer to search for, find, or replace a desired "string."

3.68 Text entry. Initial entry and subsequent editing of textual material, typified by messages.

3.69 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.

3.70 Transillumination. Light passed through, rather than reflected off, an element to be viewed, e.g., illumination used on console panels or indicators utilizing edge and/or back lighting techniques on clear, translucent, flourescent, or sandwich type plastic materials.

3.71 Warning signal. A signal which alerts the operator to a dangerous condition requiring immediate action.

3.72 Wet bulb globe temperature (WBGT). A meterological measurement which can be used as an index to designate conditions of temperature and humidfty at which on-set of heat stress can be expected at a particular energy expenditure level. It is calculated as follows:

$$WBGT = 0.7T_{WB_{np}} + 0.2T_g + 0.1T_A,$$

where $T_{WB_{np}}$ = non-psychrometric (np) wet-bulb (WB) temperature

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

TA = non-psychrometric, but shaded, dry bulb (air) temperature.

4. GENERAL REQUIREMENTS

4.1 Objectives.. Military systems, equipment and facilities shall provide work environments which foster effective procedures, work patterns, and personnel safety and health, and which 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 operator capabilities. 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. Criterion for selecting off-the-shelf commercial or Government equipment shall be the degree *to* which the equipment conforms to this standard. Where off-the-shelf equipment requires modification in order to interface with other equipment, the modification shall be designed to comply with the criteria herein. Redesign of off-the-shelf equipment must have the approval of the procuring activity.

4.3 Function allocation. Design shall reflect allocation of functions *to* personnel, equipment and personnel-equipment combinations to achieve:

a. Required sensitivity, precision, time, and safety.

b. Required reliability of system performance.

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

d. Required performance in a cost-effective manner.

4.4 Human enqineerinq design. The design of military systems, equipment and facilities shall reflect human engineering, life support, and biomedical factors that affect human performance, including, when applicable:

a. Satisfactory atmospheric conditions Including composition, pressure, temperature and humidity, including safeguards against uncontrolled variability beyond acceptable limits.

b. Range of acoustic noise, vibration, acceleration, shock, blast, and impact forces and safeguards against uncontrolled variability beyond safe limits.

c. Protection from thermal, toxicological, radiologlcal, mechanical, electrical, electromagnetic, pyrotechnic, visual, and other hazards.

d. Adequate 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.

e. Adequate physical, visual, auditory, and other communication links between personnel, and between personnel and their equipneflt, under both normal and emergency conditions.

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

g. Provisions for insuring safe, efficient task performance under reduced and elevated gravitational forces with safe guards against injury, equipment damage and disorientation.

h. Adequate natural or artificial illumination for the perfonance of operation, control, trafning, and maintenance.

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

j. Provision of acceptable personnel accommodations including body support and restraint, seating, rest, and sustenance, i.e., oxygen, food, water, and waste management.

k. Provfsion of non-restrictive personal life support and protective equipment.

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

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

n. Satisfactory remote handling provisions and tools.

0. Adequate emergency systems for contingency management, escape, survival and 'rescue.

p. 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 mafntafning military systems or equipment. Task allocation and control movements shall be compatible with restrictions imposed on human performance by C/PE.

4.5 Fail *safe* design. A fail safe design shall be provided in those areas where failure can 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. It shalt be capable of being operated, maintained, and repaired 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 alert, battle stress, or other emergency or non-routine conditions.

4.9 Ruggedness. Systems and equipment shall be sufficiently rugged to withstand handling in the field 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 survivability. As applicable, equipment design shall be compatible with NBC 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 environments required by the system. Equipment design shall also facilitate NBC hardness surveillance and shall minimize susceptibility to reduction of inherent NBC hardness as a result of maintenance/operator-induced errors/damage: i.e.,

a) NBC hardness shall be easily verifiable by maintenance personnel before and after maintenance actions (hardness surveillance),

b) NBC hardness shall not be degraded when routine (scheduled) and corrective (unscheduled) maintenance are-performed,

c) Maintenance of the equipment's inherent NBC 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. DETAILED REQUIREMENTS

5.1 Control/display integration.

5.1.1 General criteria.

5.1.1.1 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 should 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.

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

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

5.1.1.4 Feedback. Feedback on control response adequacy shall be provided as rapidly as possible. Critical control functions, such as those entered by keyboard, shall provide adequate feedback to the operator prior to entry to ensure that the keyed entry is, in fact, errorless and the one that the operator desires to enter.

5.1.1.5 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.

5.1.1.6 Simultaneous access. If more than one crew member must have simultaneous access to a particular group of controls or displays in order to insure 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 adequately perform assigned tasks.

5.1.2 Position relationships.

5.1.2.1 Functional grouping. Functionally related controls and displays shall be located in proximity to one another--arranged in functional groups, e.g., power, status, test.

5.1.2.1.1 Functional group arrangement.

5.1.2.1.1.1 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.

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

5.1.2.1.1.3 Functional group marking. Functional groups may be set apart by outlining with contrasting lines which completely encompass the groups. Where such coding is specified by the procuring activity, and where gray panels are used, noncritical functional groups (i.e., those not associated with emergency operations) shall be outlined with a 1.5 mm (1/16 in) black border (27038 of FED-STD-595), and those involving emergency or extremely critical operations shall be outlined with a 5 mm (3/16 in) red border (21136 of FED-STD-595). 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 orangeyellow (23538 of FED-STD-595) and black (27038 of FED-STD-595) striped border shall be used to outline functional groups involving emergency or extremely critical operations. Control-display areas in aircraft crew stations shall be delineated in accordance with MIL-M-18012.

5.1.2.1.1.4 Consistency. Location of recurring functional groups and individual items shall be similar from panel to panel. Mirror image arrangements shall not be used.

5.1.2.2 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.

5.1.2.3 Arrangement within groups. Controls and displays within functional groups shall be located according to operational sequence or function, or both.

5.1.2.3.1 Left-to-right arrangement. If controls must be arranged in fewer rows than displays, controls affecting the top row of displays shall be positioned at the far left; controls affecting the second row of displays shall be placed immediately to the right of these, etc.

5.1.2.3.2 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, etc. However, this type of arrangement shall be avoided whenever possible.

5.1.2.3.3 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.

5.1.2.3.4 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 so as to obscure displays when manipulating the control,

5.1.2.3.5 Combined control. When separate displays are affected by a combined control (e.g., concentrically ganged knobs), the display shall be arranged from left to right with the combined control underneath the center of the displays, but not so as to obscure displays when manipulating controls.

5.1.2.3.6 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.

5.1.2.3.7 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 aircraft engine controls shall be oriented as if the operator faces the normal direction of vehicle movement.)

5.1.2.3.8 Emergency use. Emergency displays and controls shall be located where they can be seen and reached with minimum delay (e.g., warning lights within a 30-degree 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).

5.1.3 Movement relationships.

5.1.3.1 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.

5.1.3.2 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.

5.1.3.3 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 setting.

5.1.3.4 **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.

5.1.3.5 **Fixed pointer circular scale.** Displays with moving scales and fixed pointers or cursors should 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.

5.1.3.6 **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.

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

5.1.3.8 **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 vehicle.

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

5.1.3.10 **Labeling.** When control-display relationships specified herein cannot be adhered to, controls shall be clearly labeled (see para 5.5) to indicate the direction of control movement required.

5.1.3.11 **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.-

5.1.4 **Control display movement ratio.**

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

5.1.4.2 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.

5.1.4.3 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 -- approximately 150 mm (6 in) display element movement shall be provided for one complete turn of the knob.

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

5.1.4.5 Bracketing. When bracketing is used to locate a maximum or minimum rather than a specific value (e.g., 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 in order to make the peak or dip associated with that value clearly noticeable.

5.1.4.6 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.

5.1.4.7 Lever, two-dimensional setting. When a lever is provided to make settings in two dimensions to coarse tolerances--2.5 mm (0.1 in)--one unit of display element movement shall be used to two and one-half units of lever movement.

5.1.4.8 Counters. When counters are provided, the control-display ratio shall be such that one revolution of the knob produces approximately 50 counts (i.e., the right hand drum rotates five times).

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5.2 Visual displays.

5.2.1 General. Visual displays should be utilized 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.

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

5.2.1.2 Display illumination and light distribution.

5.2.1.2.1 Display illumination.

5.2.1.2.1.1 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 luminance co.07 - 0.35 cd/m^2 (0.02 - 0.10 fL)] red light (greater than 620 nm) shall be provided.

5.2.1.2.1.2 Night vision device compatibility. Where night vision device compatibility is required, display illumination color other than red may be used. The lighting shall be continuously variable to the full OFF position. In the OFF position, no current shall flow through the lamps.

5.2.1.2.1.3 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 required by Tables XXI and XXII, as applicable. No current shall be provided to luminaires at extreme counter-clockwise rotation of a dimming control. Panel light levels shall be continuously variable from 0.1 cd/m^2 (0.03 fL) near OFF to 3.5 cd/m^2 (1 fL) at 50% of clockwise rotation.

5.2.1.2.2 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.

5.2.1.2.3 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.

5.2.1.3 **Information.**

5.2.1.3.1 Content. **The information displayed to an operator shall be sufficient to 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.**

5.2.1.3.2 Precision. Information shall be displayed only within the limits and precision required for specific operator actions or decisions.

5.2.1.3.3 Format. Information shall be presented to the operator in a directly useable form. Requirements for transposing, computing, interpolating, or mentally translating into other units shall be avoided. Additional requirements for computer display formats are contained in 5.15.

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

5.2.1.3.5 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 compatible for, both users.

5.2.1.3.6 Display failure clarity. Failure of a display or its circuit shall be immediately apparent to the operator.

5.2.1.3.7 Display circuit failure. Failure of the display circuit shall not cause a failure in the equipment associated with the display.

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

5.2.1.3.9 **Duration. Signals and display information shall have durations of sufficient length to be reliably detected under expected operator workload and operational environment.**

5.2.1.3.10 Timeliness. Displays such as cathode ray tube displays, head-up displays, collimated displays and other displays requiring refreshed information shall be updated in a synchronous manner, where possible, and be refreshed to the degree of timeliness required by personnel in the normal operating or servicing mode.

5.2.1.3.11 Advisory and alerting. Displays such as multifunction displays, cathode ray tube displays, head-up displays, collimated 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.

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

5.2.1.3.13 **Numeric digital displays.** Numeric digital displays shall not be used as the only display of information when perception of the pattern of variation is important to proper perception. Numeric digital displays shall not be used when rapid or slow digital display rates inhibit proper perception.

5.2.1.4 **Location and arrangement.**

5.2.1.4.1 **Location.** Displays 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.

5.2.1.4.2 **Access.** Visual displays should be visually accessible without resorting to use of ladders, flashlights or other special equipment in order to read the display.

5.2.1.4.3 **Orientation.** Display faces shall be perpendicular to the operator's normal line of sight whenever feasible and shall not be less than r/4 rad (45°) from the normal line of sight (see Figure 1). Parallax shall be minimized.

5.2.1.4.4 **Reflection.** Displays shall be constructed, arranged, and mounted to prevent reduction of information transfer due to the reflection of the ambient illumination from the display cover. Reflection of instruments and consoles in windshields and other enclosures shall be avoided. If necessary, techniques (such as shields and filters) shall be employed to insure that system performance will not be degraded.

5.2.1.4.5 **Vibration.** Vibration of visual displays shall not degrade user performance below the level required for mission accomplishment (see 5.8.4.2).

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

5.2.1.4.7 **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.

5.2.1.4.8 **Frequency of use.** Displays used most frequently should be grouped together and placed in the optimum visual zone (see Figure 2).

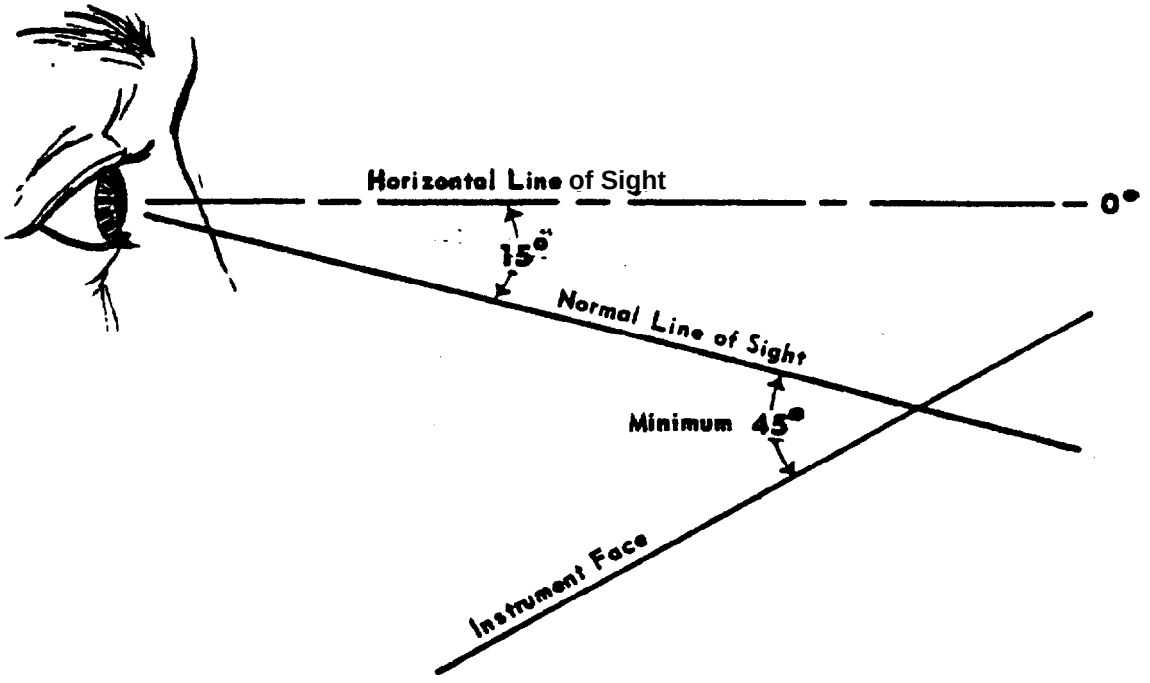


FIGURE 1. LINES OF SIGHT

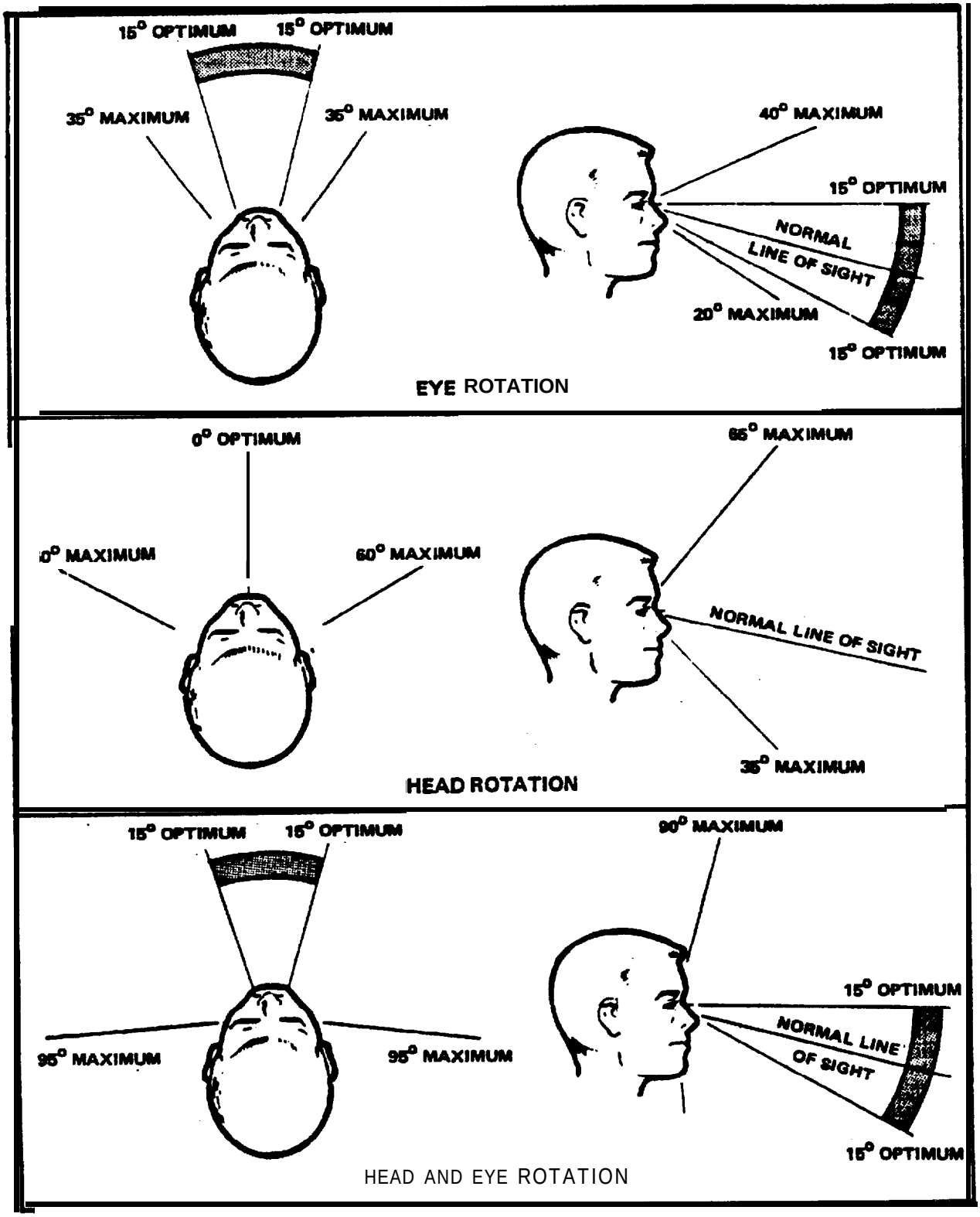


FIGURE 2. VERTICAL AND HORIZONTAL VISUAL FIELD

5.2.1.4.9 Importance. **Important or critical displays shall be located in a privileged position in the optimum projected visual zone or otherwise highlighted.**

5.2.1.4.10 Consistency. **The arrangement of displays within a system shall be consistent in principle from application to application, within the limits specified herein.**

5.2.1.4.11 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 mm (25 in). Otherwise, there is no maximum limit other than that imposed by legibility limitations, which shall be compensated for by proper design. NOTE: A viewing distance of up to 760 mm (30 inches) may be used with ejection seats.

5.2.1.4.12 Minimum viewing distance. The effective viewing distance to displays, with the exception of cathode ray tube displays (see 5.2.4.2) and collimated displays, shall never be less than 330 mm (13 in) and preferably not less than 510 mm (20 in).

5.2.1.4.13 Aircrew station signals. Signals for aircrew stations shall be in accordance with MIL-STD-411. Human Engineering design for other members of the crew who occupy positions in the air vehicle other than on the flight deck (such as in multi-engined specialized aircraft) shall be in accordance with the criteria in this standard. (See 5.14.2.1)

5.2.1.5 Coding.

5.2.1.5.1 Objectives. Coding techniques shall be used to facilitate:

a. Discrimination between individual displays

b. Identification of functionally related displays

c. Indication of relationship between displays

d. Identification of critical information within a display

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

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

5.2.1.5.4 Symbology. Symbology for Aircrew displays shall be in accordance with MIL-STD-1787.

5.2.2 Transilluminated displays.

5.2.2.1 General. Three general types of transilluminated displays that may be used include:

a. Single- and multiple-legend lights, which present information in the form of meaningful words, numbers, symbols, and abbreviations.

b. Simple indicator lights.

c. Transilluminated panel assemblies. which present qualitative status or system readiness information.

5.2.2.1.1 Use. Transilluminated indicators should 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 functions.

5.2.2.1.2 Equipment response. Lights, including those used in illuminated push buttons, shall display equipment response and not merely control position.

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

5.2.2.1.4 Positive feedback. Changes in display status shall signify changes in functional status rather than results of control actuation alone. The absence or extinguishment of a signal or visual indication shall *not* be 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.

5.2.2.1.5 Grouping. Master caution, master warning, master advisory and summation lights used to indicate the condition of an entire subsystem shall be set apart from the lights which show the status of the subsystem components, except as required under paragraph 5.2.2.1.8.

5.2.2.1.6 Location. When a transilluminated indicator is associated with a 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.

5.2.2.1.7 Location, critical functions. For critical functions, indicators shall be located within 265 mrad (15°) of the operator's normal line of sight (see Figure 2). 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.

5.2.2.1.8 Maintenance displays. Indicator lights used solely for maintenance and adjustment shall be covered or non-visible during normal equipment operation, but shall be readily accessible when required.

5.2.2.1.9 Luminance. The luminance of transilluminated displays shall be compatible with the expected ambient illuminance level, and shall beatleast 10% greater than the surrounding luminance. Where glare must be reduced, the luminance of transilluminated displays should not exceed 300% of the surrounding luminance.

5.2.2.1.10 Luminance control. When displays will be used under varied ambient illuminance, adimming 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 non-crftical operations, but shall not be used if inadvertent failure to turn on an indicator could lead to critical operator failures, i.e., failure to detect or perform a critical step in an operation.

5.2.2.1.11 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.

5.2.2.1.12 Contrast within the indicator. The luminance contrast (See 3.17) within the indicator shall be at least 0.1. This 0.1 luminance contrast requirement does not apply to special displays specifically designed for legibility in sunlight. For low ambient illumination applications (e.g., MIL-L-25467), this ratio should be at least 9.0 (See 3.17), with the background luminance less than the figure luminance.

5.2.2.1.13 Lamp redundancy. Incandescent display lamps shall 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.

5.2.2.1.14 Lamp testing. When indicator lights using incandescent bulbs are installed on a control panel, a master light test control shall be incorporated. When applicable, design shall allow testing of all control panels at one time. Panels containing three or fewer lights may be designed for individual press-to-test bulb testing. Circuitry should 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.

5.2.2.1.15 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.

5.2.2.1.16 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.

5.2.2.1.17 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 insure they are properly installed.

5.2.2.1.18 Color coding. With the exception of aircrew station signals which shall conform to MIL-STD-411, and training equipment which shall conform to MIL-T-23991, transilluminated displays shall conform to the following color coding scheme, in accordance with Type I - Aviation colors of MIL-C-25050.

a. 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 which should be coded RED are those which display such information as "no-go", "error", "failure", "malfunction", etc.

b. FLASHING RED shall be used only to denote emergency conditions which require operator action to be taken without undue delay, or to avert impending personnel injury, equipment damage, or both.

c. YELLOW shall be used to advise an operator that a condition exists which is marginal. YELLOW shall also be used to alert the operator to situations where caution, recheck, or unexpected delay is necessary.

d. GREEN shall be used to indicate that the monitored equipment is in tolerance or a condition is satisfactory and that it is all right to proceed (e.g., "go-ahead", "in-tolerance", "ready", "function activated").

e. WHITE shall be used to indicate system conditions that do not have "right" or "wrong" implications, such as alternative functions "e.g., Missile No. 1 selected for launch, etc.) or transitory conditions (e.g., action or test in progress, function available), provided such indication does not imply success or failure of operations.

f. BLUE may be used for an advisory light, but preferential use of BLUE should be avolded.

5.2.2.1.19 Flashing lights. The use of flashing lights shall be minimized. Flashing lights should be used only when it is necessary to call the operator's attention to some condition requiring immediate action. The flash rate shall be within 3 to 5 flashes per second with approximately equal amounts of ON and OFF time. Flashing lights which could be simultaneously

active should have synchronized flashes. If the indicator is energized and the flasher device fails, the light shall illuminate and burn steadily (see 5.3.2.4).

5.2.2.2 Legend lights.

5.2.2.2.1 Use. Legend lights shall be used in preference to simple indicator lights except where design considerations demand that simple indicators be used.

5.2.2.2.2 Color coding. Legend lights shall be color coded in conformance with 5.2.2.1.18. Legend lights required to denote personnel or equipment disaster (FLASHING RED), caution or impending danger (YELLOW), and master summation go {GREEN) or no-go (RED), shall be discriminably larger, and preferably brighter, than all other legend lights.

5.2.2.2.3 Positive vs negative legend. When the operator's dark adaptation must be maintained, or where legibility in high ambient illumination is critical, illuminated label/opaque background-format shall be used and illuminated background/opaque label format shall be used only for critical alerting indicators (e.g., master warnfng lights). Where operator dark adaptation is not required, illuminated background/opaque label format should be used; contrast reversal may be employed under these conditions to designate displays which have physical appearance similar to legend switches on the same panel.

5.2.2.2.4 Lettering The size and other characteristics of lettering shall conform to 5.5 herein, or as otherwise specified by the procuring activity.

5.2.2.2.5 Visibility and legibility. In other than aircrew stations, and with the exception of warning and caution indicators, the lettering on single-legend indicators shall be visible and legible whether or not the indicator is energized,

5.2.2.2.6 Multi-function legends. Indicators designed to provide alternately-presented legends shall present only one legend at a time, i.e., only the legend in use shall be visible. If the indicator device utilizes "stacked" legends, it shall be designed so that:

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

b. Parallax is mfnimized.

c. 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.

5.2.2.3 Simple indicator lights.

5.2.2.3.1 Use. Simple indicator lights should be used when design considerations preclude the use of legend lights.

5.2.2.3.2 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.

5.2.2.3.3 Coding. Simple indicator lights shall be coded in conformance with Table 11; however, the different sizes shown are intended only for the attention-getting value that larger lights of at least equal luminance provide in relation to indicator lights of lesser importance.

5.2.2.4 Transilluminated panel assemblies.

5.2.2.4.1 Use. Transilluminated (Integrally lighted) panel assemblies may be used to:

a. Provide illuminated labels for a control panel.

b. Provide a light source for illuminating transilluminated control knobs.

c. Provide illuminated association markings on a control panel, e.g., connecting lines between controls, outlines around a functionally-related group of controls or displays or both.

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

5.2.2.4.2 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 vfsibiltty, legibility, color and illumination as specified herein.

5.2.2.4.3 Re-lamping. When replaceable incandescent lamps are used as the illuminant source for integral lighting of panel assemblies, lamps shall be readily accessible without disconnecting the panel(s). A sufficient number of lamps shall be provided so that failure of one Tamp will not cause any part of the display to be unreadable.

5.2.2.4.4 Brightness. Brightness of illuminated markings and transill uminated controls shall be compatible with the ambient environment and operating conditions (e.g., dark adaptation requirements). Brightness control (dinning) by the operator shall be provided where applicable to maintain appropriate visibility and operator dark adaptation level.

5.2.3 Scale indicators.

5.2.3.1 General.

TABLE II. CODING OF SIMPLE INDICATOR LIGHTS

SIZE/TYPE	COLOR			
	RED	YELLOW	GREEN	WHITE
13 mm (1/2 in.) DIAMETER or SMALLER/STEADY	Malfunction; action stopped; failure; stop action.	Delay; check; recheck.	Go ahead; in tolerance; acceptable; ready.	Functional or physical position; action in progress.
26 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/sec)	Emergency condition (impending personnel or equipment disaster).			

5.2.3.1.1 **Types of scale indicators.** The types of scale indicators that may be used include:

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

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

5.2.3.1.2 Use. The use of scale indicators should conform to the criteria in Table III 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.

5.2.3.1.3 Type of information. Scale indicators should be used to display quantftative 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.

5.2.3.1.4 Linear scales. Except where system requirements clearly dictate nonlinearity to satisfy operator information requirements, linear scales shall be used in preference to nonlinear scales.

5.2.3.1.5 Scale markings.

5.2.3.1.5.1 Graduations. Scale graduations shall progress by 1, 2, or 5 units or decimal multiples thereof.

5.2.3.1.5.2 Intermediate marks. The number of minor or intermediate marks between numbered scale pointers shall not exceed nine.

5.2.3.1.6 Numerals.

5.2.3.1.6.1 Major marks. Except for measurements that are normally expressed in decimals, whole numbers shall be used for major graduation marks.

5.2.3.1.6.2 Starting point. Display scale shall start at zero, except where this would be inappropriate for the function involved.

5.2.3.1.7 Pointers.

5.2.3.1.7.1 Length. The control or display pointer should extend to, but not overlap, the shortest scale graduation marks.

5.2.3.1.7.2 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.

TABLE III. APPLICATION OF VARIOUS TYPES OF MECHANICAL DISPLAYS

USE	SCALES		COUNTERS	PRINTERS	FLAGS
	Moving Pointer	Fixed Pointu			
QUANTITATIVE INFORMATION	FAIR May be difficult to read while pointer is in motion.	FAIR May be difficult to read while scale is in motbn.	GOOD Minimum time and error for exact numerical value; however, cannot be read when changing rapidly	GOOD Minimum time and error for exact numerical value. Provides reference records.	N/A
QUALITATIVE INFORMATION	GODD 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.	POOR Numbers must be read. Position changes not ● mtiy detected.	GOOD Easily detected. Economical of space.
SETTING	GOOD Simple and direct relation of motion of pointer to motion of setting knob. Position change rids monitoring.	FAIR Relation to motion of setting knob may be ● nb@mua. No pointer position change to aid monitoring. Not readable during rapid setting.	DODD Most accurate monitoring of numerical setting. Relation to motbn of setting knob ion direct than fur moving pointer. Not read- ● blr during rapid setting.	NIA	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	NIA	N/A
GENERAL	Requires largest ● xpoud ● nl il- luminated area on panel. Scale length limited unless multiple pointers used.	Saves panel space. Only small section of scale need be exposed and il- luminated. Use of tape allows long scale.	Most economical of space and il- lumination. Scale length limited only by number of counter drums.	Limited application.	Limited application

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

5.2.3.1.7.4 Color. Pointer color from the tip to the center of the dial shall be the same as the color of the marks. The tail of the pointer shall be the same color as the dial face, unless the tail is used as an-indicator ftself or unless the pointer is used for horizontal alignment.

5.2.3.1.8 Luminance contrast. Luminance contrast (see -3.17) of at least 3.0 shall be provided between the scale face and the Markings and pointer.

5.2.3.1.9 Calibration information. Provision shall be made for placing calibration information on instruments without degrading dial legibility.

5.2.3.1.10 Coding.

5.2.3.1.10.1 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.

5.2.3.1.10.2 Pattern- or color-coding. When certain operating conditions always fall within a given range on the scale, these areas shall be made readily identifiable by means of pattern- or color-coding applied to the face of the instrument.

5.2.3.1.10.3 Choice of colors. Red, yellow, and green may be applied, provided they conform to the meanings specified in 5.2.2.1.18 and are distinguishable under all expected lighting conditions.

5.2.3.1.10.4 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.

5.2.3.2 Moving-pointer, fixed-scale indicators.

5.2.3.2.1 Numerical progression. The increase of numerical progression on fixed scales shall read clockwise, from left to right, or from the bottom up, depending on display design and orientation.

5.2.3.2.2 Orientation. Numbers on stationary scales shall be oriented in the upright position.

5.2.3.2.3 Circular scales.

5.2.3.2.3.1 Scale reading and pofnter movement. The magnitude of the scale reading shall increase with clockwise movement of the pointer.

5.2.3.2.3.2 Zero position and direction of movement. When positive and negative values are displayed around a zero or a null position, the zero or null point shall be located at either the 12 or 9 o'clock position. The

magnitude of positive values shall increase with clockwise movement of the pointer, and the magnitude of negative values shall increase with counterclockwise movement.

5.2.3.2.3.3 Scale break. There shall be an obvious break of at least 175 mrad (10°) of arc between the two ends of the scale, except on multirevolution instruments such as clocks.

5.2.3.2.3.4 Number of pointers. Whenever precise readings are required not more than two coaxial pointers shall be mounted on one indicator face.

5.2.3.2.3.5 Pointer alignment. When a stable value exists for given operating conditions in a group of circular-scale indicators, the indicators 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. If a matrix of indicators is needed, preference shall be given to the 9 o'clock position.

5.2.3.2.3.6 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 the scale marks or numerals, and scale marks shall be on or close to the plane of the pointer tip to avoid visual parallax (see Figure 3). If readout accuracy is not critical (i.e., gross relationship between the pointer and number is all that is required), an arrangement of numerals inside the scale annulus may be used. (See examples in Figure 3).

5.2.3.2.4 Curved (arc), horizontal straight, and vertical straight scales.

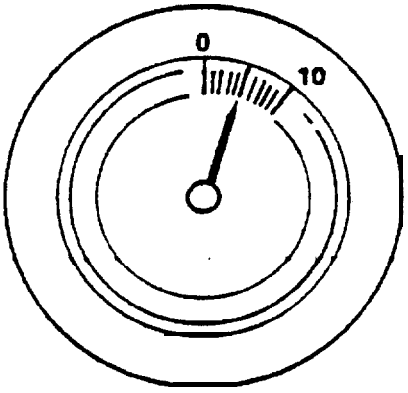
5.2.3.2.4.1 Scale reading and pointer movement. The magnitude of the scale reading shall increase with movement of the pointer up or to the right.

5.2.3.2.4.2 Zero position and direction of movements. 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 the left.

5.2.3.2.4.3 Placement of pointers. Pointers shall be located to the right of vertical scales and at the bottom of horizontal scales.

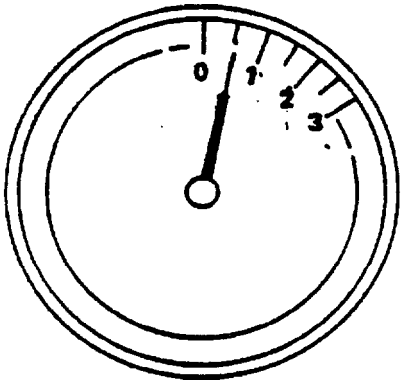
5.2.3.2.4.4 Placement of numerals. Numerals shall be placed on the side of the oraduation marks away from the pointer to avoid having numbers covered by the pointer. If space i's limited (for curved or arc scales) numerals may be placed inside of graduation marks to avoid undue constriction of the scale.

5.2.3.2.4.5 Pointer alignment. When a common stable value exists for given operating conditions in a group of indicators, they shall be arranged either

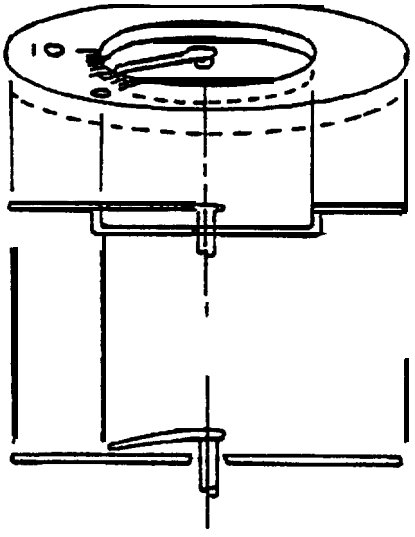


FOR MAXIMUM READING ACCURACY

(THE POINTER IS AN EQUAL DISTANCE – NOMINAL 0.8–1.6 mm (0.031–0.061 in.) – FROM ALL SCALE MARKS, NEVER OVERLAPPING ANY MARK OR NUMERAL)



ALTERNATE FORMAT FOR GROSS READING OF NUMBERS



TO PREVENT OR MINIMIZE VISUAL PARALLAX

FIGURE 3. RELATIVE POSITION OF SCALE MARKS, NUMERALS, AND POINTERS ON CIRCULAR DIALS

in rows so that all pointers line up horizontally (for vertical scales) or in columns so that all pointers line up vertically (for horizontal scales).

5.2.3.3 Fixed-pointer, moving-scale indicators.

5.2.3.3.1 Numerical progression. On fixed-pointer, moving scale indicators, numbers shall progress in magnitude in clockwise direct ion around the faces of circular dials (counter-clockwise dial movement for numerical increase). On vertical or horizontal straight moving scales, numbers shall increase from bottom to top or from left to right.

5.2.3.3.2 Orientation. Numerals on moving scales shall be upright when in the reading position.

5.2.3.3.3 Alignment of pointer or fixed reference line. For circular scales, alignment of pointer or fixed reference line shall be in the 12 o'clock position for right-left directional information and in the 9 o'clock position for up-down information. For purely quantitative information, either position may be used.

5.2.3.3.4 Setting. If the display will be used for setting in a value (e.g., tuning in a desired wavelength), the unused portion of the dial face shall be covered, and the open window shall be large enough to permit at least one numbered graduation to appear at each side of any setting.

5.2.3.3.5 Tracking. If the display will be used for tracking, as in the case of a directional indicator, the whole face of the dial shall be exposed.

5.2.3.3.6 Moving tape displays. When the scale length required for acceptable readout accuracy exceeds the limits of the display package capacity (i.e., compaction of scale marking would make the display illegible or subject to readout error), moving tape scale format may be used.

5.2.3.3.7 Composite scalar/pictorial displays. Combinations of scales, pointers and pictori alired symbols may be used to combine functionally-related information into a single instrument-or display (e.g., artificial horizon, command heading, true/relative bearing). Design of significant reference features (e.g., aircraft or ship symbols, horizon, altitude or pitch scales) shall conform to the general criteria herein for direction-of-motion, scale-pointer relationships, and legibility.

5.2.4 Cathode ray tube (CRT) displays.

5.2.4.1 Signal size. When a target of complex shape is to be distinguished from a nontarget shape that is also complex, the target signal should subtend not less than 6 mrad (20 minutes) of visual angle and should subtend not less than 10 lines or resolution elements. Image quality shall be consistent with the operator's needs.

5.2.4.2 Viewing distance. A 400 mm (16 in) viewing distance shall be orovided 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 should permit the observer to view the scope from as close as desired. Displays which must be placed at viewing distances greater than 400 mm (16 in) due to other considerations shall be appropriately modified in aspects such as display size, symbol size, brightness ranges, line-pair spacing and resolution.

5.2.4.3 Screen luminance. The ambient illuminance shall not contrfbute 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. Contrast adjustment shall not be included in flight deck displays because they are disallowed by FAA regulation.

5.2.4.4 Faint signals. When the detection of faint signals is required and when the ambient illuminance may be above 2.7 lux (0.25 ft-c), scopes shall be hooded, shielded, or recessed. (In some Instances, a suitable filter system may be employed, subject to approval by the procuring activity.)

5.2.4.5 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.

5.2.4.6 Ambient illuminance. The ambient illuminance in the CRT area shall be appropriate for other visual functions (e.g., 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 surround. 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.

5.2.4.7 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 on the CRT or filter control over the light source.

5.2.4.8 Adjacent surfaces. Surfaces adjacent to the scope shall have a dull matte finish.

5.2.4.9 Pictorial/graphic situation formats. Pictorial or situation data such as plan position indicator data, shall be presented as luminous symbols/ dark background.

5.2.4.10 Font legibility. Where alpha-numeric characters appear on CRT-like displays, the font style shall allow discrimination of similar characters, such as letter 1 and number 1; 1 etter Z and number 2.

5.2.5 Large-screen displays.

5.2.5.1 Use. Large-screen displays may be used when:

a. 4 group of operators frequently refer to the same information and are required to interact as a team, based on the same information.

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

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

d. It may be desirable to have general information available to persons who should not interrupt on-going group operations by looking over the shoulder(s) of individual operator(s) to see their individual displays.

5.2.5.2 Avoidance. Large-screen displays shall be used only when the spatial and environmental conditions allow satisfactory observational geometry to insure 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 5.2.6.6.

5.2.5.3 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 5.5). The display shall not be closer to any observer than 1/2 the display width or height, whichever is greater.

5.2.5.4 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.

5.2.5.5 Control of displayed information. Control of large-screen group display systems shall ensure that critical information cannot be modified or deleted inadvertently or arbitrarily; and therefore:

a. Control of changes in the group display shall be under the control of designated operators who operate according to pre-established procedures, upon command of a person in charge, or both.

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

5.2.5.6 Content of displayed information. The content of displayed information shall be evident to a trained observer without requiring reference to display control settings.

5.2.6 Other displays.

5.2.6.1 General.

5.2.6.1.1 Types. Where applicable, direct-reading counters, printers, plotters, flags, optical projection, LED, gas discharge, liquid crystal and electroluminescent displays may be used.

5.2.6.1.2 Applications. The selection of the above types of displays for various applications should be based on the following specific criteria as well as the criteria in Table III.

5.2.6.2 Counters.

5.2.6.2.1 Use. Counters should be used for presenting quantitative data when a continuous trend indication is not required and when a quick, precise indication is required.

5.2.6.2.2 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.

5.2.6.2.3 Spacing between *numerals*. The horizontal separation between numerals shall be between one-quarter and one-half the numeral width. Commas shall not be used.

5.2.6.2.4 Movement.

a. Snap action. Numbers shall change by snap action in preference to continuous movement.

b. Rate. Numbers shall follow each other not faster than 2 per second when the observer is expected to read the numbers consecutively.

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

d. 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 pushbuttons are used to manually reset mechanical counters, actuating force required shall not exceed 16.7 N (60 oz).

5.2.6.2.5 Illumination. Counters shall be self-illuminated when used in areas in which ambient illumination will provide display luminance below 3.5 cd/m^2 (1 ft-L).

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

5.2.6.2.7 Contrast. Color of the numerals and background shall provide high contrast-on white or converse, as appropriate).

5.2.6.3 Printers.

5.2.6.3.1 Use. Printers should be used. when a visual record of data is necessary or desirable. Use of printers should conform to Table III.

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

5.2.6.3.3 Contrast. A minimum of 3.0 luminance contrast shall be provided between the printed material and the background on which it is printed.

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

5.2.6.3.5 Take-up provision. A take-up device for printed material shall be provided.

5.2.6.3.6 Annotation. Where applicable, printers should be mounted so that the printed matter (e.g., paper, metalized paper) may be easily annotated while still in the printer.

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

5.2.6.3.8 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.

5.2.6.3.9 Control, replenishment and service. Printers shalt conform to the criteria of 5.2.6.4.8.

5.2.6.4 Plotters and recorders.

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

5.2.6.4.2 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.

5.2.6.4.3 Contrast. A minimum of 1.0 luminance contrast (see 3.17) shall be provided between the plotted function and the background on which it is drawn.

5.2.6.4.4 Take-up device. A take-up device for extruded plotting materials shall be provided when necessary or desirable.

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

5.2.6.4.6 Smudging/smearing. The plot should be resistant to smudging or smearing under operational use.

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

5.2.6.4.8 Control, replenishment and service. Plotters and recorders shall conform to criteria herein with regard to:

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

b. Possitive indication of the remaining supply of plotting materials (e.g., paper, ink, ribbon).

c. 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.

d. Minor servicing on site by a technician, e.g., adjustment of drive system, cleaning, or replacement of operating items that ordinarily would not be available to an operator.

5.2.6.5 Flags.

5.2.6.5.1 Use. Flags should be used to display qualitative, non-emergency conditions. Use of flags should conform to Table III.

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

5.2.6.5.3 Snap action. Flags shall operate by snap action.

5.2.6.5.4 Contrast. A minimum of 3.0 luminance contrast (see 3.17) shall be provided between flags and their backgrounds under all expected lighting conditions.

5.2.6.5.5 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.

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

5.2.6.5.7 Test provision. A convenient means shall be provided for testing the operation of flags.

5.2.6.6 Large screen optical projection displays.

5.2.6.6.1 Use. Provfding ambient light can be properly controlled, optical projection displays are suitable for applications requiring group presentation, pictorial and spatial information, past history vs 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.

5.2.6.6.2 Seating area. Viewing distance/image width relationship and off-center viewing of optical projection displays for group viewing should conform to the preferred limits of Table IV and shall not exceed the acceptable limits indicated. For individual viewing from a fixed location, off-centerline viewing shall not exceed 175 mrad (10°).

TABLE IV. GROUP **VIEWING** OF **OPTICAL** PROJECTION DISPLAYS

FACTOR	OPTIMUM	PREFERRED LIMITS	ACCEPTABLE LIMITS
Ratio of $\frac{\text{viewing distance}}{\text{screen diagonal}}$	4	3–6	2–8
Angle off centerline	0 mrad (0°)	350 mrad (20°)	525 mrad (30°)
*Image luminance (no film in operating projector)	35 cd/m^2 (10 ft–L)	27–48 cd/m^2 (8–14 ft–L)	17–70 cd/m^2 (5–20 ft–L)
Luminance variation across screen (ratio of maximum to minimum luminance)	1	1.5	3.0
Luminance variation as a function of viewing location (ratio of maximum to minimum luminance)	1	2.0	4.0
Ratio of $\frac{\text{ambient light}}{\text{brightest part of image}}$	0	0.002–0.01	0.1 max**

*For still pojeaions higher values may be used
**For presentations not involving gray scale or color (e.g.. line drawings, tables) 0.2 may be used.

5.2.6.6.3 **Image luminance and light distribution.** Image luminance and light distribution should conform to the preferred limits and shall not exceed the acceptable limits of Table IV. In any case, the luminance of the screen center at maximum viewing angle shall be at least half its maximum luminance.

5.2.6.6.4 **Legibility of projected data.**

5.2.6.6.4.1 Style. A simple style of numerals and letters shall be used. Capftal letters shall be used, rather than lower case, 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 5.5.5.5, 5.5.5.6, 5.5.5.10, and 5.5.5.11, respectively.

5.2.6.6.4.2 Size. The height of letters and numerals should be not less than 4.5 mrad (15 minutes) of visual angle and, in no instance, shall be less than 3 mrad (10 minutes) as measured from the longest anticipated viewing distance.

5.2.6.6.4.3 Contrast.

5.2.6.6.4.3.1 Luminance ratio. Under optimal ambient lighting conditions, the luminance ratio (see 3.13) for optically projected displays should be 500:1. The minimum luminance ratio for viewing charts, printed text and other linework via slides or opaque projectors shall be 5:1. For projections which are limited in shadows and detail, such as animation and photographs with limited luminance range, the minimum luminance ratfo shall be 25:1. For images which show a full range of colors (or grays in black-and-white photographs), the minimum luminance ratio shall be 100:1.

5.2.6.6.4.3.2 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.

5.2.6.6.4.4 Alignment. Nisregistration of superimposed alphanumeric data or other symbols shall be minimized.

5.2.6.6.5 Keystone effects. Projector-screen arrangement shall minimize "keystone effect," e.g., distortion of projected data proportions due to non-perpendicularity between projector and screen.

5.2.6.7 Light emitting diodes (LEDs).

5.2.6.7.1 General. In general, the standard for LEDs shall be the same as the requirements for transilluminated displays, paragraph 5.2.2 of this standard, unless specified below.

5.2.6.7.2 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).

5.2.6.7.3 Intensity control. The dimming of LEDs should be compatible with the dimming of incandescent lamps.

5.2.6.7.4 Color coding. LED color coding shall conform to 5.2.2.1.18, herein, with the exception of red alpha-numeric displays; however, red LEDs should not be located in the proximity of red lights used as outlined in 5.2.2.1.18.

5.2.6.7.5 Lamp testing. LED indicator lights with 100,000 hours or longer MTBF (mean time between failure) shall not require the lamp test capability specified in 5.2.2.1.14.

5.2.6.8 Dot matrix/segmented displays.

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

5.2.6.8.2 Use. Dot matrix, fourteen segment and sixteen segment displays may be used for applications involving interactive computer systems, instruments, avionics, 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.

5.2.6.8.3 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.

5.2.6.8.4 Alphanumeric character and symbol sizes. Alphanumeric and symbolic characters shall not subtend less than 4.7 mrad (16 min) of visual angle. Flight display characters, which must be read under aircraft environmental conditions, shall subtend not less than 7 mrad (24 min) of visual angle.

5.2.6.8.5 Use of upper case. Alphanumeric characters shall be upper case.

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

5.2.6.8.7 Emitter color. Monochromatic displays shall use the following colors in-order of preference: green (555nm), Yellow (575nm), orange (585nm), and red (660nm). Blue emitters should be avoided.

5.2.6.8.8 Intensity control. Dimming controls shall be provided where applicable to maintain appropriate legibility and operator dark adaptation level.

5.2.6.8.9 Display testing. See 5.2.6.7.5.

5.2.6.8.10 Location of red alphnumeric LEDs/segmented displays. Red LEDs/segmented displays shall not be grouped with or located adjacent to red warning lights.

5.2.6.9 Electroluminescent displays.

5.2.6.9.1 Use. Electroluminescent displays may be used wherever system requirements dictate the use of transilluninated displays. 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.

5.2.6.9.2 Alphanumeric character and symbol sizes. The height of alphanumeric characters and geometric and pictorial symbols shall not subtend less than 4.5 mrad (15 minutes) of visual angle. Alphanumerical characters shall be composed of upper case letters. Flight display alphanumerics shall not subtend less than 7 mrad (24 minutes) of visual angle to insure adequate legibility under aircraft environmental conditions.

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5.3 Audio displays.

5.3.1 General.

5.3.1.1 Use. Audio displays should be provided when:

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

b. The common mode of visual display is restricted by over-burdening; ambient light variability or limitation; operator mobility; degradation of vision by vibration, high g-forces, hypoxia, or other environmental considerations; or anticipated operator inattention.

c. The criticality of transmission 'response makes supplementary or redundant transmission desirable.

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

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

f. Voice communication is necessary or desirable.

5.3.1.2 Signal type. When an audio presentation is required, the optimum type of signal should be presented in accordance with the Table V.

5.3.1.3 False alarms. The design of audio display devices and circuits shall preclude false alarms.

5.3.1.4 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.

5.3.1.5 Circuit test. All audio displays shall be equipped with circuit test devices or other means of operability test.

5.3.1.6 Aircrew stations. Audio signals for air crew stations shall conform to MIL-STD-411, where applicable.

5.3.1.7 Use with several visual displays. One audio signal may be used in conjunction with several visual displays, provided that immediate discrimination is not critf cal to personnel safety or system performance.

5.3.2 Audio warnings.

5.3.2.1 Warninq signals. Audio signals should be provided, as necessary, to warn personnel of impending danger, to alert an 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

TABLE V. FUNCTIONAL EVALUATION OF AUDIO SIGNALS

FUNCTION	TYPE OF SIGNAL		
	TONES (Periodic)	COMPLEX SOUNDS (Non-Periodic)	SPEECH
QUANTITATIVE INDICATION	POOR Maximum of 5 to 6 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.	FOOD 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 (e.g., 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	Good for automatic communication of limited information. Meaning must be learned. Easily generated.	Some sounds available with common meaning (e.g., fire bell). Easily generated.	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.

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. NOTE; Certain audio signals have been standardized for aircraft use by joint service and international agreement. Stipulation of audio signals for future aircraft design should be in consonance with these agreements (see MIL-STD-411).

5.3.2.2 Nature of signals. Audio warning signals should normally consist of two elements: an alerting signal and an identifying or action signal.

5.3.2.2.1 Two element signals. when reaction time is critical and a two element signal is necessary, an alerting signal of 0.5 second duration shall be provided. Al? essential information shall be transmitted in the first 2.0 seconds of the identifying or action signals.

5.3.2.2.2 Single element signal. When reaction time is critical, signals shall be of short duration. If a single element signal is permissable, all essential information shall be transmftted in the first 0.5 second.

5.3.2.3 Caution signals. Caution signals shall be readily distinguishable from warning signals and shall be used to indicate conditions requiring awareness, but not necessarily immediate action.

5.3.2.4 Relation to visual displays. When used in conjunction with visual displays, audio warning devices shall be supplementary or supportive. The audio signal shall be used to alert and direct operator attention to the appropriate visual display.

5.3.3 Characteristics of audio warning signals.

5.3.3.1 Frequency.

5.3.3.1.1 Range. The frequency range shall be between 200 and 5,000 Hz and, if possible, between 500 and 3,000 Hz. When signals must travel over 300 m (985 ft), sounds with frequencies below 1,000 Hz should be used. Frequencies below 500 Hz should be used when signals must bend around obstacles or pass through partitions. The selected frequency band shall differ from the most intense background frequencies and shall be in accordance with other criteria in this section.

5.3.3.1.2 Spurious signals. The frequency of a warning tone shall be different from that of the electric power employed in the system, to preclude the possibilfty that a minor equipment failure may generate a spurious sfgnat.

5.3.3.2 Intensity.

5.3.3.2.1 Compatibflity 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.

5.3.3.2.2 **Compatibility with clothing and equipment.** As applicable, audio signals shall be loud enough to be heard and understood through equipment or garments (e.g., parka hood, NBC protective hood, hearing protective devices) covering the ears of the listener.

5.3.3.2.3 **Discomfort.** Audio warning signals should not be of such intensity as to cause discomfort or "ringing" in the ears as an after-effect.

5.3.4 **Signal characteristics in relation to operational conditions and objectives.**

5.3.4.1 Audibility. A signal-to-noise ratio of at least 20 dB shall be provided in at least one octave band between 200 and 5,000 Hz at the operating position of the intended receiver.

5.3.4.2 Alerting capability.

5.3.4.2.1 Attention. Signals with high alerting capacity should be provided when the system or equipment imposes a requirement on the operator for concentration of attention. Such signals shall not, however, be so startling as to preclude appropriate responses or interfere with other functions by holding attention away from other critical signals.

5.3.4.2.2 **Onset and sound pressure level.** The onset of critical alerting signals should be sudden, and a relatively high sound pressure level should be provided as specified 5.3.4.1.

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

5.3.4.2.4 Headset. When the operator is wearing earphones covering both ears during normal equipment operation, the audio warning signal shall be directed to the operator's headset as well as to the work area. Binaural headsets should not be used in any operational environment below 85 dB(A) when that environment may contain sounds that provide the operator with useful information when that information cannot be directed to the operator's headset. Such sounds may include voices, machine noise that indicates wear or malfunction and other auditory indications of system performance/mission status.

5.3.4.3 Discriminability.

5.3.4.3.1 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.

5.3.4.3.2 Coding. Where discrimination of warnfng 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 (e.g., maintenance, emergency conditions, and health hazards). Such signals shall be sufficiently different to minimize the operator's search of visual displays.

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

5.3.4.3.4 Action segment. The identifying or action segment of an audio warning signal shall specify the precise emergency or condition requiring action.

5.3.4.3.5 Differentiation from routine signals. Audio alarms intended to bring the operator's attention to a malfunction or failure shall be differentiated from routine signals, such as bells, buzzers, and normal operation noises.

5.3.4.3.6 Prohibited types of signals. The following types of signals shall not be used as warning devices where possible confusion might exist because of the operational environment:

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

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

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

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

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

f. Signals that resemble random noise, periodic pulses, steady or frequency modulated simple tones, or any other signals generated by standard countermeasure devices (e.g., "bagpipes").

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

5.3.4.4 Compatibility.

5.3.4.4.1 Existing signals. The meaning of audio warning signals selected for a system should be consistent with warning signal meanings already established for that function.

5.3.4.4.2 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.

5.3.4.5 Masking.

5.3.4.5.1 Other critical channels. Audio warning signals shall not interfere with any other critical functions or warning signals, or mask any other critical audio signals.

5.3.4.5.2 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. In such a situation and when required by operating conditions, this dichotic presentation may further provide for alternation of the two signals from ear to ear.

5.3.5 Verbal warning signals.

5.3.5.1 Nature of signals. Verbal warning signals shall consist of:

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

b. A brief standardization speech signal (verbal message) which identifies the specific condition and suggests appropriate action.

5.3.5.2 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.

5.3.5.3 Vocal criteria.

5.3.5.3.1 Type of voice. The voice used in recording verbal warning signals shall be distinctive and mature.

5.3.5.3.2 Delivery style. Verbal warning signals shall be presented in a formal, impersonal manner.

5.3.5.4 Speech processing. Verbal warning signals shall be processed only when necessary to increase or preserve intelligibility, such as by increasing the strength of consonant sounds relative to vowel strength. Where a signal must be relatively intense because of high ambient noise, peak-clipping (see 3.24) maybe used to protect the listener against auditory overload.

5.3.5.5 Message content. In selecting words to be used in audio warning signals, priority shall be given to intelligibility, aptness, and conciseness in that order.

5.3.5.6 Message categories.

5.3.5.6.1 Critical warning signals. Critical warning signal shall be repeated with not more than a 3-second pause between messages until the condition is corrected or overridden by the crew.

5.3.5.6.2 Message priorities. A message priority system shall be established and more critical messages shall override the presentation of any message occuring 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.

5.3.6 Controls for audio warning devices.

5.3.6.1 Automatic or manual shut-off. When an audio signal is designed to persist as long as it contributes useful information. a shut-off switch controllable by the operator, the sensing mechanism, or both, shall be provided, depending on the operational situation and personnel safety factors.

5.3.6.2 Automatic reset. Whether audio warning signal 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 sfgnalling system so that the warning device can sound again if the condition repeats.

5.3.6.3 Redundant Visual Warning. All non-verbal aural annunciations shall be accompanied by a visual annunciation which defines the condition. In a cockpit,-this may be an illuminated display. In the case of a warning horn on a backing vehicle, the vehicle's backward motion is adequate visual annunciation.

5.3.6.4 Volume control.

5.3.6.4.1 Automatic or manual. The volume (loudness) of an audio warning 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 inaudibie level.

5.3.6.4.2 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.

5.3.6.4.3 Caution signal controls. Audio caution signals shall be provided with manual reset and volume controls.

5.3.6.5 Duration. Audio warning signal duration shall be at least 0.5 second, and may continue until the appropriate response is made. Completion of a corrective action by the operator or by other means shall automatically terminate the signal.

5.3.6.6 Duration limitations. In an emergency situation, signals that persist or increase progressively in level shall not be used if manual shut-off may interfere with the corrective action required.

5.3.7 Speech transmission equipment.

5.3.7.1 Frequency. Microphones and associated system-input devices shall be designed to respond optimally to that part of the speech spectrum most essential to intelligibility (i.e., 200 to 6,100 Hz). Where system engineering necessitates speech-transmission bandwidths narrower than 200 to 6,100 Hz, the minimum acceptable frequency range shall be 250 to 4,000 Hz.

5.3.7.2 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.

5.3.7.3 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 non-noise-cancelling microphones of equivalent transmission characteristics.

5.3.7.4 Pre-emphasis. If necessary, speech system input devices should employ frequency pre-emphasis with a positive slope frequency characteristic no greater than 18 dB per octave from 140 to 1,500 to and no greater than 9 dB per octave over the frequency range 1,500 to 4,800 Hz, when no clipping is used.

5.3.7.5 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 employed at system input and may be preceded by frequency pre-emphasis as specified in 5.3.7.4.

5.3.7.6 Noise shields. When the talker is in an intense noise field, the microphone should be put in a noise shield. Noise shields should be designed to meet the following requirements:

a. A volume of at least 250 cu cm (15.25 cu in) to permit a pressure gradient microphone to function normally.

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

c. A hole or combination of holes covering a total area of 65 sq mm (0.1 sq in) in the shield to prevent pressure buildup.

d. Prevention of a standing wave pattern by shape, or by use of sound absorbing material.

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

5.3.8 Speech reception equipment.

5.3.8.1 Frequency range. Headphones and loudspeakers shall be subject to the same frequency response restrictions us microphones and transmission equipment except that loudspeakers for use in multi-speaker installations and multiple channels fed into headphones (e.g., where several speech channels are to be monitored simultaneously) shall respond uniformly (±5 dB) over the range 100 to 4,800 Hz.

5.3.8.2 Loudspeakers for multi-channel monitoring.

5.3.8.2.1 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 $\pi/4$ rad (45°) left to $\pi/4$ rad (45°) right of the operator's normal forward facing position.

5.3.8.2.2 Filtering. When additional channel differentiation is required, apparent lateral separation shall be enhanced by applying low-pass filtering (frequency cutoff, F_C = 1,800 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 1,000 Hz cutoff shall be provided in the second channel, and a low-pass filter with 2,500 Hz cutoff shall be provided in the third channel. A visual signal shall be provided to show which channel is in use.

5.3.8.3 Use of de-emphasis. When transmission equipment employs pre-emphasis and peak clipping is not used, reception equipment shall employ frequency de-emphasis of characteristics complementary to those of pre-emphasis only if it improves intelligibility, i.e., de-emphasis shall be a negative-slope frequency response not greater than 9 dB per octave over the frequency range 140 to 4,800 Hz.

5.3.8.4 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 othrwise, binaural headsets shall be

wired so that the sound reaches the two ears in opposing phases. Their attenuation qualities should be capable of reducing the ambient noise level to less than 85 dB(A). Provisions should be incorporated to furnish the same protection to those who wear glasses.

5.3.9 Operator comfort and convenience.

5.3.9.1 Comfort. Communication equipment to be worn by an operator (e.g., headphones and telephone headsets) shall be designed to preclude operator discomfort. Metal parts of the headset shall not come in contact with the user's skin.

5.3.9.2 Hands-free operation. Operator microphones, headphones, and telephone headsets shall be designed to permit hands-free operation under normal working conditions.

5.3.9.3 Accessibility of handsets. Where communication requirements necessitate the use of several telephone handsets, the accessibility of their standby locations shall be determined by operational priorfty, i.e., the most frequently or urgently needed handset shall be the most accessible. Color-coding may also be employed where operating personnel will have visual contact with headsets under the working conditions.

5.3.10 Operating controls for voice communication equipment.

5.3.10.1 Volume controls. Accessible volume or gain controls shall be provided for each communication receiving channel (e.g., loudspeakers or headphones) with sufficient electrical power to drive sound pressure level to at least 100 dB overall when using two earphones, and shall have pressure operated gain control switches to compensate for altitude in unpressurized compartments. The minimum setting of the volume control shall be limited to an audible level, i.e., it shall not be possible to inadvertently disable the system with the volume control. White separation of power (on-off) and volume control adjustment functions into separate controls is preferred, should conditions justify their combination, a noticeable detent 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.

5.3.10.2 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.

5.3.10.3 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.

5.3.11 Speaker/side tone. The speaker's verbal input shall be in phase with its reproduction as heard on the headset. This side tone should not be filtered or modified before it is received in the headset.

5.3.12 Speech intelligibility.

5.3.12.1 General. When information concerning the speech intelligibility of a system mired, three recommended methods are available, with the appropriate selection being dependent upon the requirements of the test.

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

b. The modified rhyme test (MRT) (see Human Engineering Guide to Equipment Design) should be used if the test requirements are not as stringent or if time and training do not permit the use of the ANSI method.

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

5.3.12.2 Criteria. The Intelligibility criteria shown in Table VI shall be used for voice communication. The efficiency of communications needed and the type material to be transmitted shall determine which of the three communication requirements of Table VI is to be selected.

TABLE VI. INTELLIGIBILITY CRITERIA FOR VOICE COMMUNICATIONS SYSTEMS

COMMUNICATION REQUIREMENT	SCORE		
	PB	MRT	AI
Exceptionally high intelligibility; separate syllables understood	99%	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 99% sentences correctly heard (not acceptable for operational equipment)	43%	75%	0.3

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5.4 Controls.

5.4.1 General criteria.

5.4.1.1 Selection.

5.4.1.1.1 Distribution of work load. Controls shall be selected and distributed so that none of the operator's limbs will be overburdened.

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

5.4.1.1.3 Multirotation controls. Hultirotation controls shall be used when precision is required over a wide range of adjustment.

5.4.1.1.4 Detent controls. Detent controls shall be selected whenever the operational mode requires control operation in discrete steps.

5.4.1.1.5 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.

5.4.1.2 Direction of movement.

5.4.1.2.1 Consistency of movement. Direction of control movement shall be consistent with the related movement of an associated display, equipment component, or vehicle. In general, 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. Valve controls are excepted (see 5.4.1.2.4).

5.4.1.2.2 Multidimensional operation. When the vehicle, the equipment, or the components are capable of motion in more than two dimensions, exception to 5.4.1.2.1 shall be made if necessary to ensure consistency or anticipated response (e.g., forward motion of a directional control causes some vehicles to dive 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 (e.g., control motion to the right is compatible with clockwise roll, right turn, and direct movement to the right).

5.4.1.2.3 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.

5.4.1.2.4 Valve controls. Rotary valve controls should open the valve with a counterclockwise motion. Valve controls shall be provided with double-ended arrows showing the direction of operations and labeled at each end to indicate the functional result (e.g., open and close).

5.4.1.3 Arrangement and grouping.

5.4.1.3.1 Grouping. All controls which function in sequential operation necessary to a particular task, or which 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 prevent cycling through unnecessary steps. Cycling through the control's ON/OFF position shall be avoided.

5.4.1.3.2 Sequential operation. Where sequential operations follow a fixed pattern, controls shall be arranged to facilitate operation (e.g., in a pattern left-to-right and top-to-bottom, as a printed page).

5.4.1.3.3 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).

5.4.1.3.4 Consistency. The arrangement of functionally similar, or identical, primary controls shall be consistent from panel to panel throughout the system, equipment, or vehicle, e.g., a movement of a control to the right or left should result in a corresponding movement of a displayed element to the right or left.

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

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

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

5.4.1.4 Coding.

5.4.1.4.1 Methods and requirements. The use of a coding mode (e.g., 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 VIII for advantages and disadvantages.)

TABLE VII. MINIMUM SEPARATION DISTANCES FOR CONTROLS

	TOGGLE SWITCHES	*PUSH-BUTTONS	CONTINUOUS ROTARY CONTROLS	ROTARY SELECTOR SWITCHES	DISCRETE THUMBWHEEL CONTROLS
TOGGLE SWITCHES	SEE FIG 13	13 mm (0.5 in.)	19 mm (0.75 in.)	19 mm (0.75 in.)	13 mm (0.5 in.)
*PUSHBUTTONS	13 mm (0.5 in.)	SEE FIG.11	13 mm (0.5 in.)	13 mm (0.5 in.1	13 mm (0.5 in.)
CONTINUOUS ROTARY CONTROLS	19 mm (0.75 in.)	13 mm (0.5 in.)	SEE FIG 7	25 mm (1.0 in.)	19 mm Co.76 In.)
ROTARY SELECTOR SWITCHES	19 mm (0.75 in.)	13 mm (0.5 in.)	25 mm (1.0 in.)	SEE FIG 4	19 mm (0.75 in.1
DISCRETE THUMBWHEEL CONTROL6	13 mm (0.5 in.)	13 ram (0.5 in.)	19 mm (0.75 in.)	19 mm (0.75 in.)	SEE FIG 6

*For pushbuttons not separated by barriers

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

TABLE VIII. ADVANTAGES AND DISADVANTAGES OF VARIOUS TYPES OF CODING

ADVANTAGES	TYPE OF CODING					
	LOCATION	SHAPE	SIZE	MODE OF OPERATION	LABELING	COLOR
Improves visual identification.	X	X	X		X	X
Improves nonvisual identification (tactual and kinesthetic).	X	X	X	X		
Helps standardization.	X	X	X	X	X	X
Aids identification under low levels of illumination and colored lighting.	X	X	X	X	(When trans-illuminated)	(When trans-illuminated)
May aid in identifying control position (settings).		X		X	X	
Requires little (if any) training; is not subject to forgetting.					X	
DISADVANTAGES						
May require extra space.	X	X	X	X	X	
Affects manipulation of the control (ease of use).	X	X	X	X		
Limited in number of available coding categories.	X	X	X	X		X
May be less effective if operator wears gloves.		X	X	X		
Controls must be viewed (i.e., must be within visual areas and with adequate illumination present).					X	X

5.4.1.4.2 Location-coding. Controls associated with similar functions should be in the same relative location from operator work station to work station and from panel to panel.

5.4.1.4.3 Size-coding. No more than three different size 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"). When knob thickness is the coding parameter, differences between thicknesses shall not be less than 10 mm (0.4").

5.4.1.4.4 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:

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

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

c. Shapes shall be tactually identifable when gloves are worn, where applicable.

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

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

f. Shapes should be associated with or resemble control function, and not alternate functions.

5.4.1.4.5 Color-coding.

5.4.1.4.5.1 Choice of colors. Controls shall be black (17038, 27038, or 37038) or gray (26231 or 36231). If color coding is required, only the following colors identified in FED-STD-595 shall be selected for control coding.

a. Red, 11105, 21105, 31105

b. Green, 14187

c. Orange-Yellow, 13538, 23538, 33538

d. White, 17875, 27875, 37875

e. Blue, 15123 shall be used if an additional color is absolutely necessary.

5.4.1.4.5.2 Immediate action controls. Color coding of immediate action controls for aircraft shall conform to MIL-M-18012.

5.4.1.4.5.3 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.

5.4.1.4.5.4 Control panel contrast. The color of the control shall provide contrast between the panel background and the control.

5.4.1.4.5.5 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 spectral characteristics of ambient light during the mission, or 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.

5.4.1.5 Labeling of controls. Control labeling shall conform to the criteria in paragraph 5.5.

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

5.4.1.7 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.).

5.4.1.8 Prevention of accidental actuation.

5.4.1.8.1 Location and design. Controls shall be designed and located so that they are not susceptible to being moved accidentally, particularly critical controls whose inadvertent operation might cause damage to equipment, injury to personnel or degredation of system functions.

5.4.1.8.2 Internal controls. Internal or hidden controls should 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.

5.4.1.8.3 Rapid operation. Any method of protecting a control from inadvertent operation shall not preclude operation within the time required.

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

a. 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.

b. 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.

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

d. Provide the controls with interlocks so that extra movement (e.g., a side movement out of a detent position or a pull-to-engage clutch) or the prior operation of a related or locking control is required.

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

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

g. Design the controls for operation by rotary action.

5.4.1.8.5 Dead man controls. Dead man controls, which will result in system shut-down to a non-critical operating state when force is removed, shall be utilized wherever operator incapacity can produce a critical system condition.

5.4.1.8.6 Foot-operated controls.

5.4.1.8.6.1 Use. Foot-operated controls may be used under the following conditions:

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

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

c. Specific foot-operated controls have been so well established that the operator expects such operating functions to be performed using foot controls (e.g., aircraft rudder/brake pedals, automotive clutch, brake and accelerator pedals).

d. A safety "shut-down" control is required during an operation in which the operator's hands cannot be freed to reach a safety switch.

5.4.1.8.6.2 Avoidance. Foot operated controls should not be used under the following conditions:

a. Where a standing operator is confronted with a sensitive balancing requirement (e.g., a moving platform where balancing on the non-operating foot may become difficult as the operating foot is moved from a support to actuating position).

b. Precise control operations are required.

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

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

a. Frequent, maximum reaching.

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

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

d. Maximum force application frequently or for extended duration.

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

f. 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 as the operator shifts the foot from one control to another.

5.4.1.8.6.4 Configuration and placement. Configuration and placement of foot operated controls shall accommodate the anthropometry of the operator's foot wearing operational shoes or boots. They shall be located so that the actuation of a control by one foot does not interfere with the actuation 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.

5.4.2 Rotary controls.

5.4.2.1 Discrete rotary controls.

5.4.2.1.1 Rotary selector switches.

5.4.2.1.1.1 Use. Rotary selector switches should be used for discrete functions when three or more detented positions are required. Rotary selector

switches should 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.

5.4.2.1.1.2 Moving pointer. Rotary selector switches should be designed with a moving pointer and a fixed scale.

5.4.2.1.1.3 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.

5.4.2.1.1.4 Positions. A rotary selector switch which 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. In addition, the following criteria shall apply:

a. 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.

b. 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.

5.4.2.1.1.5 Contrast. A reference line shall be provided on rotary switch controls. This line shall have at least 3.0 luminance contrast (see 3.17) with the control color under all lighting conditions.

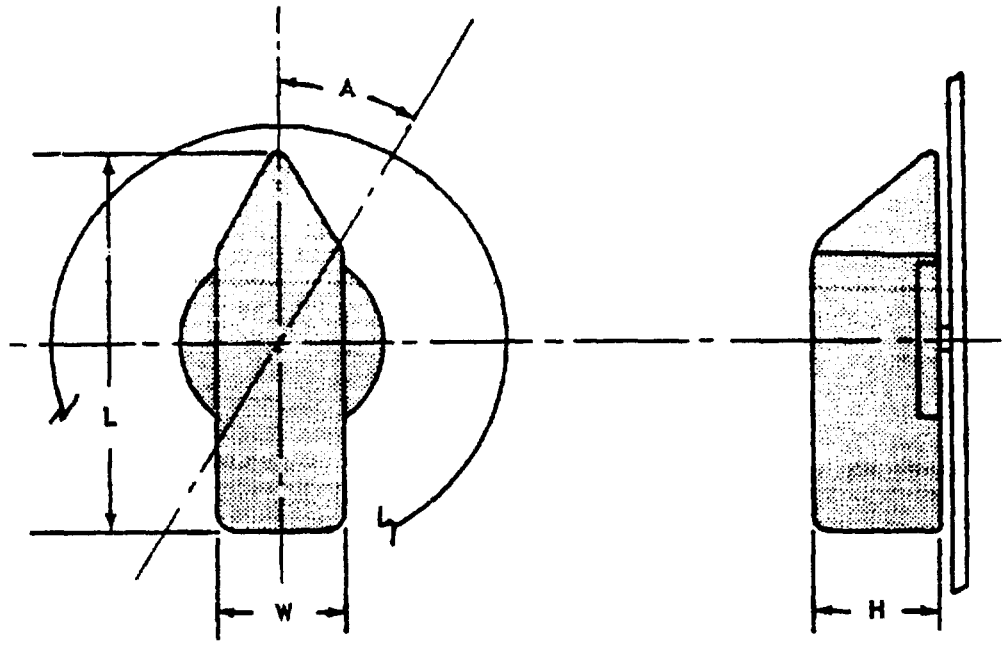
5.4.2.1.1.6 Parallax. The knob pointer shall be mounted sufficiently close to its scale to minimize parallax between the pointer and the scale markings. When viewed from the normal opertor's position, the parallax errors shall not exceed 25% of the distance between scale markings.

5.4.2.1.1.7 Dimensions, resistance, displacement, and separation. Control dimensions, resistance, displacement, and separation between adjacent edges of areas swept by rotary selector switches should conform to the criteria in Figure 4.

5.4.2.1.2 Key operated switches (KOS).

5.4.2.1.2.1 Use. KOS are used to prevent unauthorized operation. Ordinarily, they control system operation by go no-go.

5.4.2.1.2.2 Dimensions, displacement, and resistance. Dimensions, displacement, and resistance shall conform to the criteria in Figure 5.



	DIMENSIONS			RESISTANCE
	L Length	W Width	H Depth	
Minimum	25 mm (1 in.)		16 mm (5/8 in.)	115 mN · m (1 in.–lb)
Maximum	100 mm (4 in.)	25 mm (1 in.)	75 mm (3 in.)	680 mN · m (6 in.–lb)

	DISPLACEMENT		SEPARATION	
	A			
	*	**	One-Hand Random	Two-Hand Operation
Minimum	262 mrad (15°)	525 mrad (30°)	25 mm (1 in.)	75 mm (3 in.)
Maximum	700 mrad (40°)	1570 mrad (90°)	-	-
Preferred	-	-	50 mm (2 in.)	125 mm (5 in.)

*For facilitating performance.

**When special engineering requirements demand large separation or when tactually ("blind") positioned controls are required.

FIGURE 4. ROTARY SELECTOR SWITCH

5.4.2.1.2.2 Dimensions, displacement, and resistance. Dimensions, displacement, and resistance shall conform to the criteria in Figure 5.

5.4.2.1.2.3 Color, shape and size coding. Color, shape, or size coding or a combination may be used as follows:

a. 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 (# 11105 or 21105 of FED-STD-595) shall be reserved for emergency functions.

b. 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.

c. Size coding, within the height limits of Figure 5, may also be used if no more than two sizes are employed.

5.4.2.1.2.4 Marking and labeling. Keylock switch applications shall include appropraite positional markings and labels (see 5.5).

5.4.2.1.2.5 Other requirements.

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

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

c. Locks should be oriented so the key's vertical position is the OFF position.

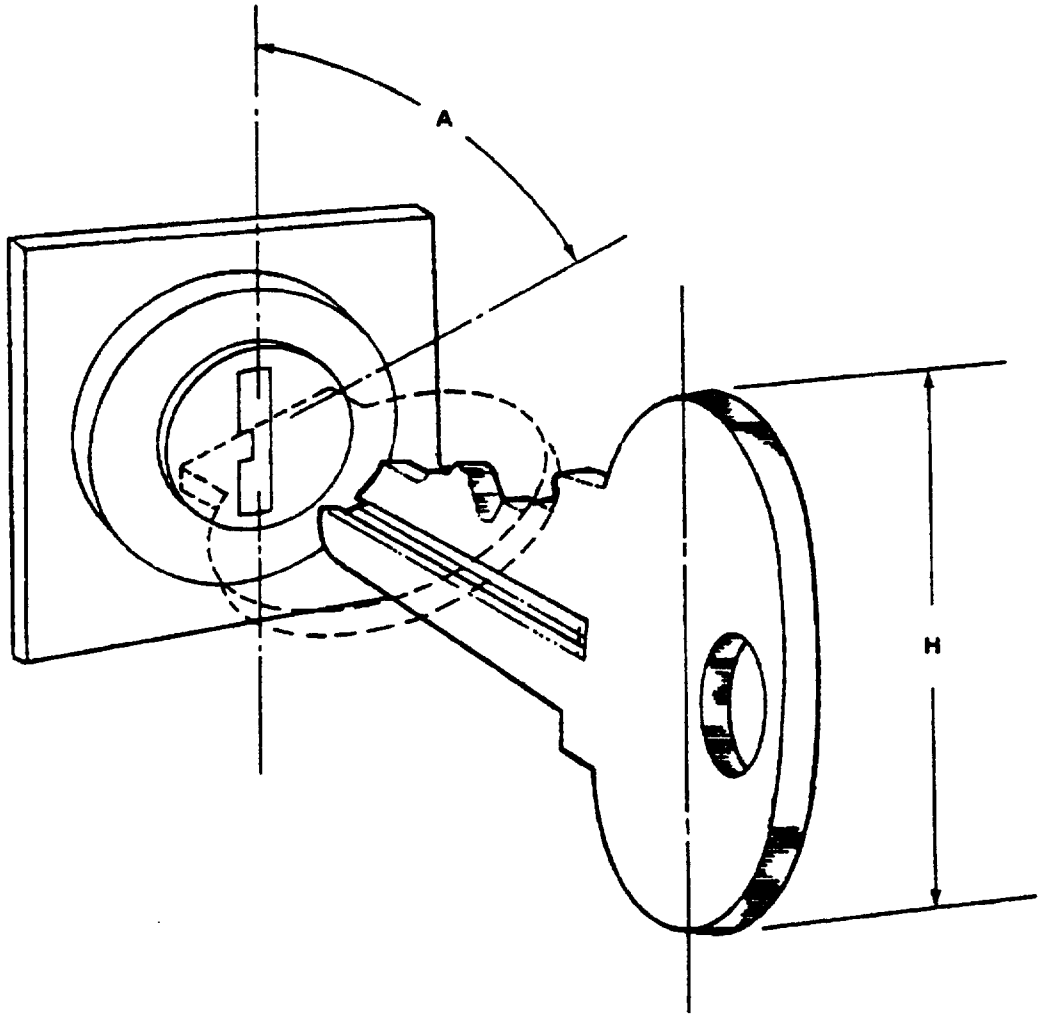
d. Operators should normally not be able to remove the key from the lock unless the switch is turned OFF.

e. Actuation of an item by a key operated switch should be accomplished by turning the key clockwise from the vertical OFF position.

5.4.2.1.3 Discrete thumbwheel controls.

5.4.2.1.3.1 Application. 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 purposes is discouraged. Detent indexing units should provide 10 positions (0 - 9) in digital or binary (3 or 4 bits and complement) outputs.

5.4.2.1.3.2 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 $\pi/6$ rad (30°) viewing angle to the left and right of a perpendicular to the thumbwheel digits.



	DISPLACEMENT (A)	HEIGHT (H)	RESISTANCE
MINIMUM	525 mrad (30°)	13 mm (1/2 in.)	115 mN·m (1 in.–lb)
MAXIMUM	1570 mrad (90°)	75 mm (3 in.)	680 mN·m (6 in.–lb)

FIGURE 5. KEY-OPERATED SWITCH

thumbwheels shall not preclude viewing the digits within $\pi/6$ rad (30°) viewing angle to the left and right of a perpendicular to the thumbwheel digits.

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

5.4.2.1.3.4 Direction of movement. Moving the thumbwheel edge forward, or upward, or to the right shall increase the setting.

5.4.2.1.3.5 Numerals.

5.4.2.1.3.5.1 Internal illuminance. For areas in which ambient illumination will provide display brightness below 3.5 cd/m^2 (1 ft-L), the thumbwheel shall be internally illuminated. Digits shall appear as illuminated characters on a black background, and their dimensions should approximate the following:

a. Height: 4.8 mm (3/16")

b. Height-to-Width Ratio: 3:2

c. Height-to-Stroke Width Ratio: 10:1

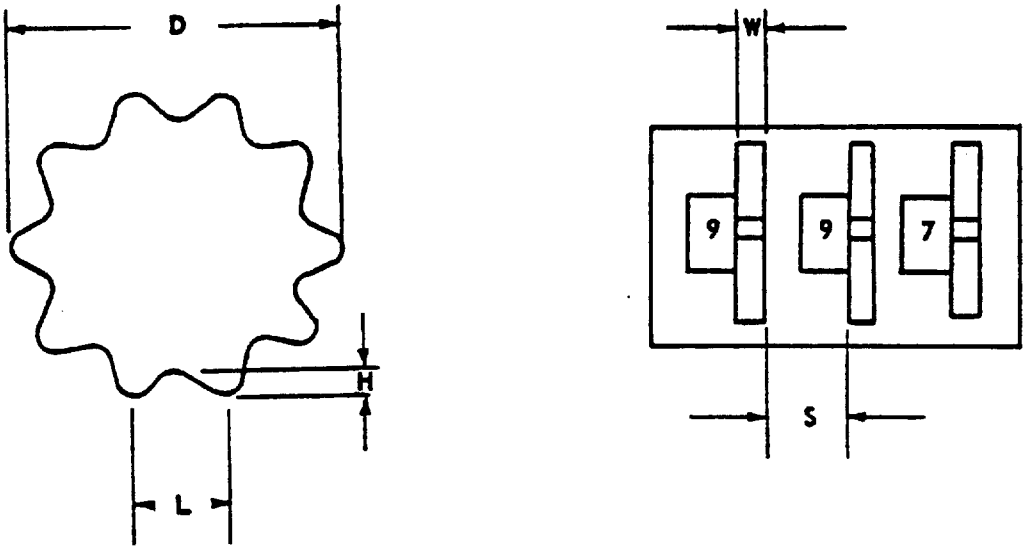
5.4.2.1.3.5.2 External illuminance. In areas where ambient illumination will provide a display luminance above 3.5 cd/m^2 (1 ft-L), internal illumination is not required. Digits should be bold, black numerals engraved on a light (or white) thumbwheel background. The dimensions should approximate those specified in 5.4.2.1.3.5.1, except that the height-to-stroke width ratio should be approximately 5:1.

5.4.2.1.3.6 Visibility. Thumbwheel design shall permit viewing of inline digital read-out from all operator positions.

5.4.2.1.3.7 Dimensions. Control dimensions shall conform to the criteria in Figure 6.

5.4.2.1.3.8 Resistance. Detents shall be provided for discrete position thumbwheels. Resistance shall be elastic, building up and then decreasing as each detent is approached so that the control snaps into position without stopping between adjacent detents. The resistance shall be within the limits indicated in Figure 6.

5.4.2.1.3.9 Separation. The separation between adjacent edges of thumbwheel controls shall conform to the criteria in Figure 6 and shall be sufficient to preclude accidental activation of adjacent controls during



	D DIAMETER	L TROUGH DISTANCE	W WIDTH	H DEPTH	S SEPARATION	RESISTANCE
MINIMUM	30 mm (1-1/8 in.)	11 mm (7/16 in.)	3 mm (1/8 in.)	3 mm (1/8 in.)	10 mm (13/32 in.)	1.7 N (6 oz)
MAXIMUM	75 mm (3 in.)	19 mm (3/4 in.)		13 mm (1/2 in.)		5.6 N (20 oz)

FIGURE 6. DISCRETE THUMBWHEEL CONTROL

5.4.2.2 Continuous adjustment rotary controls.

5.4.2.2.1 Knobs.

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

5.4.2.2.1.2 Dimensions, torque and separation. The dimensions of knobs shall be within the limits specified in Figure 7. 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 should approximate the minimum values and should have resistance as low as possible without permitting the setting to be changed by vibration or merely touching the control. Resistance and separation between adjacent edges of knobs shall conform to Figure 7.

5.4.2.2.1.3 Knob style. Unless otherwise specified by the procuring activity, control knob style shall conform to MIL-STD-1348.

5.4.2.2.2 Ganged control knobs.

5.4.2.2.2.1 Application. Ganged knob assemblies may be used in limited applications when panel space is at a premium. Two-knob assemblies are preferred. Three-knob configurations should be avoided. Ganged knob configurations should not be used under the following conditions:

a. Extremely accurate or rapid operations are required.

b. Frequent changes are necessary.

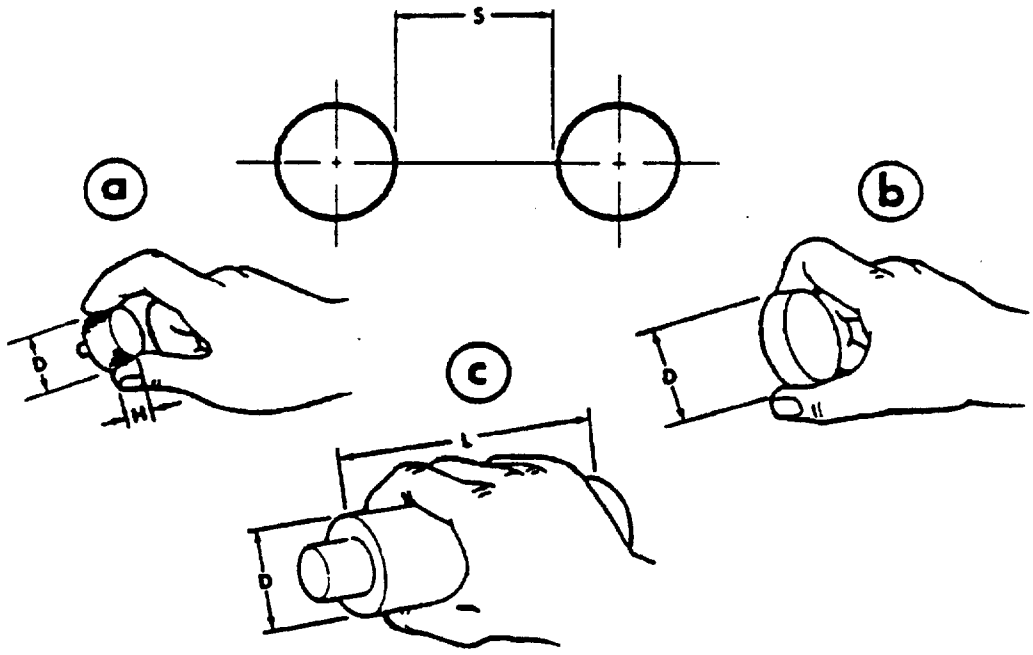
c. Heavy gloves must be worn by the operator.

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

5.4.2.2.2.2 Dimensions and separation. Dimensions and separation should conform to Figure 8.

5.4.2.2.2.3 Resistance. Resistance shall conform to requirements in Figure 8. Knobs should be serrated. Fine serrations should be used on precise adjustment knobs; coarse serrations should be used on gross adjustment knobs.

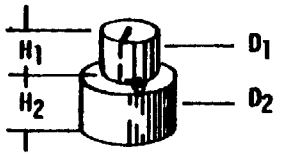
5.4.2.2.2.4 Marking. An indexing mark or pointer shall be provided on each knob. Marks or pointers should differ sufficiently to make it apparent which knob indexing mark is being observed.

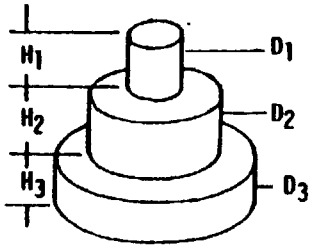


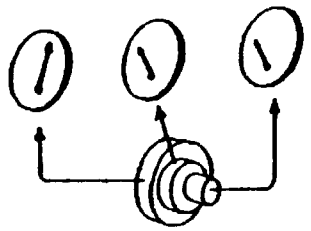
	DIMENSIONS				
	a Fingertip Grasp		b Thumb and Finger Encircled	c Palm Grasp	
	H Height	D Diameter	D Diameter	D Diameter	L Length
Minimum	13 mm (1/2 in.)	10 mm (3/8 in.)	25 mm (1 in.)	38 mm (1-1/2 in.)	75 mm (3 in.)
Maximum	25 mm (1 in.)	100 mm (4 in.)	75 mm (3 in.)	75 mm (3 in.)	-
	TORQUE		SEPARATION		
	*	**	S One Hand Individually	S Two Hands Simultaneously	
Minimum	-		25 mm (1 in.)	50 mm (2 in.)	
Optimum	-	-	50 mm (2 in.)	125 mm (5 in.)	
Maximum	32 mN-m (4-1/2 in.-oz.)	42 mN-m (6 in.-oz.)	-	-	

*To and including 25 mm (1.0 in.) diameter knobs
**Greater than 25 mm (1.0 in.) diameter knobs

FIGURE 7. KNOBS







GANGED KNOB/DISPLAY ASSOCIATION

	DIMENSIONS									
	TWO KNOB ASSEMBLY				THREE KNOB ASSEMBLY					
	H_1	H_2	D_1	D_2	H_1	H_2	H_3	D_1	D_2	D_3
MINIMUM	16 mm (5/8")	13 mm (1/2")	13 mm (1/2")	22 mm (7/8")	19 mm (3/4")	19 mm (3/4")	6 mm (1/4")	13 mm (1/2")	44 mm (1-3/4")	75 mm (3")
MAXIMUM				100 mm (4")						100 mm (4")

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

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

FIGURE 8. GANGED KNOBS

5.4.2.2.2.5 Knob/display relationship. When each knob of a ganged assembly must be related to an array of visual displays, 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 (see Figure 8).

5.4.2.2.2.6 Inadvertent operation. When it is critical to prevent inadvertent activation of one knob as the other is being adjusted, a secondary knob control movement shall be required (e.g., 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 should be optimized as shown in Figure 8. Contrasting colors between knobs may also be used to improve individual knob identification.

5.4.2.2.3 Continuous adjustment thumbwheel controls.

5.4.2.2.3.1 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.

5.4.2.2.3.2 Orientation and movement. Thumbwheels shall be oriented and move in the directions specified in Figure 9. If a thumbwheel is used as a continuous control which affects vehicle motion, movement of the thumbwheel forward or up shall cause the vehicle to move down or forward.

5.4.2.2.3.3 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.

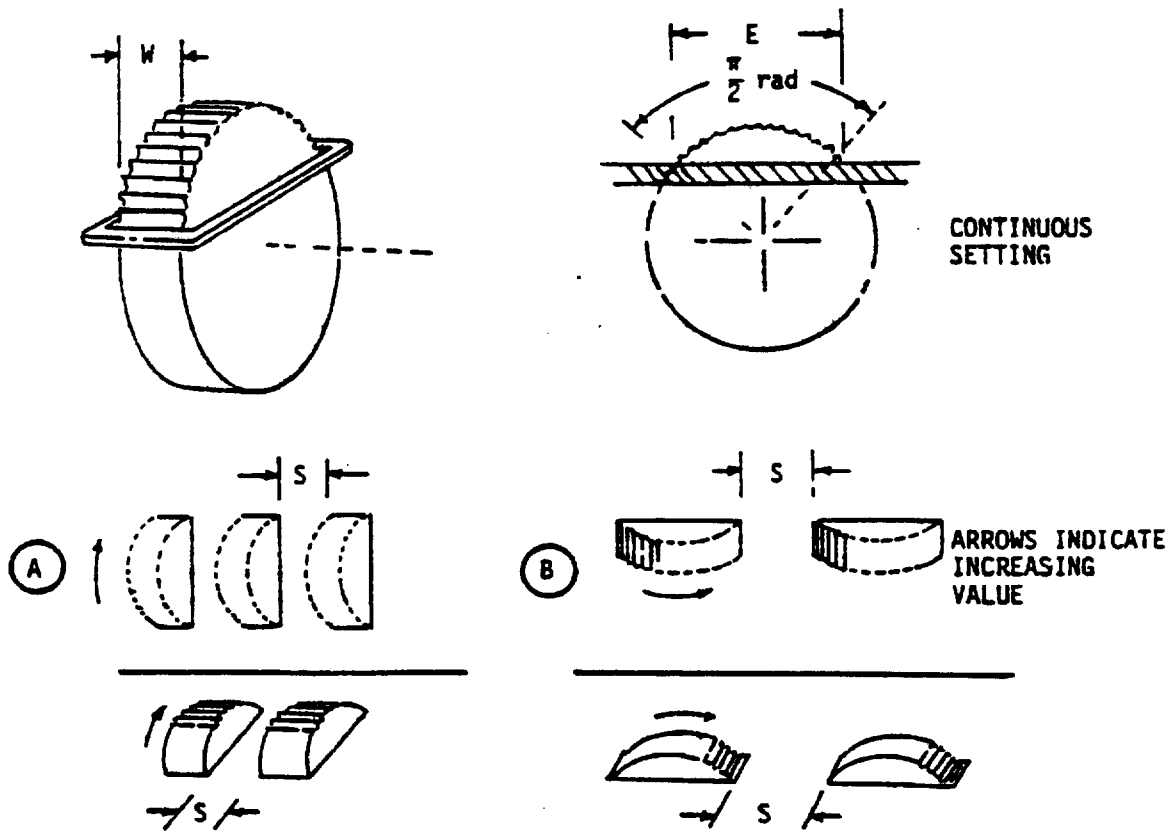
5.4.2.2.3.4 Dimensions, separation and resistance. Dimensions, separation and resistance shall conform to criteria in Figure 9.

5.4.2.2.3.5 Labeling and visibility. Marking and labeling shall conform to requirements herein, with respect to visibility of markings and legibility of label alphanumerics.

5.4.2.2.3.6 OFF position. A detent shall be provided for continuous thumbwheels having an OFF position.

5.4.2.2.4 Cranks.

5.4.2.2.4.1 Use. Cranks should be used for tasks requiring many rotations of a control, particularly where high rates or large forces are involved. For tasks involving large slewing movements, plus small, fine adjustments, a crank handle may be mounted on a knob or handwheel, the crank for slewing and the knob or handwheel for fine adjustments. Where cranks are used for tuning, or other processes involving numerical selection, each rotation should correspond to a multiple of 1, 10, 100, etc. Simultaneously operated handcranks should 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



	E RIM EXPOSURE	W WIDTH	S		RESISTANCE
			(A)	(B)	
MINIMUM	25 mm * (1")	3 mm * (1/8")	25 mm (1") Add 13 mm (1/2") for gloves	50 mm (2") Add 25 mm (1") for gloves	TO MINIMIZE EFFECTS OF INADVERTENT INPUT IF OPERATOR SUBJECT TO MOTION
MAXIMUM	100 mm (4")	23 mm (7/8")	N/A	N/A	3.3 N (12 oz.)

*Preferred. Some miniature applications may require less.

FIGURE 9. THUMBWHEEL ADJUSTMENT

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 (e.g., crosshairs) without overshooting or undershooting and successive corrective movements.

5.4.2.2.4.2 Grip handle. The crank grip handle shall be designed so that it turns freely around its shaft.

5.4.2.2.4.3 Dimensions, resistance and separation. Dimensions, resistance and separation between adjacent swept circular areas of cranks shall conform to the criteria of Figure 10.

5.4.2.2.4.4 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 should 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.

5.4.2.2.4.5 Crank balance. In applications where resistance is light, the crank shall be balanced to prevent the handle weight from turning the crank from its last setting.

5.4.2.2.5 Handwheels. (Two-hand operated)

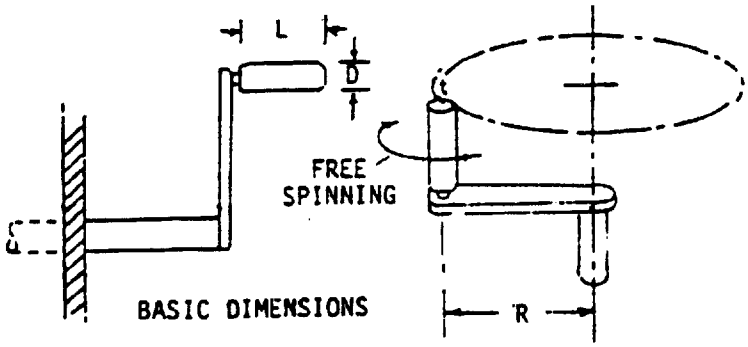
5.4.2.2.5.1 Use. Handwheels, designed for nominal two-hand operation, should be used when the breakout or rotational forces are too high to be easily overcome with a one-handed control, provided that two hands are available for this task. Typical applications are steering, latch securing, valve opening/closing and direct-linkage adjustment.

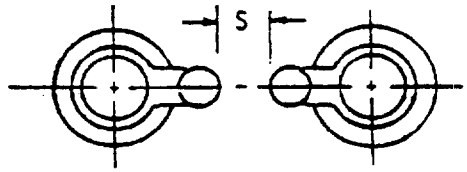
5.4.2.2.5.2 Turning aids. Knurling, indentation, high-friction covering, or a combination of these shall be built into the handwheel to facilitate operator grasp for applying maximum torque and to reduce the possibility of the wheel's being jerked from the operator's hands.

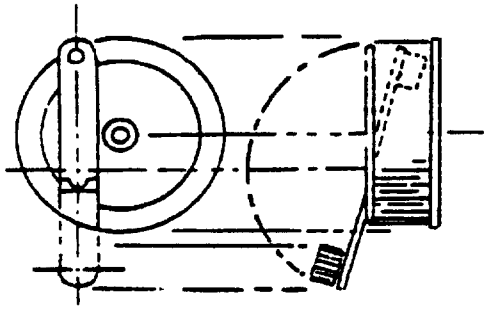
5.4.2.2.5.3 Spinner handles. For applications where the wheel may be rotated rapidly through several revolutions, a spinner handle may be added. Such handles shall not be used, however, if the projecting handle is vulnerable to inadvertent displacement of a critical wheel setting or if it creates a safety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

5.4.2.2.5.4 Direction of movement. Except for valves (see 5.4.1.2.4), 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.

5.4.2.2.5.5 Dimensions, resistance, displacement and separation. Control dimensions, resistance, displacement and separation between edges of adjacent handwheels shall conform to the criteria in Table IX.

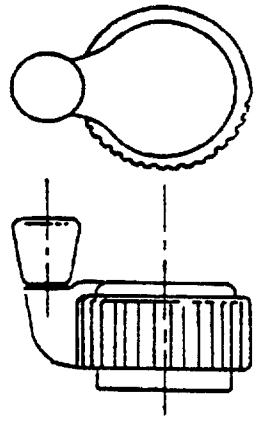


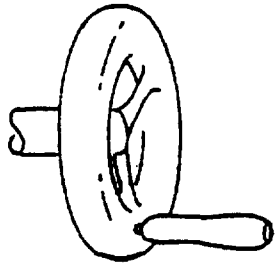




FOLDING HANDLE

COMBINED FINGER/
SPINNER STYLES
(CONSOLES)





MACHINE CRANK

LOAD	SPECIFICATION	HANDLE				R, TURNING RADIUS			
		L, LENGTH		D, DIAMETER		RATE BELOW 100 RPM		RATE ABOVE 100 RPM	
		mm	in.	mm	in.	mm	in.	mm	in.
LIGHT LOADS: Less than 22 N (5 lb). (Wrist and finger movement)	MINIMUM	25	1	10	3/8	38	1½	13	1/2
	PREFERRED	38	1½	13	1/2	75	3	65	2½
	MAXIMUM	75	3	16	5/8	125	5	115	4½
HEAVY LOADS: More than 22 N (5 lb). (Arm movement)	MINIMUM	75	3	25	1	190	7½	125	5
	PREFERRED	95	3-3/4	25	1	--	--	--	--
	MAXIMUM	--	--	38	1½	510	20	.230	9

S, Separation between adjacent controls: 75 mm (3") minimum.

FIGURE 10. CRANKS

5.4.2.2.5.6 Steering wheel shape. Except for established uses in submarines, armored combat vehicles, aircraft, and other applications where maximum wheel deflection does not exceed ±2/3 π rad (120°), all steering wheels shall be round.

5.4.2.2.5.7 Power steering failure. Steering systems shall be designed with sufficient mechanical advantage to meet the force requirements of Table IX, even when the primary operating mode is powerassisted, i.e., the operator shall be able to steer the vehicle to a safe stop in the event of a power failure.

5.4.2.2.5.8 Steering ratio. Steering systems should be designed so that the maximum turning limits of the vehicle can be achieved with no more than 3½ turns if consistent with force limits of Table IX.

5.4.3 Linear controls.

5.4.3.1 Discrete linear controls.

5.4.3.1.1 Push buttons (finger or hand operated).

5.4.3.1.1.1 Use. Push buttons should 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.

5.4.3.1.1.2 Shape. The push button surface should 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.

5.4.3.1.1.3 Positive indication. A positive indication of control activation shall be provided (e.g., snap feel, audible click, or integral light).

5.4.3.1.1.4 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.

5.4.3.1.1.5 Dimensions, resistance, displacement, and separation. Except for use of push buttons in keyboards, control dimensions, resistance, displacement, and separation between adjacent edges of finger or hand-operated pushbuttons shall conform to the criteria in Figure 11.

5.4.3.1.1.6 Interlocks or barriers. Mechanical interlocks or barriers may be used instead of the spacing required by Figure 11.

5.4.3.1.2 Foot operated switches.

5.4.3.1.2.1 Use. Foot-operated switches should be used only where the operator is likely to have both hands occupied when switch activation may be

TABLE IX. HANDWHEELS

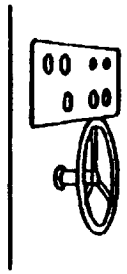
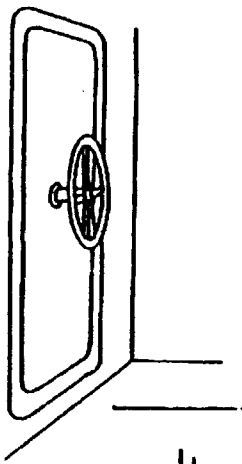
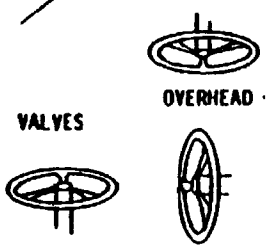
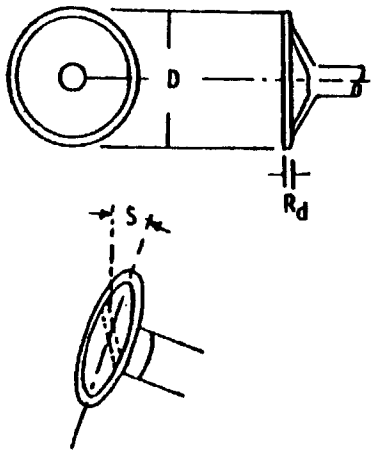
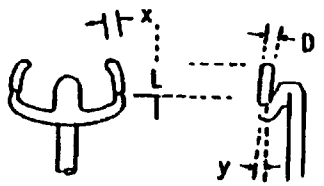
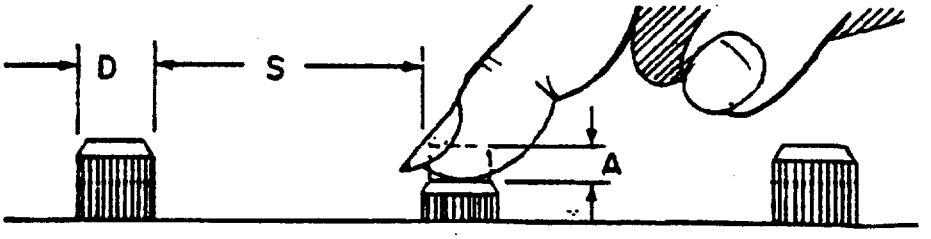
CONFIGURATION EXAMPLE	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
		DIAMETER	RIM DIAM	MIN HAND CLEARANCE		
	CONTINUOUS ADJUSTMENT FOR ALTERNATE SLEWING/PRECISE POSITIONING, USING DISPLAY REFERENCE. RESISTANCE LOW (e.g., BELOW 110 N (25 lb)	200-510 mm (8-20")	19-32 mm (3/4 - 1-1/4")	75 mm (3") around rim	See control/ display ratios 5.1.4	710 mm (28") elbow-elbow clearance
	CONTINUOUS LOCK-UNLOCK OPERATION	200 mm (8") for 22 N (5 lb) to 510 mm (20") for 155 N (35 lb)	19-32 mm (3/4 - 1-1/4")	75 mm (3") around rim	N/A	710 mm (28") elbow-elbow clearance
	HIGH TORQUE VALVES	200-400 mm (8-16") for overhead; 200-510 mm (8-20") for other positions; 300-1520 mm (12-60") abv standing surface	19-32 mm (3/4 - 1-1/4")	75 mm (3") around rim	See 5.1.4 when applicable	710 mm (28") elbow-elbow clearance

TABLE IX. HANDWHEELS (CONCLUDED)

CONFIGURATION EXAMPLE	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
		D, DIAMETER	R_d, RIM DIAM	S, SLOPE		
	VEHICLE STEERING (AUTOMOTIVE). MAX RESISTANCE POWER STEERING MAX NON-POWER = 220 N (50 lb)	355-400 mm (14-16") for pwr steering 400-510 mm (16-20") for non-pwr steering	19-32 mm (3/4 - 1-1/4")	525 mrad (30°) for light vehicle (preferred) 785 mrad (45°) for heavy vehicle (preferred)	Max of ±2/3 π rad (120°) when both hands must remain on wheel	N/A
		D, GRIP DIAM	L, GRIP LGTH	X-Y GRIP TILT		
	AIRCRAFT STEERING (COMBINE WITH LEVER FOR PITCH, RUDDER PEDALS FOR ROLL/STEER)	32 mm (1-1/4") preferred	100 mm (4") minimum	X = 262 mrad (15°) Y = 0-262 mrad (0-15°) preferred	±525 mrad (30°) max preferred	N/A



	DIMENSIONS		RESISTANCE		
	DIAMETER D				
	Fingertip	Thumb or Palm	Single Finger	Different Fingers	Thumb or Palm
Minimum	9.5 mm (3/8 in.)	19 mm (3/4 in.)	2.8 N (10 oz.)	1.4 N (5 oz.)	2.8 N (10 oz.)
Maximum	25 mm (1 in.)		11 N (40 oz.)	5.6 N (20 oz.)	23 N (80 oz.)

	DISPLACEMENT	
	A	
	Fingertip	Thumb or Palm
Minimum	2 mm (5/64 in.)	3 mm (1/8 in.)
Maximum	6 mm (1/4 in.)	38 mm (1-1/2 in.)

	SEPARATION			
	S			
	Single Finger	Single Finger Sequential	Different Fingers	Thumb or Palm
Minimum	13 mm (1/2 in.)	6 mm (1/4 in.)	6 mm (1/4 in.)	25 mm (1 in.)
Preferred	50 mm (2 in.)	13 mm (1/2 in.)	13 mm (1/2 in.)	150 mm (6 in.)

Note: Above data for barehand application. For gloved hand operation, minima should be suitably adjusted.

FIGURE 11. PUSHBUTTONS (FINGER OR HAND OPERATED)

required, or when load sharing among limbs is desirable. Because foot-operated switches are susceptible to accidental activation, their uses should be limited to non-critical or infrequent operations such as press-to-talk communication or vehicle headlight dimming.

5.4.3.1.2.2 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 should possess a frictional surface to minimize the possibility of the foot slipping off the switch.

5.4.3.1.2.3 Dimensions, resistance and displacement. Dimensions, reistance and displacement of foot-operated switches shall conform to the criteria in Figure 12. Although not recommended (i.e., 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 (8 in.) apart (vertical).

5.4.3.1.2.4 Feedback. A positive indication of control activation shall be provided (e.g., snap feel, audible click, association visual or auditory display).

5.4.3.1.3 Keyboards.

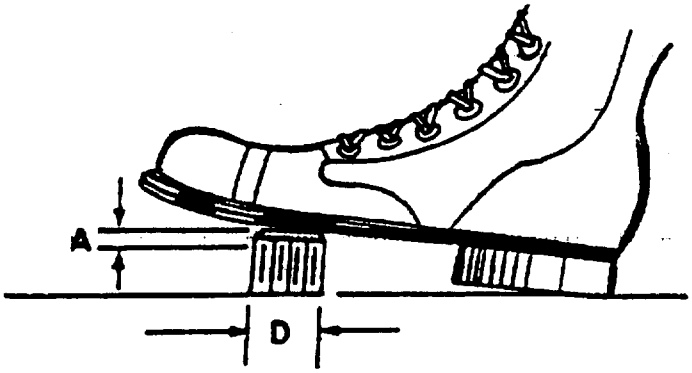
5.4.3.1.3.1 Use. Arrangements of push buttons in the form of keyboards should be used when alphabetic, numeric or special function information is to be entered into a system.

5.4.3.1.3.2 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:

a. Numeric keyboard. The configuration of a keyboard used to enter solely numeric information should be a 3 x 3 + 1 matrix with the zero digit centered on the bottom row.

b. Alpha-numeric keyboard. Keyboard configurations for entry of alphabetic and some numeric information shall conform to MIL-STD-1280. For some applications the entry of data varies from primarily alphabetic to primarily numeric. For these applications two alternatives are preferred: Provide a keyboard of the type shown in Figure 2 of MIL-STD-1280 (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.

5.4.3.1.3.3 Dimensions, resistance, displacement, and separation. The control dimensions, resistance, displacement and separation between adjacent



	DIAMETER	RESISTANCE		DISPLACEMENT			
	D			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.)

FIGURE 12. FOOT-OPERATED SWITCHES

edges of the pushbuttons which form keyboards shall conform to the criteria in Table X. For a given keyboard these criteria shall be uniform for all individual keys. For those applications where 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 X).

5.4.3.1.3.4 Slope. The slope of nonportable keyboards should be 260-435 mrad (15-25°) from the horizontal. The preferred slope is 280-300 mrad (17-18°). The slope of a portable device can be varied according to the preference of the operator.

5.4.3.1.3.5 Multiple keyboards. Systems containing more than one keyboard shall maintain the same configuration for alphanumeric, numeric and special function keys throughout the system.

5.4.3.1.3.6 Feedback. Feedback shall be provided to inform the operator whether the key was pressed, the intended key was pressed, and the next operation may be initiated, where applicable.

5.4.3.1.4 Toggle switch controls.

5.4.3.1.4.1 Use. Toggle switches should be used for functions which require two discrete positions or where space limitations are severe. Toggle switches with three positions shall be used only where the use of a rotary control, legend switch control, etc., is not feasible or when the toggle switch is of the spring-loaded, center position-off type. Three position toggle switches which 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.)

5.4.3.1.4.2 Accidental actuation. When the prevention of accidental actuation is of primary importance (i.e., 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 (3 lb). If a cover guard is used, its location when open shall not interfere with the operation of the protected device or adjacent controls.

5.4.3.1.4.3 Dimensions, resistance, displacement, and separation. Dimensions, resistance, displacement, and separation between adjacent edges of toggle switches shall conform to the criteria in Figure 13. Resistance should gradually increase, then drop when the switch snaps into position. The switch shall not be capable of being stopped between positions.

5.4.3.1.4.4 Positive indication. An indication of control activation shall be provided (e.g., snap feel, audible click, associated or integral light).

TABLE X. KEYBOARDS

	Dimensions		Resistance		
	Diameter D*				
	Bare-handed	Arctic mittens**	Numeric	Alpha-numeric	Dual Function
Minimum	10 mm.	19 mm	1 N	250 mN	250 mN
Maximum	19 mm		4 N	1.5 N	1.5 N
Preferred	13 mm.	19 mm			

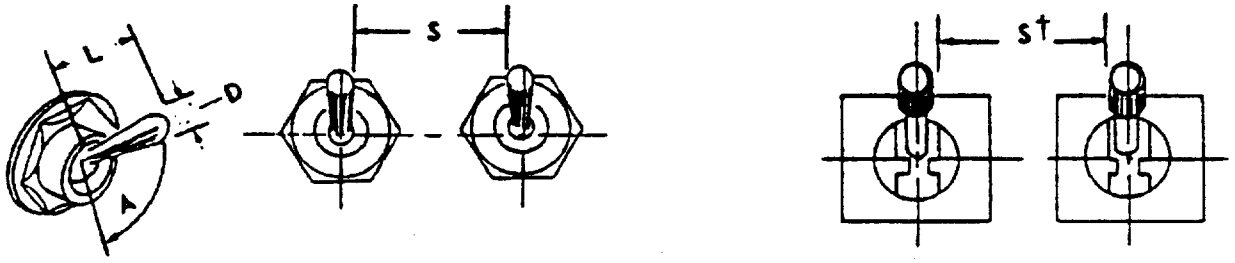
	Displacement			Separation
	Numeric	Alpha-numeric	Dual Function	(between adjacent key tops)
Minimum	0.8 mm	1.3 mm	0.8 mm	6.4 mm
Maximum	4.8 mm	6.3 mm	4.8 mm	
Preferred				6.4 mm

*See Figure 11
**Trigger finger type

	Dimensions		Resistance		
	Diameter D*				
	Bare-handed	Arctic mittens**	Numeric	Alpha-numeric	Dual Function
Minimum	0.385 in.	0.75 in.	3.5 oz	0.9 oz	0.9 oz
Maximum	0.75 in.		14.0 oz	5.3 oz	5.3 oz
Preferred	0.5 in.	0.75 in.			

	Displacement			Separation
	Numeric	Alpha-numeric	Dual Function	(between adjacent key tops)
Minimum	0.03 in.	0.05 in.	0.03 in.	0.25 in.
Maximum	0.19 in.	0.25 in.	0.19 in.	
Preferred				0.25 in.

*See Figure 11
**Trigger finger type



	DIMENSIONS			RESISTANCE	
	L Arm Length *	L Arm Length **	D Control Tip	Small Switch	Large Switch
Minimum	13 mm (1/2 in.)	38 mm (1-1/2 in.)	3 mm (1/8 in.)	2.8 N (10 oz.)	2.8 N (10 oz.)
Maximum	50 mm (2 in.)	50 mm (2 in.)	25 mm (1 in.)	4.5 N (16 oz.)	11 N (40 oz.)

	DISPLACEMENT BETWEEN POSITIONS	
	A	
	2 Position	3 Position
Minimum	525 mrad (30°)	295 mrad (17°)
Maximum	1400 mrad (80°)	700 mrad (40°)
Desired	...	435 mrad (25°)

	SEPARATION			
	S			
	Single Finger Operation	†	Single Finger Sequential Operation	Simultaneous Operation by Different Fingers
Minimum	19 mm (3/4 in.)	25 mm (1 in.)	13 mm (1/2 in.)	16 mm (5/8 in.)
Optimum	50 mm (2 in.)	50 mm (2 in.)	25 mm (1 in.)	19 mm (3/4 in.)

*Use by bare finger **Use with heavy handwear †Using a lever lock toggle switch

FIGURE 13. TOGGLE SWITCHES

5.4.3.1.4.5 Orientation. Toggle switches should be vertically oriented with OFF in the down position. Horizontal orientation and actuation of toggle switches shall be employed only for compatibility with the controlled function or equipment location.

5.4.3.1.5 Legend switches.

5.4.3.1.5.1 Dimensions, resistance, displacement, and separation. Dimensions, resistance, displacement, and separation between adjacent edges of legend switches shall conform to the criteria in Figure 14, except that maximum switch separation does not apply to non-matrix applications.

5.4.3.1.5.2 Barrier height. Barrier height from panel surface shall conform to the criteria in Figure 14. Unless otherwise specified, barriers are required on critical switches and on switches likely to be inadvertently activated. Barriers, when used, shall not obscure visual access to controls, labels or displays, and shall have rounded edges.

5.4.3.1.5.3 Other requirements.

a. For positive indication of switch actuation, the legend switch shall be provided with a detent or click. When touch sensitive switches are used, a positive indication of actuation shall be provided, e.g., an integral light within or above the switch being actuated.

b. The legend shall be legible with or without internal illumination.

c. 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 hrs.

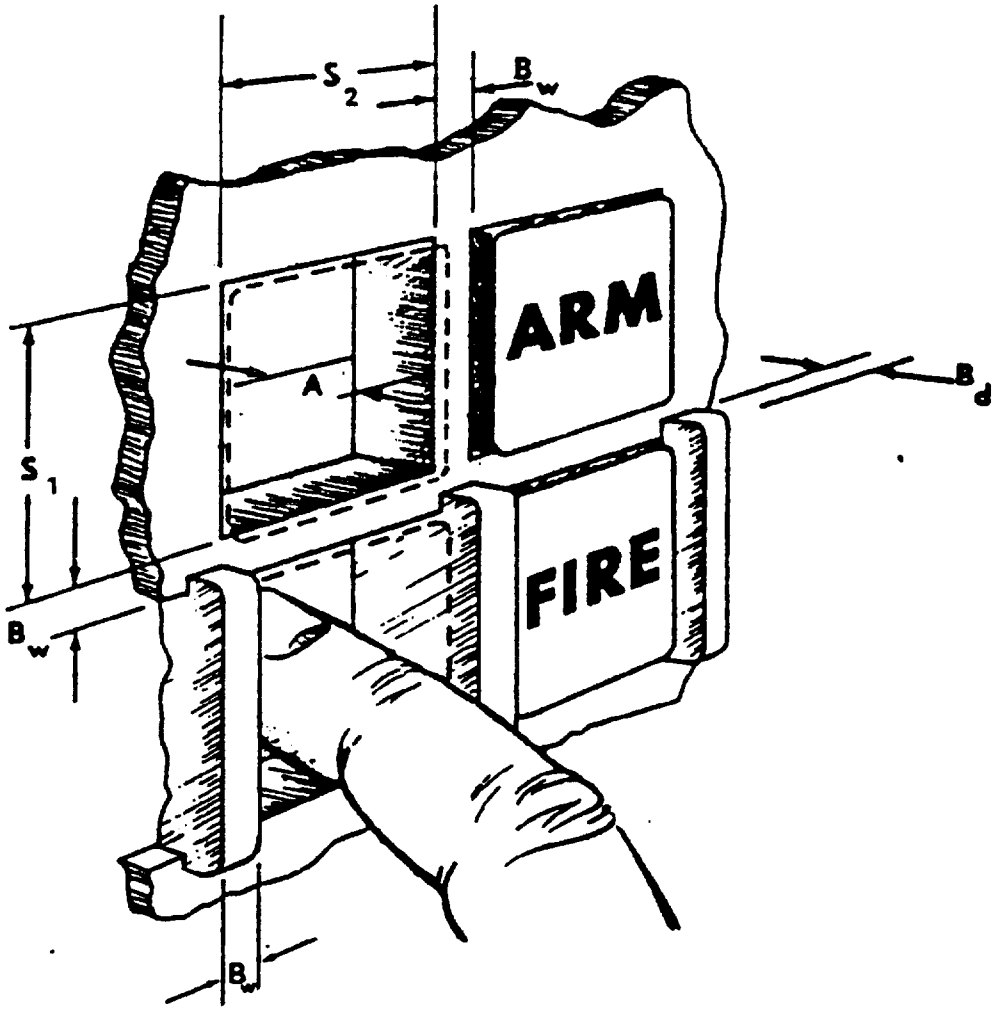
d. Lamps within the legend switch shall be replaceable from the front of the panel by hand and the legends or covers shall be keyed to prevent the possibility of interchanging the legend covers.

e. There shall be a maximum of three lines of lettering on the legend plate.

5.4.3.1.6 Rocker switches.

5.4.3.1.6.1 Use. Rocker switches may be used in lieu of toggle switches for functions which require two discrete positions. They may be used for applications where toggle switch handle protrusions might snag the operator's sleeve or phone cord, or where 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, etc., is not feasible or when the rocker switch is of the spring-loaded center-off type.

5.4.3.1.6.2 Accidental actuation. When the prevention of accidental actuation is of primary importance (i.e., critical, dangerous or hazardous



	S_1, S_2 Size	A DISPLACEMENT	BARRIERS		RESISTANCE
			B_w	B_d	
Minimum	19 mm* (3/4 in.)	3 mm** (1/8 in.)	3 mm (1/8 in.)	5 mm (3/16 in.)	2.8 N*** (10 oz.)
Maximum	38 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.)

* 15mm (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.

FIGURE 14. LEGEND SWITCH

conditions would result), channel guards or equivalent protective measures shall be provided.

5.4.3.1.6.3 Positive indication. An indication of control actuation shall be provided (e.g., snap feel, audible click, associated or integral light).

5.4.3.1.6.4 Dimensions, resistance, displacement and separation. Dimensions, resistance, displacement and separation between centers of rocker switches shall conform to the criteria in Figure 15. Resistance should gradually increase, then drop when the switch snaps into position. The switch shall not be capable of being stopped between positions.

5.4.3.1.6.6 Orientation. Where practicable, rocker switches shall be vertically oriented. Actuation of the upper wing shall turn the equipment or component on, cause the quantity to increase, or cause the equipment of component to move forward, clockwise, to the right or up. Horizontal orientation of rocker switches shall be employed only for compatibility with the controlled function or equipment location.

5.4.3.1.6.7 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 other color coding considerations, see 5.2.2.1.18. For areas where ambient illumination will provide display luminance below 3.5 cd/m^2 (1 Ft-L), the rocker switch should be internally illuminated. Digits and letters shall appear as illuminated characters on an opaque background and their dimensions should approximate the following:

a. Height: 4.8 mm (3/16")

b. Height-to-Width Ratio: 3:2

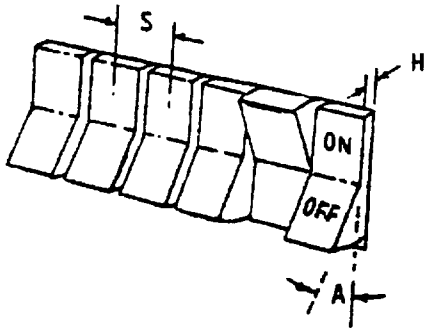
c. Height-to-Stroke-Width Ratio: 10:1

5.4.3.1.7 Slide switch controls.

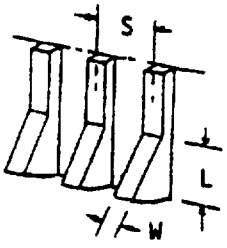
5.4.3.1.7.1 Use. Slide switch controls may be used for functions which require two discrete positions. Slide switch controls may also be used for functions which require a higher number of discrete positions in which the switches are arranged in a matrix to permit easy recognition of relative switch settings (e.g., audio settings across frequencies), but shall not be used where mispositioning is to be avoided.

5.4.3.1.7.2 Accidental actuation. When the prevention of accidental actuation is of primary importance (i.e., critical, dangerous, or hazardous conditions would result), channel guards or other equivalent means shall be provided.

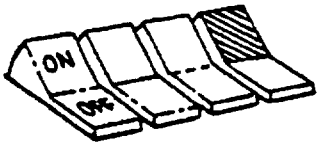
5.4.3.1.7.3 Dimensions, resistance, and separation. Dimensions, resistance and separation of slide switch handles shall conform to criteria in Figure 16. Detents shall be provided for each control setting. Resistance should



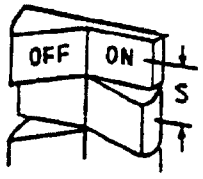
STANDARD ROCKER SWITCH: USE AS ALTERNATE TWO-POSN TOGGLE SWITCH TO PROVIDE LABELING SURFACE, EASE OF COLOR CODING, SWITCH ILLUMINATION.



NARROW WIDTH, ESPECIALLY DESIRABLE FOR TACTILE DEFINITION WITH GLOVES.



ALTERNATE (CONTRAST) COLOR FOR ON VERSUS OFF TO PROVIDE CONSPICUOUS CUE OF SWITCH POSITION. ILLUMINATED "ON" DESIRABLE AS SECOND FEEDBACK CUE.



	DIMENSIONS		RESISTANCE
	W, WIDTH	L, LENGTH	
MINIMUM	6 mm (1/4")	13 mm (1/2")	2.8 N (10 oz.)
MAXIMUM			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")	530 mrad (30^{o})	19 mm (3/4")	32 mm (1-1/4")

FIGURE 15. ROCKER SWITCHES

Detents shall be provided for each control setting. Resistance should gradually increase, then drop when the switch snaps into position. The switch shall not be capable of stopping between positions.

5.4.3.1.7.4 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 employed only for compatibility with the controlled function or equipment location.

5.4.3.1.7.5 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.

5.4.3.1.8 Discrete push-pull controls.

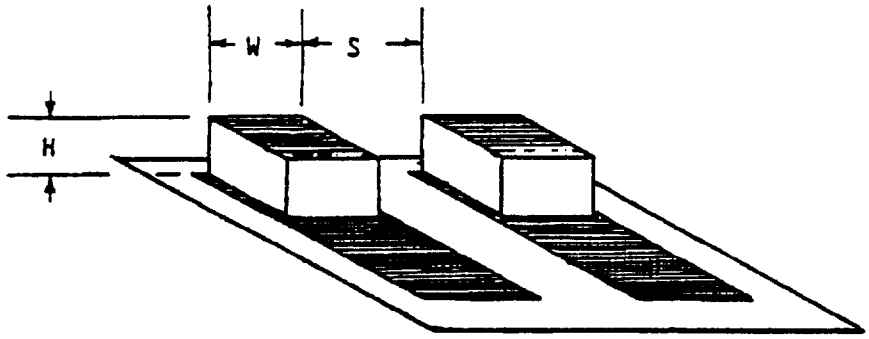
5.4.3.1.8.1 Applications. Push-Pull controls may be used when two discrete functions are to be selected. However such applications should be used sparingly and for applications in which such configurations are typically expected (e.g., vehicle headlight switch, choke, etc.). They may also be used in certain cases where limited panel space suggests a miniaturized knob that may be used to serve two related, but distinct functions (e.g., an ON-OFF/Volume switch for a T.V. monitor.) A three-position push-pull control is acceptable in isolated instances where the criticality of inadvertent selection of the wrong position has no serious consequences (e.g., the typical vehicle headlight switch configuration that provides three "pull" positions--OFF/Park/Headlight-plus a rotary panel light and dome light switch).

5.4.3.1.8.2 Handle dimensions, displacement and clearances. Push-Pull control handles shall conform to criteria in Table XI.

5.4.3.1.8.3 Rotation. Except for combination push-pull/rotate switch configurations, push-pull control handles shall be keyed to a non-rotating shaft, unless the control is to be used for a special application (e.g., 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.

5.4.3.1.8.4 Detents. Mechanical detents shall be incorporated into push-pull controls to provide tactile indication of positions.

5.4.3.1.8.5 Snagging and inadvertent contact. Use, location and operating axis of push-pull type controls shall preclude the possibility of the operator's:



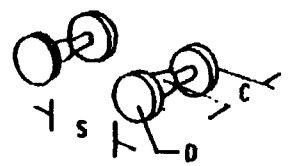
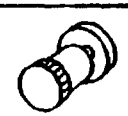
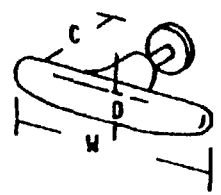
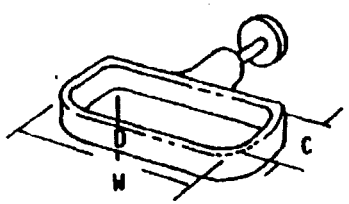
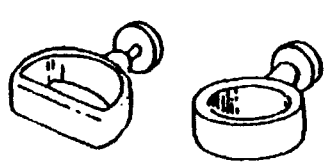
	DIMENSIONS			RESISTANCE	
	H ACTUATOR HEIGHT *	H ACTUATOR HEIGHT **	W ACTUATOR WIDTH	SMALL SWITCH	LARGE SWITCH
MINIMUM	6 mm (1/4")	13 mm (1/2")	6 mm (1/8")	2.8 N (10 oz.)	2.8 N (10 oz.)
MAXIMUM	--	--	25 mm (1")	4.5 N (16 oz.)	11 N (40 oz.)

	SEPARATION, S		
	SINGLE FINGER OPERATION	SINGLE FINGER SEQUENTIAL OPERATION	SIMULTANEOUS OPERATION BY DIFFERENT FINGERS
MINIMUM	19 mm (3/4")	13 mm (1/2")	16 mm (5/8")
OPTIMUM	50 mm (2")	25 mm (1")	19 mm (3/4")

*Use by bare finger.
**Use with heavy handwear.

FIGURE 16. SLIDE SWITCHES

TABLE XI. PUSH-PULL CONTROLS

CONFIGURATION EXAMPLE	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	PUSH-PULL CONTROL, LOW RESISTANCE, FOR TWO-POSITION, MECHANICAL AND/OR ELECTRICAL SYSTEMS. ALTERNATE THREE POSITION PLUS ROTARY FUNCTION ACCEPTABLE FOR APPLICATION SUCH AS VEHICLE HEADLIGHT PLUS PARKING LIGHTS, PANEL AND DOME LIGHTS PROVIDE SERRATED RIM.	D, MIN DIAM: 19 mm (3/4")	C, MIN CLEARANCE: 25 mm (1") Add 13 mm (1/2") for gloved hand		25 ±13 mm (1 ±1/2") MIN BETWEEN PULL POSNS: 13 mm (1/2")	S, MIN SPACE BETWEEN: 38 mm (1-1/2") Add 13 mm (1/2") for gloved hand
	ALTERNATE HANDLE; MINIATURE ELECTRICAL PANEL SWITCH ONLY. AVOID GLOVE USE APPLICATION.	D, MIN DIAM: 6 mm (1/4")	N/A	L, MIN LGTH: 19 mm (3/4")	MINIMUM: 13 mm (1/2")	S, MIN SPACE BETWEEN: 25 mm (1")
	HIGH-FORCE PUSH-PULL, FOR TWO-POSITION MECHANICAL SYSTEM ONLY.	W, MIN WIDTH: 100 mm (4")	D, DEPTH: 16-38 mm (5/8 - 1-1/2")	C, MIN CLEARANCE: 38 mm (1-1/2") Add 6 mm (1/4") for gloved hand	MINIMUM: 25 mm (1") PREFERRED: 50 mm (2")	
 	SAME AS ABOVE. PREFERRED WHERE POSSIBLE GARMENT OR CABLE-SNAG POSSIBILITY EXISTS. NOTE: 1 & 2 FINGER PULLS ALSO ACCEPTABLE FOR LESS THAN 18 N (4 lb) APPLICATIONS.	W, MIN WIDTH: 100 mm (4") Add 25 mm (1") for gloves	D, DEPTH: 16-38 mm (5/8 - 1-1/2")	C, MIN CLEARANCE: 32 mm (1-1/2")	MINIMUM: 25 mm (1") PREFERRED: 50 mm (2")	S, MIN SPACE BETWEEN: 13 mm (1/2")

a. Bumping a control while getting into or out of position (as in a vehicle).

b. Snagging clothing, communication cables, or other equipment items on the control.

c. Inadvertently deactuating the control setting while reaching for another control.

5.4.3.1.8.6 Direction of control motion. Control direction shall be as follows:

a. Pull towards the operator for ON or actuation; push away for OFF or deactuation.

b. Clockwise for actuation or increasing function of combination pull/rotary switches.

5.4.3.1.8.7 Resistance. Force for pulling a panel control with fingers should be not more than 18 N (4 lb), for pulling a T-bar with four fingers should be not more than 45 N (10 lb).

5.4.3.1.9 Printed circuit (PC) switch controls.

5.4.3.1.9.1 Use. PC switches may be used when manual programming functions are required in systems employing printed circuit boards.

5.4.3.1.9.2 Dimensions, resistance, displacement and separation. Dimensions, resistance, displacement and separation between adjacent PC switch actuators shall conform to the following:

a. Dimensions of actuators shall be sufficiently high to permit error-free manipulation by the operator when using some commonly available stylus (e.g., pencil or pen). The design of the actuators shall not require the use of a special tool for manipulation.

b. Actuator resistance shall be sufficiently high to avoid inadvertent actuation under expected use conditions. Resistance should gradually increase, then drop when the actuator snaps into position. The actuator shall not be capable of stopping between positions.

c. When actuators are slide-type, they shall have sufficient travel (displacement) to permit easy recognition of switch setting. At a minimum, the travel should be twice the length of the actuator. When actuators are rocker-type, the actuated wing shall be flush with the surface of the module.

d. Actuators shall have sufficient separation to permit error-free manipulation by the operator (i.e., the stylus cannot inadvertently contact adjacent actuators).

5.4.3.1.9.3 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.

5.4.3.2 Continuous adjustment linear controls.

5.4.3.2.1 Levers.

5.4.3.2.1.1 Use. Levers may be used when large amounts of force or displacement are involved or when multidimensional movements of controls are required.

5.4.3.2.1.2 Coding. When several levers are grouped in proximity to each other, the lever handles shall be coded.

5.4.3.2.1.3 Labeling. When practicable, all levers shall be labeled as to function and direction of motion.

5.4.3.2.1.4 Limb support. When levers are used to make fine or continuous adjustments, support shall be provided for the appropriate limb segment as follows:

a. For large hand movements: elbow

b. For small hand movements: forearm

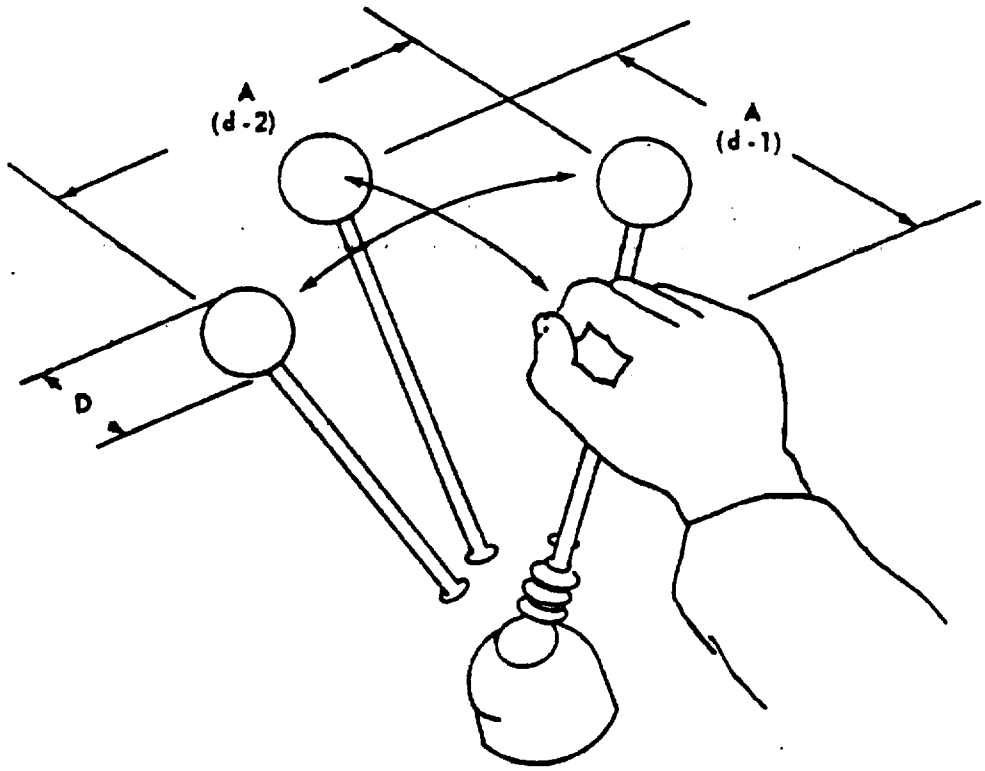
c. For finger movements: wrist.

5.4.3.2.1.5 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 Figure 17.

5.4.3.2.1.6 Resistance. The resistance incorporated in levers shall be within the limits indicated in Figure 17, measured as linear force applied to a point on the handle. (NOTE: 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 percent 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.)

5.4.3.2.1.7 Displacement and separation. Control displacement (for the seated operator) and separation shall conform to the criteria in Figure 17.

5.4.3.2.2 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



	DIAMETER		RESISTANCE			
	D		(d-1)		(d-2)	
	Finger Grasp	Hand Grasp	One Hand	Two Hands	One Hand	Two Hands
Minimum	13 mm (1/2 in.)	38mm (1-1/2 in.)	9 N (2 lb)	9 N (2 lb)	9 N (2 lb)	9 N (2 lb)
Maximum	38mm (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			
	Forward (d-1)	Lateral (d-2)	One Hand Random	Two Hands Simultaneously
Minimum	-	-	50 mm (2 in.)	75 mm (3 in.)
Preferred			100 mm (4 in.)	125 mm (5 in.)
Maximum	360 mm (14 in.)	970 mm (38 in.)		

FIGURE 17. LEVER

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 positioning speed, displacement joysticks should 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 which are used for rate control should be spring-loaded for return to center when the hand is removed. Displacement joysticks which have a 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.

5.4.3.2.2.1 Hand operated displacement joysticks

5.4.3.2.2.1.1 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.

5.4.3.2.2.1.2 Dynamic characteristics. Movement shall not exceed 45 degrees 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 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 second.

5.4.3.2.2.1.3 Dimensions, resistance, and clearance. The hand grip length should be in the range of 110 - 180 mm (4.3" - 7.1"). The grip diameter shall not exceed 50 mm (2"). Clearances of 100 mm (4") to the side and 50 mm (2") 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.

5.4.3.2.2.2 Finger operated displacement joysticks

5.4.3.2.2.2.1 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 should be sufficient to maintain the handle position when the hand is removed.

5.4.3.2.2.2.2 Dynamic characteristics. Movement shall not exceed 45 degrees 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 utilized as indicated in Figure 18, 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 second.

5.4.3.2.2.2.3 Dimensions, resistance, and clearance. The joystick should be mounted on a desk or shelf surface as shown in Figure 18. 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.

5.4.3.2.2.3 Thumbtip/fingertip operated displacement joysticks.

5.4.3.2.2.3.1 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 hand grip shall not simultaneously function as a joystick controller.

5.4.3.2.2.3.2 Dynamic characteristics. Movement shall not exceed 45 degrees from the center position.

5.4.3.2.2.3.3 Dimensions, resistance, and clearance. Joysticks shall be mounted to provide wrist or hand support. Console mounted devices shall be mounted as shown in Figure 18. Modular devices shall be mounted to allow actuation of the joystick without slippage, movement, or tilting of the mounting base.

5.4.3.2.3 Isometric joystick (two axis controllers). (Also known as stiff stick, force stick, or pressure stick. The control has no perceptible movement, but its output is a function of the 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 should ordinarily not be used in applications where it would be

necessary for the operator to maintain a constant force on the control for a long period of time or where 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 accuracy, isometric joysticks should be selected over displacement joysticks. Isometric joystick 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 in order to aid the operator in bringing the follower back onto the display.

5.4.3.2.3.1 Hand-operated.

5.4.3.2.3.1.1 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.

5.4.3.2.3.1.2 Dynamic characteristics. Maxmimum force for full output shall not exceed 118 N (26.7 lb).

5.4.3.2.3.1.3 Dimensions, resistance, and clearance. The hand grip length should be in the range of 110 - 180 mm (4.3" - 7.1"). The grip diameter shall not exceed 50 mm (2"). Clearances of 100 mm (4") to the side and 50 mm (2") 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.

5.4.3.2.3.2 Finger operated.

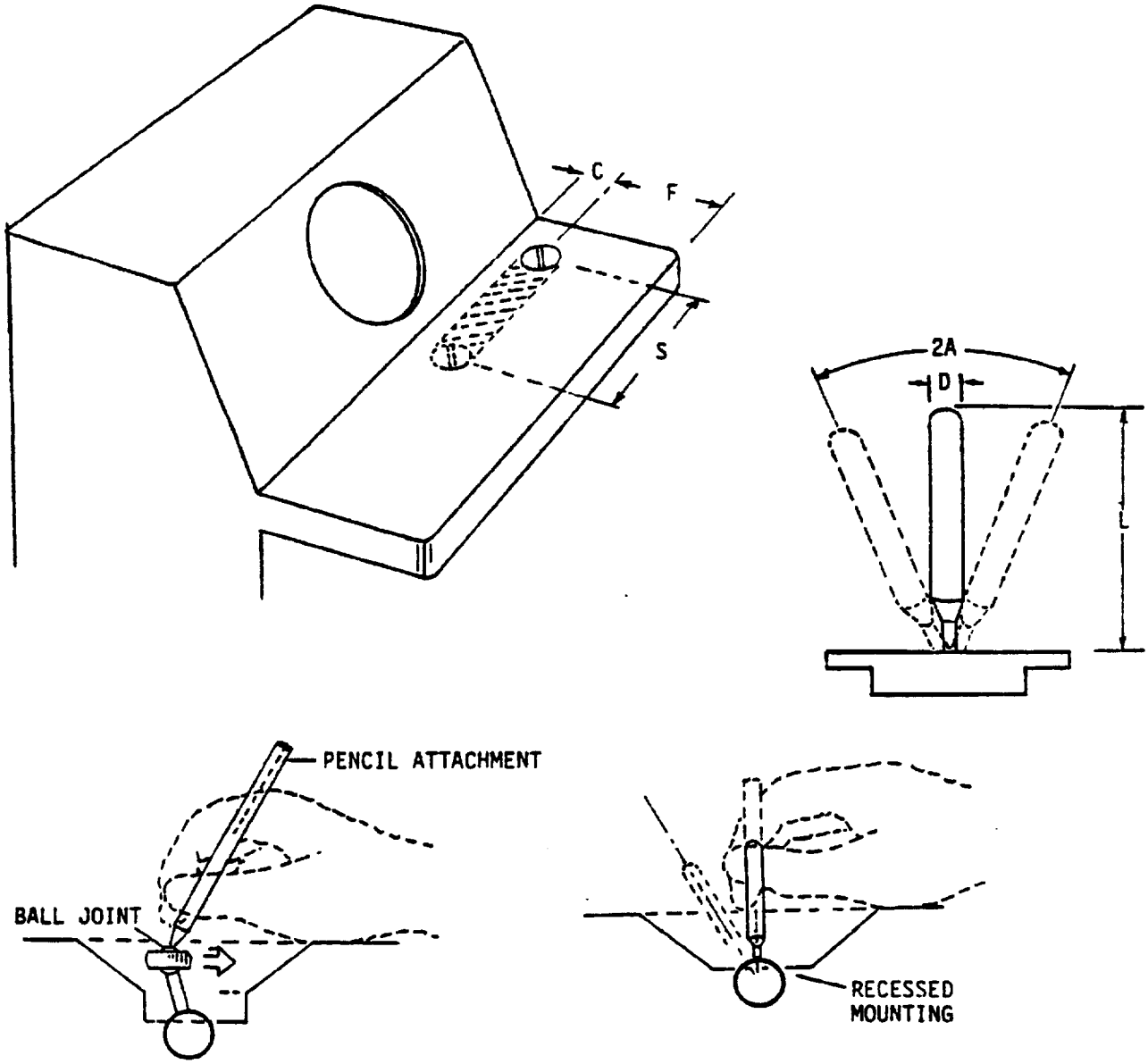
5.4.3.2.3.2.1 Specific use.

5.4.3.2.3.2.2 Dynamic characteristics.

5.4.3.2.3.2.3 Dimensions, resistance, and clearance. The joystick should be mounted on a desk or shelf surface as shown in Figure 18. 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.

5.4.3.2.3.3 Thumbtip/fingertip operated.

5.4.3.2.3.3.1 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 hand grip shall not simultaneously function as a joystick controller.



	DIMENSIONS		RESISTANCE	DISPLACEMENT	CLEARANCE		
	D DIAM	L LENGTH		A	S DISPLAY CL TO STICK CL	C AROUND STICK	F STICK CL TO SHELF FRONT
MINIMUM	6.5 mm (1/4")	75 mm (3")	3.3 N (12 oz.)		0	*	120 mm (4-3/4")
MAXIMUM	16 mm (5/8")	150 mm (6")	8.9 N (32 oz.)	$\frac{\pi}{4}$ rad (45^{o})	400 mm (15-3/4")		250 mm (9-7/8")

*Maximum stick excursion plus 100 mm (4").

FIGURE 18. ISOTONIC JOYSTICKS

5.4.3.2.3.3.2 Dynamic characteristics.

5.4.3.2.3.3.3 Dimensions, resistance and clearance. Joysticks shall be mounted to provide wrist or hand support. Console mounted devices shall be mounted as shown in Figure 18. Modular devices shall be mounted to allow actuation of the joystick without slippage, movement, or tilting of the mounting base.

5.4.3.2.4 Ball control (Also known as track ball, ball tracker, joyball and rolling ball.)

5.4.3.2.4.1 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 without limit in any direction it is well suited for applications where there may be accumulative travel in a given direction. In any application which 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 should be used only as position controls (i.e., a given movement of a ball makes a proportional movement of the follower on the display).

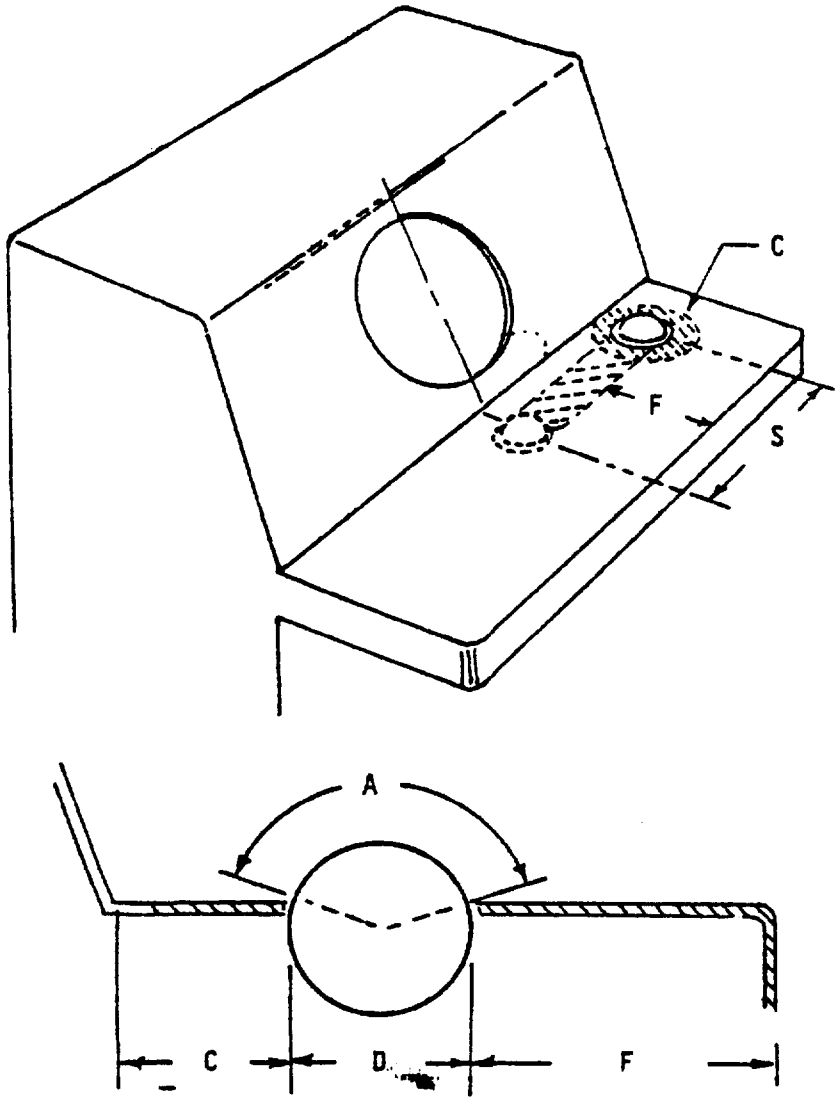
5.4.3.2.4.2 Dynamic characteristics. The ball control shall be capable of rotation in any direction so as to generate any combination of x and y output values. When moved in either the x or y directions alone there shall be no apparent cross-coupling (follower movement in the orthogonal direction). While 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.

5.4.3.2.4.3 Limb support. When trackball controls are used to make precise or continuous adjustments, wrist support or arm support or both shall be provided. (See 5.4.3.2.1.4.)

5.4.3.2.4.4 Dimensions, resistance and clearance. Dimensions, resistance and clearances should conform to the criteria in Figure 19. The smaller diameter ball controls should 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 (see Figure 19).

5.4.3.2.5 Grid-and-stylus devices. These provisions cover various techniques which utilize some means of establishing an x and y grid and a stylus for designating specific points on that grid for control purposes (e.g., time-shared x and y potential grids and a voltage-sensitive stylus).

5.4.3.2.5.1 Application. Grid and stylus devices may be used for data pickoff from a CRT, entry of points on a display, generation of free-drawn



	DIMENSIONS		RESISTANCE		CLEARANCE		
	D DIAM	A SURFACE EXPOSURE	PRECISION REQUIRED	VIBRATION OR ACCEL CONDITIONS	S DISPLAY CL TO BALL CL	C AROUND BALL	F BALL TO SHELF FRONT
MINIMUM	50 mm (2")	1745 mrad (100°)			0	50 mm (2")	120 mm (4-3/4")
MAXIMUM	150 mm (6")	2445 mrad (140°)	1.0 N (3.6 oz.)	1.7 N (6 oz.)	320 mm (12-5/8")		250 mm (9-3/4")
PREFERRED	100 mm (4")	2095 mrad (120°)	0.3 N (1.1 oz.)				

FIGURE 19. BALL CONTROLS

graphics and similar 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, etc.) shall be presented on the display at the coordinate values selected by the stylus. Devices of this type should be used only for zero order control functions (i.e., displacement of the stylus from the reference position causes a proportional displacement of the follower).

5.4.3.2.5.2 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.

5.4.3.2.5.3 Dimensions and mounting. Transparent grids which are used as display overlays shall conform to the size of the display. Grids which are displaced from the display should approximate the display size and should be mounted below the display in an orientation to preserve directional relationships to the maximum extent (i.e., 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).

5.4.3.2.6 Free-moving XY controller (Mouse)

5.4.3.2.6.1 Application. This type of controller may be used on any flat surface to generate x and y coordinate values which control the position of the follower on the associated display. It may be used for data pickoff or for entry of coordinate values. It should be used for zero order control only (i.e., generation of x and y outputs by the controller results in proportional displacement of the follower). It should not be used for generation of free-drawn graphics.

5.4.3.2.6.2 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 $\pm$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 6110 and 175 mrad (350° and 10°). 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 $\pm$175 mrad (10°). The controller 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 which 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.

5.4.3.2.6.3 Dimensions and shape. The free-moving xy controller shall have no sharp edges but shall be shaped roughly as a rectangular solid, with limiting dimensions as follows.

	Min.	Max.
Width (spanned by thumb to finger grasp)	40 mm (1.6 in.)	70 mm (2.8 in.)
Length	70 mm (2.8 in.)	120 mm (4.7 in.)
Thickness	25 mm (1.0 in.)	40 mm (1.6 in.)

5.4.3.2.7 Light pen

5.4.3.2.7.1 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 (paragraph 5.4.3.2.5.1).

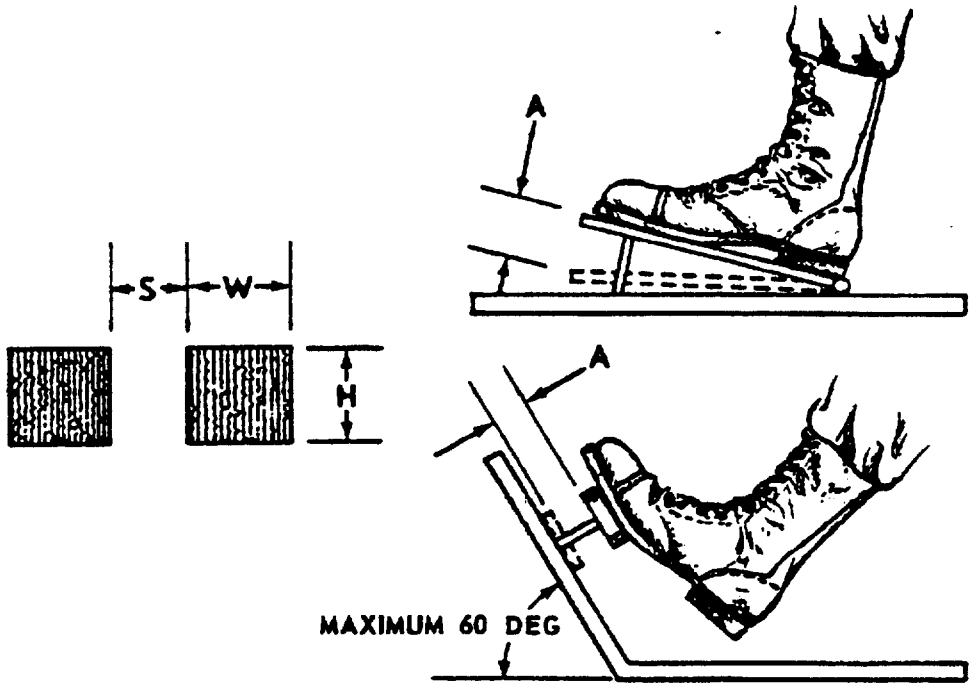
5.4.3.2.7.2 Dynamic characteristics. When used as a two-axis controller, light pen dynamic characteristics shall conform to paragraph 5.4.3.2.5.2.

5.4.3.2.7.3 Dimensions and mounting. The light pen shall be 120 - 180 mm (4.7 - 7.1") long with a diameter of 7 - 20 mm (0.3 - 0.8"). 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.

5.4.3.2.8 Pedals.

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

5.4.3.2.8.2 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 Figure 20). Pedals that may be held or must be adjusted (accelerator, clutch, etc.) shall be located so the operator can



	DIMENSIONS		DISPLACEMENT			
	H Height	W Width	A 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	-	-	65mm (2-1/2 in.)	65mm (2-1/2 in.)	65mm (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	
	S	
	One Foot Random	One Foot Sequential
Minimum	100 mm (4 in.)	50 mm (2 in.)
Preferred	150 mm (6 in.)	100 mm (4 in.)

FIGURE 20. PEDALS

"rest" and "steady" the foot, i.e., the pedal shall be an 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.

5.4.3.2.8.3 Control return. Except for controls which generate a continuous output, (e.g., rudder controls) pedals shall return to the original null position without requiring assistance from the operator (e.g., 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 (e.g., accelerator pedal).

5.4.3.2.8.4 Pedal travel path. The travel path shall be compatible with the natural articulation path of the operator's limbs (i.e., thigh, knee, ankle).

5.4.3.2.8.5 High force application aids. When high forces are required to fully actuate a pedal, appropriate aids shall be provided to assist the operator in applying maximum force including the following where applicable:

a. Seat backrest.

b. Optimized seat height-to-pedal and normal reach distance for maximum force, i.e., seat reference point (SRP) and pedal are at the same vertical height and reach distance is configured so the upper thigh and lower leg create an angle of approximately 2790 mrad (160°) (see Figure 22).

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

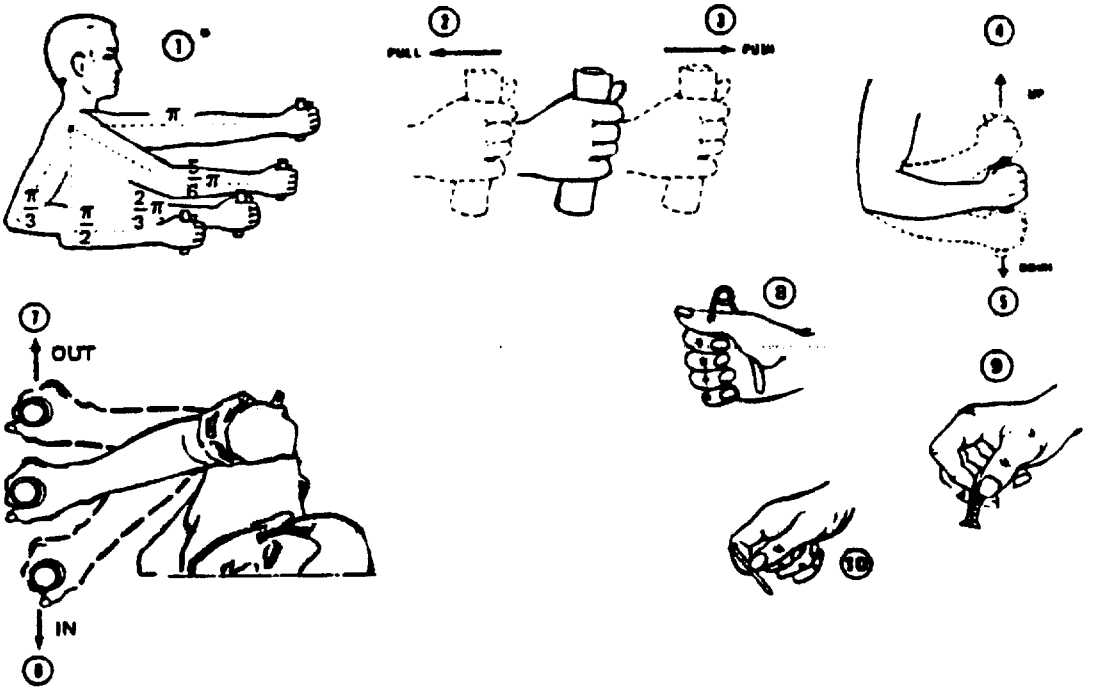
5.4.3.2.8.6 Non-slip pedal surface. Pedals used for high force applications shall be provided with a non-skid surface. Similar surfaces are desirable for all pedals.

5.4.3.2.8.7 Dimensions, resistance, displacement and separation. Dimensions, resistance, displacement and separation of pedals shall conform to the criteria in Figure 20.

5.4.4 High-force controls.

5.4.4.1 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, e.g., seat backrest, foot support. Sustained (i.e., durations longer than 3 seconds) high force requirements shall be avoided.

5.4.4.2 Arm, hand, and thumb-finger controls. Where arm, hand and thumb-finger controls requiring high control forces are to be used, the

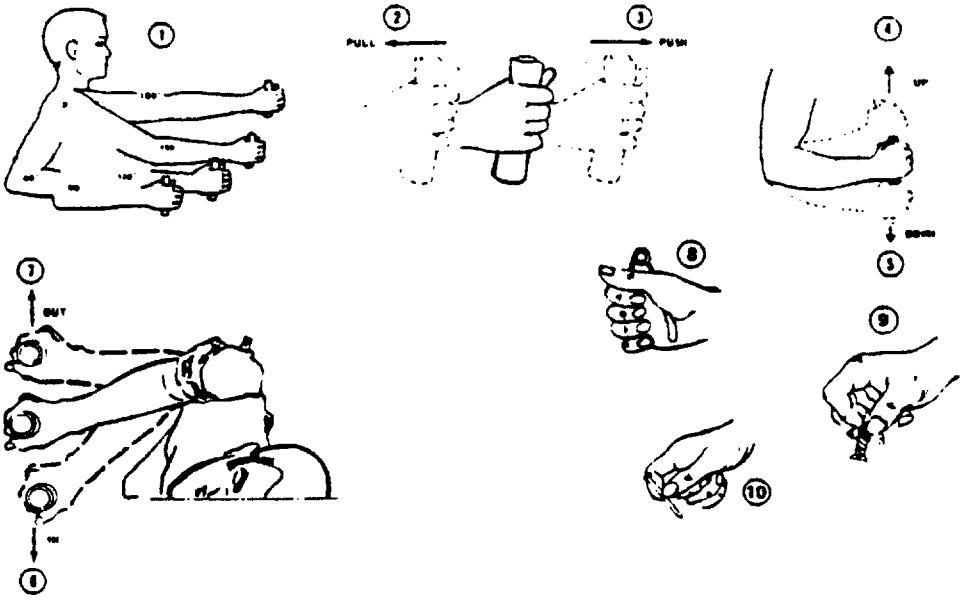


ARM STRENGTH (N)												
(1)	(2)		(3)		(4)		(5)		(6)		(7)	
DEGREE OF ELBOW FLEXION (rad)	PULL		PUSH		UP		DOWN		IN		OUT	
	L**	R**	L	R	L	R	L	R	L	R	L	R
π	222	231	187	222	40	62	58	76	58	89	36	62
5/6 π	187	249	133	187	67	80	80	89	67	89	36	67
2/3 π	151	187	116	160	76	107	93	116	89	98	45	67
1/2 π	142	165	98	160	76	89	93	116	71	80	45	71
1/3 π	116	107	98	151	67	89	80	89	76	89	53	76

HAND, AND THUMB-FINGER STRENGTH (N)				
	(8)		(9)	(10)
	HAND GRIP		THUMB-FINGER GRIP (PALMER)	THUMB-FINGER GRIP (TIPS)
	L	R		
MOMENTARY HOLD	250	260	60	60
SUSTAINED HOLD	145	155	35	35

*Elbow angle shown in radians.
**L = Left; R = Right.

FIGURE 21. ARM, HAND, AND THUMB-FINGER STRENGTH (5TH PERCENTILE MALE DATA)



ARM STRENGTH (Lb)												
(1)	(2)		(3)		(4)		(5)		(6)		(7)	
DEGREE OF ELBOW FLEXION (deg)	PULL		PUSH		UP		DOWN		IN		OUT	
	L	R*	L	R	L	R	L	R	L	R	L	R
180	50	52	42	50	9	14	13	17	13	20	8	14
150	42	56	30	42	15	18	18	20	15	20	8	15
120	34	42	26	36	17	24	21	26	20	22	10	15
90	32	37	22	36	17	20	21	26	16	18	10	16
60	26	24	22	34	15	20	18	20	17	20	12	17

HAND, AND THUMB-FINGER STRENGTH (Lb)				
	(8)		(9)	(10)
	HAND GRIP		THUMB-FINGER GRIP (PALMER)	THUMB-FINGER GRIPS (TIPS)
	L	R		
MOMENTARY HOLD	56	59	13	13
SUSTAINED HOLD	33	35	8	8

*L = LEFT; R = RIGHT

FIGURE 21. ARM, HAND, AND THUMB-FINGER STRENGTH (5TH PERCENTILE MALE DATA)(CONCLUDED)

5.4.6 Touch-screen controls for displays

5.4.6.1 Use. Touch-screen control may be used to provide an overlaying control function to a data display device such as CRTs, dot matrix/segmented displays, electroluminescent displays, programmable indicators, or other display devices where direct visual reference access and optimum direct control access are desired.

5.4.6.2 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.

5.4.6.3 Positive indication. A positive indication of touch-screen actuation shall be provided to acknowledge the system response to the control action.

5.4.6.4 Dimensions and separation. The dimensions and separation of responsive areas of the touch-screen shall conform to S_1, S_2 and B_W of Figure 14.

5.4.6.5 Resistance. Force required to operate force-actuated touch-screens shall conform to the alphanumeric resistance limits of Table X.

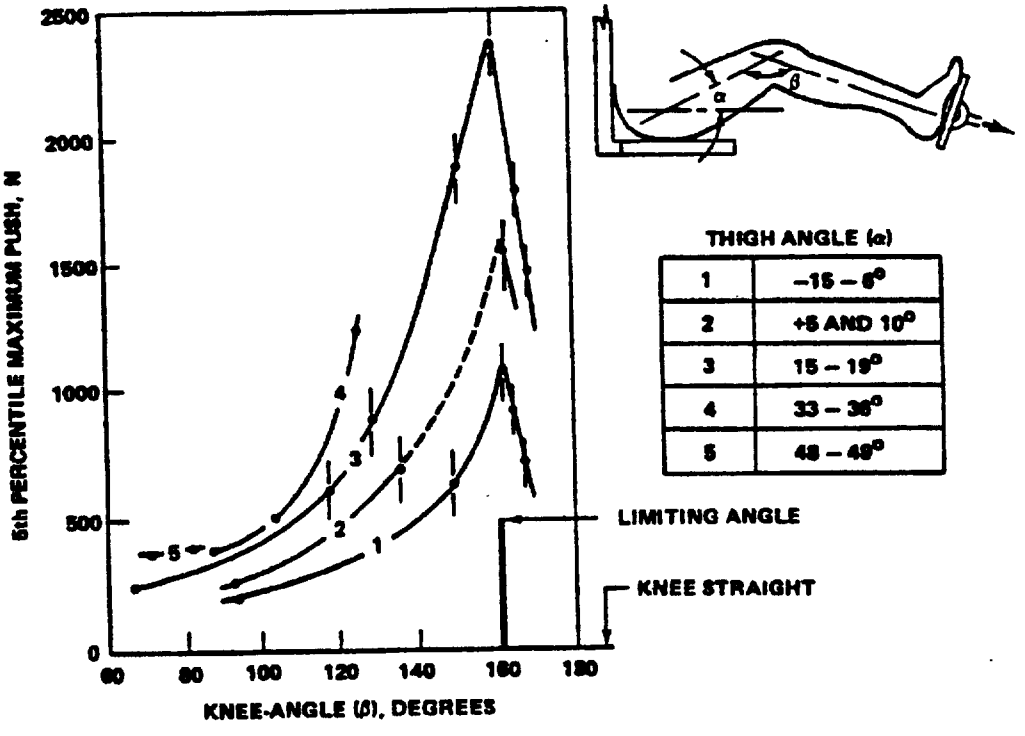


FIGURE 22. LEG STRENGTH AT VARIOUS KNEE AND THIGH ANGLES (5th PERCENTILE MALE DATA)

maximum force requirements shall not exceed those specified in Figure 21, which should be corrected, where applicable, for females. (Two-thirds of each value shown is considered to be a reasonable adjustment.)

5.4.4.3 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 the knee angle. Figure 22 specifies the mean maximum push at various knee and thigh angles. The maximum push is at about the 160 degree angle, referred to as the limiting angle. The values of Figure 22 apply to males only and should be corrected for females. (Two-thirds of each value is considered to be a reasonable adjustment.)

5.4.5 Miniature controls

5.4.5.1 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.

5.4.5.2 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 should conform to the criteria specified for the standard size of that type of control.

5.4.5.3 Other requirements. Other design considerations (e.g., labeling, orientation) shall conform to the requirements specified for the standard size of the control.

5.4.6 Touch-screen controls for displays

5.4.6.1 Use. Touch-screen control may be used to provide an overlaying control function to a data display device such as CRTs, dot matrix/segmented displays, electroluminescent displays, programmable indicators, or other display devices where direct visual reference access and optimum direct control access are desired.

5.4.6.2 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.

5.4.6.3 Positive indication. A positive indication of touch-screen actuation shall be provided to acknowledge the system response to the control action.

5.4.6.4 Dimensions and separation. The dimensions and separation of responsive areas of the touch-screen shall conform to S_1, S_2 and B_W of Figure 14.

5.4.6.5 Resistance. Force required to operate force-actuated touch-screens shall conform to the alphanumeric resistance limits of Table X.

5.5 Labeling

5.5.1 General

5.5.1.1 Application. Labels, legends, placards, signs or markings, or a combination of these shall be provided whenever it is necessary for personnel to identify, interpret, follow procedures or avoid hazards, except where it is obvious to the observer what an item is and what he or she is to do with it.

5.5.1.2 Label characteristics. Label characteristics shall be consistent with such factors as:

a. Accuracy of identification required.

b. Time available for recognition or other responses.

c. Distance at which the labels must be read.

d. Illuminant level and color.

e. Criticality of the function labeled.

f. Consistency of label design within and between systems.

5.5.1.3 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.

5.5.2 Orientation and location.

5.5.2.1 Orientation. Labels and information thereon should be oriented horizontally so that they may be read quickly and easily from left to right. Vertical orientation may be used only when labels are not critical for personnel safety or performance and where space is limited. When used, vertical labels shall read from top to bottom.

5.5.2.2 Location. Labels shall be placed on or very near the items which they identify, so as to eliminate confusion with other items and labels. Labels shall be located so as not to obscure any other information needed by the operator. Controls should not obscure labels.

5.5.2.3 Standardization. Labels shall be located in a consistent manner throughout the equipment and system.

5.5.3 Contents.

5.5.3.1 Equipment functions. Labels should primarily describe the functions of equipment items. Engineering characteristics or nomenclature may be described as a secondary consideration.

5.5.3.2 Abbreviations. Standard abbreviations shall conform to MIL-STD-12, MIL-STD-411, or MIL-STD-783. If a new abbreviation is required, its meaning shall be obvious to the intended reader. Capital letters shall be used. Periods shall be omitted except when needed to preclude misinterpretation. The same abbreviation shall be used for all tenses and for both singular and plural forms of a word.

5.5.3.3 Irrelevant information. Trade names and other irrelevant information shall not appear on labels or placards.

5.5.4 Qualities.

5.5.4.1 Brevity. Labels shall be as concise as possible without distorting the intended meaning or information and shall be unambiguous. Redundancy shall be minimized. Where the general function is obvious, only the specific function shall be identifed (e.g., frequency as opposed to frequency factor).

5.5.4.2 Familiarity. Words shall be chosen on the basis of operator familiarity whenever possible, provided the words express exactly what is intended. Brevity shall not be stressed if the results will be unfamiliar to operating personnel. For particular users (e.g., maintenance technicians), common technical terms may be used even though they may be unfamiliar to nonusers. Abstract symbols (e.g., squares and Greek letters) shall be used only when they have an accepted meaning to all intended readers. Common, meaningful symbols (e.g., % and +) may be used as necessary.

5.5.4.3 Visibility and legibility. Labels and placards shall be designed to be read easily and accurately at the anticipated operational reading distances, vibration/motion environment, and illumination.

5.5.4.4 Access. Labels shall not be covered or obscured by other units in the equipment assembly.

5.5.4.5 Label life. Labels shall be clear and distinct, have high contrast, be mounted so as to minimize wear or obscurement by grease, grime, or dirt, and shall remain legible for the overhaul interval of the equipment on which they are mounted.

5.5.4.6 Label background. Label color shall contrast with the equipment background specified in 5.7.9. No special background for the label shall be provided without approval by the procuring activity.

5.5.5 Design of label characters.

5.5.5.1 Black characters. Where the ambient illuminance will be above 10 lux (0.9 ft-c), black characters shall be provided on a light background.

5.5.5.2 Dark adaptation. Where dark adaptation 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.

5.5.5.3 Style. Style of label characters shall conform to MIL-M-18012, where consistent with 5.5.5.4, 5.5.5.5, 5.5.5.7, and 5.5.5.8, herein.

5.5.5.4 Capital vs lower case.

5.5.5.4.1 Labels. Labels shall be printed in all capitals; periods shall not be used after abbreviations.

5.5.5.4.2 Legends. Legends shall be printed in all capitals; periods or commas shall not be used.

5.5.5.4.3 Placards. Instructional material placards may employ capitals and lower case when the amount of material consists of several lines; however, for short, instructional material, all-capitals are preferred. All-capital material, consisting of larger caps for the initial letter in a paragraph, line of instruction or procedural step, may be used.

5.5.5.4.4 Signs. Signs shall consist of all-capitals, except when the sign is instructional and involves several lines of extended sentences, in which case capitals and lower case letters may be used.

5.5.5.5 Letter width. The width of letters should 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.

5.5.5.6 Numeral 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.

5.5.5.7 Wide characters. Where conditions indicate the use of wider characters, as on a curved surface, or where numerals must be aligned vertically in columns, the basic height-to-width ratio may be increased to as much as 1:1.

5.5.5.8 Stroke width normal. For black characters on a white (or light) background, the stroke width shall be 1/6 to 1/7 of the height.

5.5.5.9 Stroke width, dark adaptation. Where 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 (i.e., narrower than specified for normal daytime vision). The stroke width shall be the same for all letters and numerals of equal height.

5.5.5.10 Stroke width, transilluminated characters. For transilluminated characters, the stroke width shall be 1/10 of the height.

5.5.5.11 Character spacing. The minimum space between characters shall be one stroke width.

5.5.5.12 Word spacing. The minimum space between words shall be the width of one character.

5.5.5.13 Line spacing. The minimum space between lines shall be one-half character height.

5.5.5.14 Label size vs luminance. The height of letters and numerals shall be determined by the required reading distance and luminance. With a 710 mm (28 in) viewing distance, the height of numerals and letters shall be within the range of values in Table XII for "low" and "high" control-display luminance conditions.

5.5.5.15 Character height and viewing distance. For general dial and panel design, with the luminance normally above 3.5 cd/m^2 (1 ft-L), character height should conform to the values given below for various distances:

	Viewing distance	Minimum height
a.	less than 500 mm (19.7 in)	2.3 mm (0.09 in)
b.	0.5 - 1.0 m (19.7 - 39.4 in)	4.7 mm (0.18 in)
c.	1.0 - 2.0 m (39.4 - 78.7 in)	9.4 mm (0.37 in)
d.	2.0 - 4.0 m (78.7 - 157.5 in)	19 mm (0.75 in)
e.	4.0 - 8.0 m (157.4 - 315.5 in)	38 mm (1.50 in)

5.5.6 Equipment labeling.

5.5.6.1 Units, assemblies, subassemblies and parts.

5.5.6.1.1. General requirements. Each unit, assembly, subassembly and part shall be labeled with a clearly visible, legible, and meaningful name, number, code, mark or symbol, as applicable.

5.5.6.1.2 Location. The gross identifying label on a unit, assembly or major subassembly shall be located:

a. Externally in such a position that it is not obscured by adjacent items.

b. On the flattest, most uncluttered surface available.

c. On a main chassis of the equipment.

TABLE XII. LABEL SIZE VERSUS LUMINANCE

MARKINGS	HEIGHT*	
	3.5 cd/m^2 (1 ft–L) OR BELOW	ABOVE 3.5 cd/m^2 (1 ft–L)
For critical markings, with position variable (e.g., numerals on counters and settable or moving scales):	5 – 8 mm (0.20–0.31 in.)	3 – 5 mm (0.12–0.20 in.)
For critical markings, with position fixed (e.g., numerals on fixed scales, controls, and switch markings, or emergency instructions):	4 – 8 mm (0.16–0.31 in.)	2.5 – 5 mm (0.10–0.20 in.)
For noncritical markings (e.g., identification labels, routine instructions, or markings required only for familiarization):	1.3 – 5 mm (0.05–0.20 in.)	1.3 – 5 mm (0.05–0.20 in.)

*Values assume a 710 mm (28 in.) viewing distance. For a distance, D, other than 710 mm (28 in.), multiply the above values by D/710 mm (D/28 in.).

d. In a way to minimize wear or obscurement by grease, grime, or dirt.

e. In a way to preclude accidental removal, obstruction, or handling damage.

5.5.6.1.3 Terms. Equipment shall be labeled with terms descriptive of the test or measurement applicable to their test points (e.g., demodulator rather than crystal detector and power amplifier rather than bootstrap amplifier).

5.5.6.1.4 Other criteria. In addition to the criteria herein, equipment labels and placards shall conform to MIL-STD-129, MIL-STD-130, MIL-STD-195, MIL-STD-411, MIL-STD-783, MIL-STD-1247, and Requirement 67 of MIL-STD-454, as applicable.

5.5.6.2 Controls and displays.

5.5.6.2.1 General requirements. Controls and displays shall be appropriately and clearly labeled with the basic information needed for proper identification, utilization, actuation, or manipulation of the element. Integrally illuminated panels shall comply with MIL-P-7788.

5.5.6.2.2 Simplicity. Control and display labels shall convey verbal meaning in the most direct manner, by using simple words and phrases. Abbreviations may be used when they are familiar to operators (e.g., psi, km).

5.5.6.2.3 Functional labeling. Each control and display shall be labeled according to function, and the following criteria shall apply:

a. Similar names for different controls and displays shall be avoided.

b. Instruments shall be labeled in terms of what is being measured or controlled, taking into account the user and purpose.

c. Control labeling shall indicate the functional result of control movement (e.g., increase, ON, OFF) and may include calibration data where applicable. Such information shall be visible during normal operation of the control.

d. 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.

5.5.6.2.4 Location. The following criteria shall apply to the location of control and display labels.

a Ease of control operation shall be given priority over visibility of control position labels.

Labels should 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 thereby.

c. The units of measurement (e.g., volts, psi, meters) shall be labeled on the panel.

d. 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 functional 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.

e. Label location throughout a system and within panel groupings shall be uniform.

5.5.6.2.5 Size graduation. To reduce confusion and operator search time, labels shall be graduated in size. The characters in group labels shall be larger than those used to identify individual controls and displays. The characters identifying controls and displays shall be larger than the characters identifying control positions. With the smallest characters determined by viewing conditions, the dimensions of each character shall be at least approximately 25 percent larger than those of the next smaller label.

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5.6 Anthropometry.

5.6.1 General. Design and sizing shall insure accommodation, compatibility, operability, and maintainability by the user population. Generally, design limits shall be based upon a range from the 5th percentile female to the 95th percentile male values for critical body dimensions, as appropriate, except for Naval aviator special populations (see 5.6.4). For any body dimension, the 5th percentile value indicates that five percent of the population will be equal to or smaller than that value, and 95 percent will be larger; conversely, the 95th percentile values indicates that 95 percent of the population will be equal to or smaller than that value and five percent will be larger. Therefore, use of a design range from the 5th to 95th percentile values will theoretically provide coverage for 90 percent of the user population for that dimension. Where two or more dimensions are used simultaneously as design parameters, appropriate multivariate data and techniques should be utilized. (See Appendix for representative references.) The limited anthropometric data presented in this section in Figures 23 through 28 and Tables XIII through XVIII are intended to provide general design guidance. DOD-HDBK-743 should be consulted for more extensive data. Use of these data shall take the following into consideration:

a. The nature, frequency, safety, and difficulty of the related tasks to be performed by the operator or wearer of the equipment.

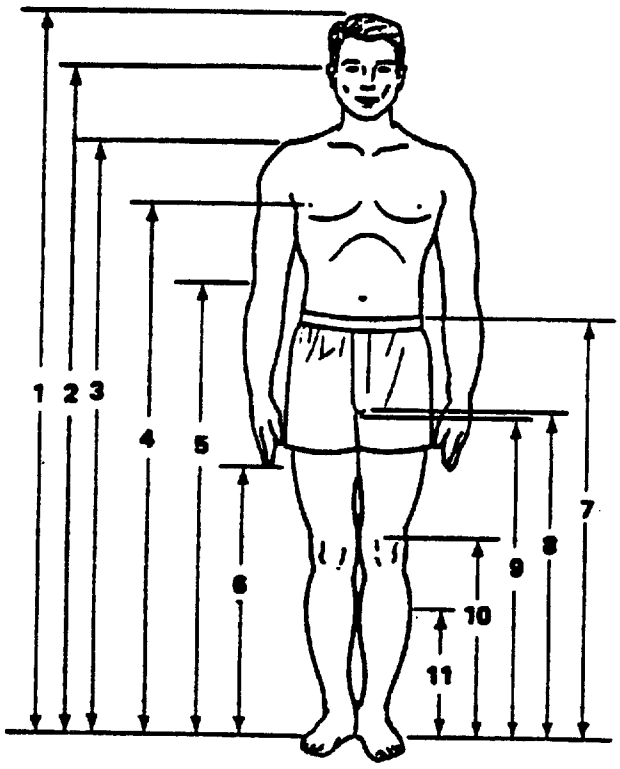
b. The position of the body during performance of these tasks.

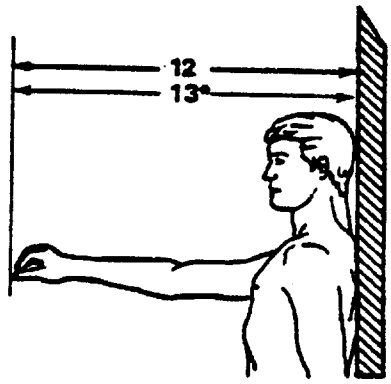
c. Mobility or flexibility requirements imposed by these tasks.

d. Increments in the design-critical dimensions imposed by the need to compensate for obstacles, projections, etc.

e. Increments in the design-critical dimensions imposed by protective clothing or equipment, packages, lines, padding, etc.

5.6.2 Anthropometric data. The anthropometric data presented in Tables XIII through XVIII are nude body measurements; data in centimeters are given in the upper half of each table, and data in inches are shown in the lower half of each table. (Note: The anthropometric data shown in these tables have been compiled and collated from several sources. The data on Ground Troops consist of measurements on a series of 6682 U.S. Army men and a series of 2008 U.S. Marines, both measured in 1966, as well as of 287 U.S. Army men measured in 1977. The data on Aviators represent 1482 U.S. Army aviation personnel, measured in 1970; 1549 U.S. Navy pilots, measured in 1964; and 2420 U.S. Air Force flying personnel, measured in 1967. The data on military women consist of measurements of 1300 U.S. Army WAC personnel and Army nurses, measured in 1977; and 1905 U.S. Air Force WAF personnel and Air Force nurses, measured in 1968.) Blanks in the tables indicate that data are not available for those dimensions. Technical reports (see appendix) should be consulted for definitions of specified measurements, methods of data collection and





*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 WALL.

FIGURE 23. STANDING BODY DIMENSIONS

TABLE XIII. STANDING BODY DIMENSIONS

	PERCENTILE VALUES IN CENTIMETERS					
	5th PERCENTILE			95th PERCENTILE		
	GROUND TROOPS	AVIATORS	WOMEN	GROUND TROOPS	AVIATORS	WOMEN
WEIGHT (kg)	55.5	60.4	46.4	91.6	96.0	74.5
STANDING BODY DIMENSIONS						
1 STATURE	162.8	164.2	152.4	185.6	187.7	174.1
2 EYE HEIGHT (STANDING)	151.1	152.1	140.9	173.3	175.2	162.2
3 SHOULDER (ACROMIALE) HEIGHT	133.6	133.3	123.0	154.2	154.8	143.7
4 CHEST (NIPPLE) HEIGHT *	117.9	120.8	109.3	136.5	138.5	127.8
5 ELBOW (RADIALE) HEIGHT	101.0	104.8	94.9	117.8	120.0	110.7
6 FINGERTIP (DACTYLION) HEIGHT		61.5			73.2	
7 WAIST HEIGHT	96.6	97.6	93.1	115.2	115.1	110.3
8 CROTCH HEIGHT	76.3	74.7	68.1	91.8	92.0	83.9
9 GLUTEAL FURROW HEIGHT	73.3	74.6	66.4	87.7	88.1	81.0
10 KNEECAP HEIGHT	47.5	46.8	43.8	58.6	57.8	52.5
11 CALF HEIGHT	31.1	30.9	29.0	40.6	39.3	36.6
12 FUNCTIONAL REACH	72.6	73.1	64.0	90.9	87.0	80.4
13 FUNCTIONAL REACH, EXTENDED	84.2	82.3	73.5	101.2	97.3	92.7
	PERCENTILE VALUES IN INCHES					
WEIGHT (lb)	122.4	133.1	102.3	201.9	211.6	164.3
STANDING BODY DIMENSIONS						
1 STATURE	64.1	64.6	60.0	73.1	73.9	68.5
2 EYE HEIGHT (STANDING)	59.5	59.9	55.5	68.2	69.0	63.9
3 SHOULDER (ACROMIALE) HEIGHT	52.6	52.5	48.4	60.7	60.9	56.6
4 CHEST (NIPPLE) HEIGHT *	46.4	47.5	43.0	53.7	54.5	50.3
5 ELBOW (RADIALE) HEIGHT	39.8	41.3	37.4	46.4	47.2	43.6
6 FINGERTIP (DACTYLION) HEIGHT		24.2			28.8	
7 WAIST HEIGHT	38.0	38.4	36.6	45.3	45.3	43.4
8 CROTCH HEIGHT	30.0	29.4	26.8	36.1	36.2	33.0
9 GLUTEAL FURROW HEIGHT	28.8	29.4	26.2	34.5	34.7	31.9
10 KNEECAP HEIGHT	18.7	18.4	17.2	23.1	22.8	20.7
11 CALF HEIGHT	12.2	12.2	11.4	16.0	15.5	14.4
12 FUNCTIONAL REACH	28.6	28.8	25.2	35.8	34.3	31.7
13 FUNCTIONAL REACH, EXTENDED	33.2	32.4	28.9	39.8	38.3	36.5

*BUSTPOINT HEIGHT FOR WOMEN

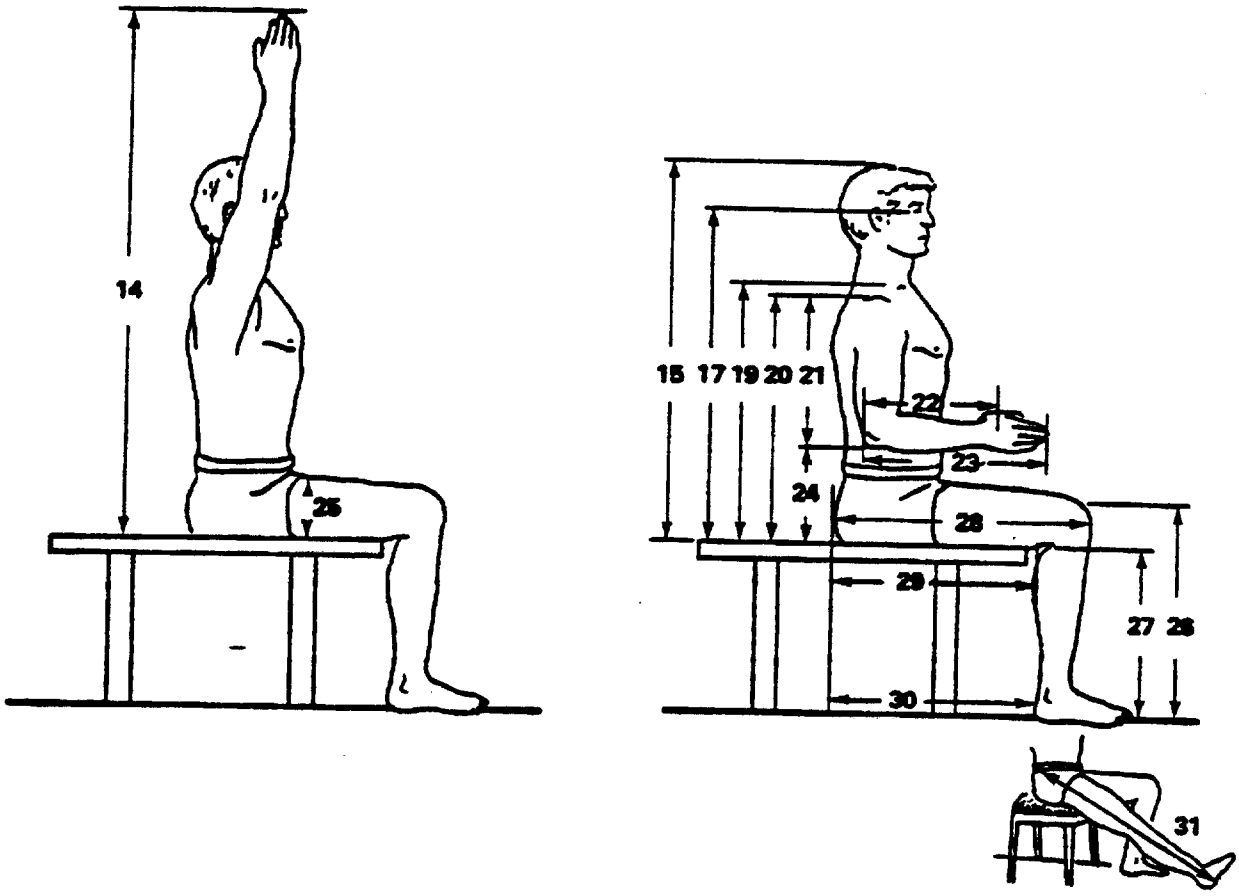


FIGURE 24. SEATED BODY DIMENSIONS

TABLE XIV. SEATED BODY DIMENSIONS

		PERCENTILE VALUES IN CENTIMETERS					
		5th PERCENTILE			95th PERCENTILE		
		GROUND TROOPS	AVIATORS	WOMEN	GROUND TROOPS	AVIATORS	WOMEN
	SEATED BODY DIMENSIONS						
14	VERTICAL ARM REACH, SITTING	128.6	134.0	117.4	147.8	153.2	139.4
15	SITTING HEIGHT, ERECT	83.5	86.7	79.0	96.9	98.8	90.9
16	SITTING HEIGHT, RELAXED	81.5	83.6	77.5	94.8	96.5	89.7
17	EYE HEIGHT, SITTING ERECT	72.0	73.8	67.7	84.8	88.1	79.1
18	EYE HEIGHT, SITTING RELAXED	70.0	71.6	66.2	82.5	84.0	77.9
19	MID-SHOULDER HEIGHT	56.8	58.3	53.7	67.7	69.2	62.5
20	SHOULDER HEIGHT, SITTING	54.2	54.6	49.9	65.4	65.9	60.3
21	SHOULDER-ELBOW LENGTH	33.3	33.2	30.8	40.2	39.7	36.8
22	ELBOW-GRIP LENGTH	31.7	32.6	29.6	38.3	37.9	35.4
23	ELBOW-FINGERTIP LENGTH	43.8	44.7	40.0	52.0	51.7	47.5
24	ELBOW REST HEIGHT	17.5	18.7	16.1	28.0	29.5	26.9
25	THIGH CLEARANCE HEIGHT		12.4	10.4		18.8	17.5
26	KNEE HEIGHT, SITTING	48.7	48.9	46.9	60.2	59.9	55.5
27	POPLITEAL HEIGHT	39.7	38.4	36.0	50.0	47.7	45.7
28	BUTTOCK-KNEE LENGTH	54.9	55.9	53.1	66.8	66.5	63.2
29	BUTTOCK-POPLITEAL LENGTH	46.8	44.9	43.4	54.5	54.6	52.8
30	BUTTOCK-HEEL LENGTH		46.7			56.4	
31	FUNCTIONAL LEG LENGTH	110.6	103.9	99.6	127.7	120.4	118.6
		PERCENTILE VALUES IN INCHES					
	SEATED BODY DIMENSIONS						
14	VERTICAL ARM REACH, SITTING	50.6	52.8	46.2	58.2	60.3	54.9
15	SITTING HEIGHT, ERECT	32.9	33.7	31.1	38.2	38.8	35.8
16	SITTING HEIGHT, RELAXED	32.1	32.9	30.5	37.3	38.0	35.3
17	EYE HEIGHT, SITTING ERECT	28.3	30.0	26.6	33.3	33.9	31.2
18	EYE HEIGHT, SITTING RELAXED	27.6	28.2	26.1	32.5	33.1	30.7
19	MID-SHOULDER HEIGHT	22.3	23.0	21.2	26.7	27.3	24.6
20	SHOULDER HEIGHT, SITTING	21.3	21.5	19.6	25.7	25.9	23.7
21	SHOULDER-ELBOW LENGTH	13.1	13.1	12.1	15.8	15.6	14.4
22	ELBOW-GRIP LENGTH	12.5	12.8	11.6	15.1	14.9	14.0
23	ELBOW-FINGERTIP LENGTH	17.3	17.6	15.7	20.5	20.4	18.7
24	ELBOW REST HEIGHT	6.9	7.4	6.4	11.0	11.6	10.6
25	THIGH CLEARANCE HEIGHT		4.9	4.1		7.4	6.9
26	KNEE HEIGHT, SITTING	19.6	19.3	18.5	23.7	23.6	21.8
27	POPLITEAL HEIGHT	15.6	15.1	15.0	19.7	18.8	18.0
28	BUTTOCK-KNEE LENGTH	21.6	22.0	20.9	26.9	26.8	24.9
29	BUTTOCK-POPLITEAL LENGTH	17.9	17.7	17.1	21.5	21.5	20.7
30	BUTTOCK-HEEL LENGTH		18.4			22.2	
31	FUNCTIONAL LEG LENGTH	43.5	40.9	39.2	50.3	47.4	46.7

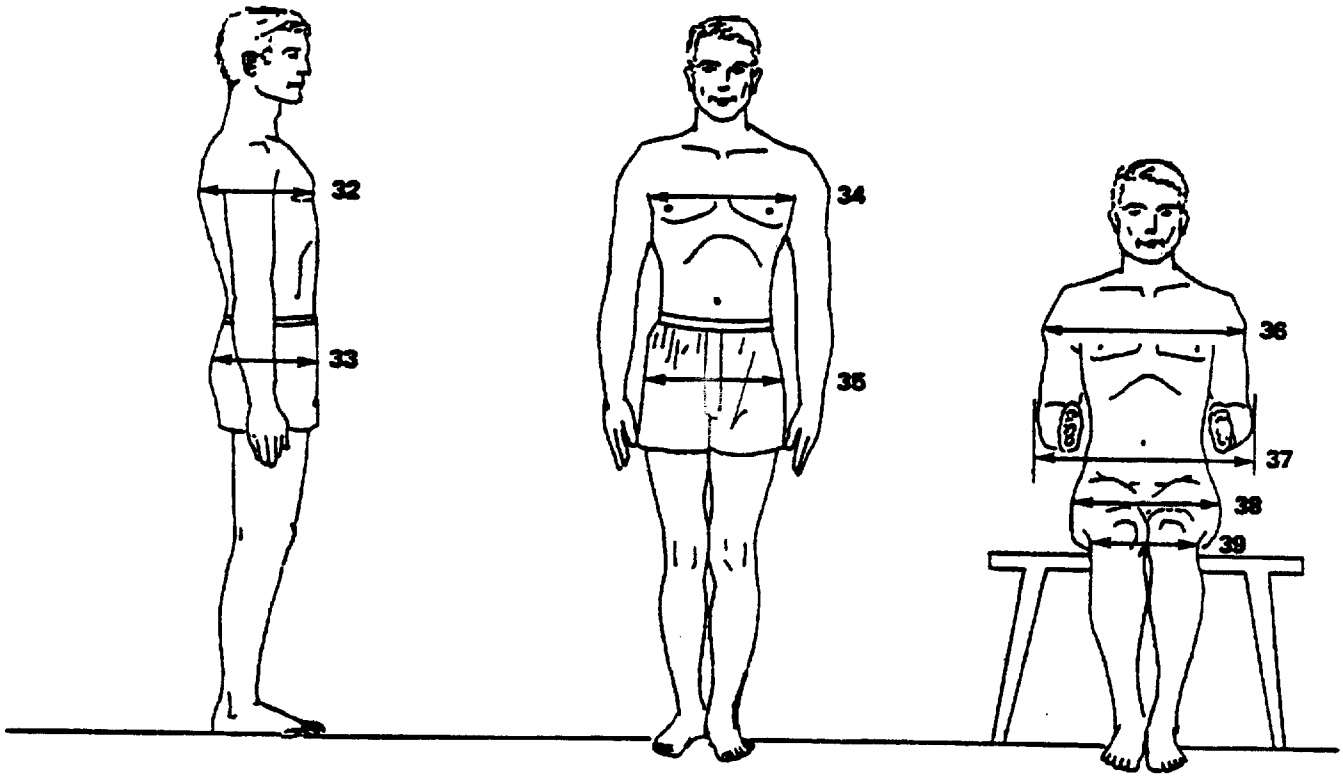


FIGURE 25. DEPTH AND BREADTH DIMENSIONS

TABLE XV. DEPTH AND BREADTH DIMENSIONS

	PERCENTILE VALUES IN CENTIMETERS					
	5th PERCENTILE			95th PERCENTILE		
	GROUND TROOPS	AVIATORS	WOMEN	GROUND TROOPS	AVIATORS	WOMEN
DEPTH AND BREADTH DIMENSIONS						
32 CHEST DEPTH*	18.9	20.4	19.6	26.7	27.8	27.2
33 BUTTOCK DEPTH		20.7	18.4		27.4	24.3
34 CHEST BREADTH	27.3	29.5	25.1	34.4	38.5	31.4
35 HIP BREADTH, STANDING	30.2	31.7	31.5	36.7	38.8	39.5
36 SHOULDER (BIDELTOID) BREADTH	41.5	43.2	38.2	49.8	52.6	45.8
37 FOREARM–FOREARM BREADTH	39.8	43.2	33.0	53.6	60.7	44.9
38 HIP BREADTH, SITTING	30.7	33.3	33.0	38.4	42.4	43.9
39 KNEE–TO–KNEE BREADTH		19.1			25.5	
	PERCENTILE VALUES IN INCHES					
DEPTH AND BREADTH DIMENSIONS						
32 CHEST DEPTH*	7.5	8.0	7.7	10.5	11.0	10.7
33 BUTTOCK DEPTH		8.2	7.2		10.8	9.6
34 CHEST BREADTH	10.8	11.6	9.9	13.5	15.1	12.4
35 HIP BREADTH, STANDING	11.9	12.5	12.4	14.5	15.3	15.6
36 SHOULDER (BIDELTOID) BREADTH	16.3	17.0	15.0	19.6	20.7	18.0
37 FOREARM–FOREARM BREADTH	15.7	17.0	13.0	21.1	23.9	17.7
38 HIP BREADTH, SITTING	12.1	13.1	13.0	15.1	16.7	17.3
39 KNEE–TO–KNEE BREADTH		7.5			10.0	

*BUST DEPTH FOR WOMEN

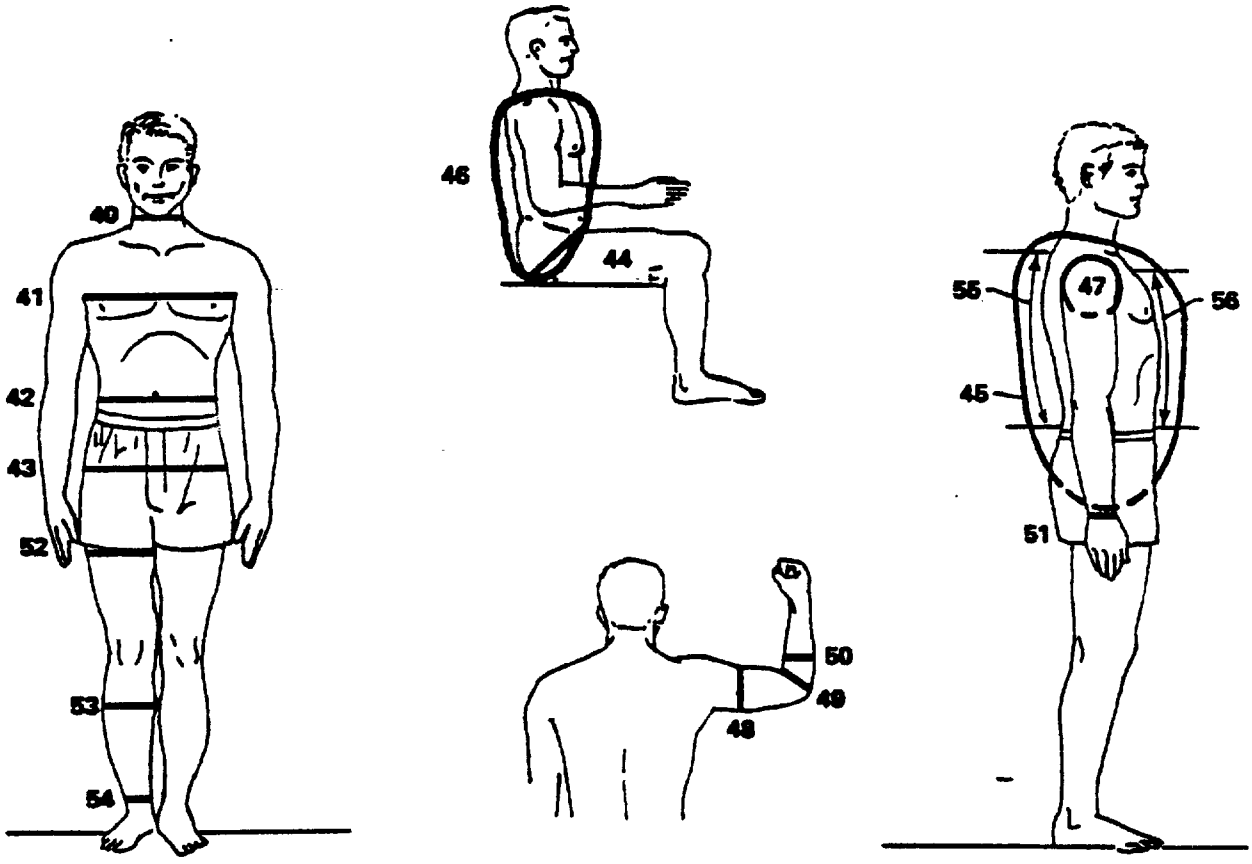


FIGURE 26. CIRCUMFERENCES AND SURFACE DIMENSIONS

TABLE XVI. CIRCUMFERENCES AND SURFACE DIMENSIONS

		PERCENTILE VALUES IN CENTIMETERS					
		5th PERCENTILE			95th PERCENTILE		
		GROUND TROOPS	AVIATORS	WOMEN	GROUND TROOPS	AVIATORS	WOMEN
	CIRCUMFERENCES						
40	NECK CIRCUMFERENCE	34.2	34.6	29.9	41.0	41.6	36.7
41	CHEST CIRCUMFERENCE*	83.8	87.5	78.4	106.9	109.9	100.2
42	WAIST CIRCUMFERENCE	68.4	73.5	59.5	95.9	101.7	83.5
43	HIP CIRCUMFERENCE	85.1	87.1	85.5	106.9	108.4	106.1
44	HIP CIRCUMFERENCE, SITTING		97.0	87.7		119.3	110.8
45	VERTICAL TRUNK CIRCUMFERENCE, STANDING	150.6	156.3	142.2	178.6	181.9	166.3
46	VERTICAL TRUNK CIRCUMFERENCE, SITTING		150.4	134.8		175.0	161.0
47	ARM SCYE CIRCUMFERENCE	39.6	39.9	33.6	50.3	53.0	41.7
48	BICEPS CIRCUMFERENCE, FLEXED	27.0	27.8	23.2	37.0	36.9	30.8
49	ELBOW CIRCUMFERENCE, FLEXED		28.5	23.5		34.2	30.0
50	FOREARM CIRCUMFERENCE, FLEXED	26.1	26.3	22.2	33.1	33.1	27.5
51	WRIST CIRCUMFERENCE	15.7	15.3	13.6	18.6	19.2	16.2
52	UPPER THIGH CIRCUMFERENCE	48.1	49.6	48.7	63.9	66.9	64.5
53	CALF CIRCUMFERENCE	31.6	33.3	30.6	41.2	41.3	39.2
54	ANKLE CIRCUMFERENCE	19.3	20.0	18.7	25.2	24.8	23.3
55	WAIST BACK LENGTH	39.2	42.4	36.7	50.8	50.9	45.4
56	WAIST FRONT LENGTH	36.1	35.7	30.5	46.2	44.2	41.4
		PERCENTILE VALUES IN INCHES					
	CIRCUMFERENCES						
40	NECK CIRCUMFERENCE	13.5	13.6	11.8	16.1	16.4	14.4
41	CHEST CIRCUMFERENCE*	33.0	34.4	30.8	41.7	43.3	39.5
42	WAIST CIRCUMFERENCE	26.9	28.9	23.4	37.8	40.0	32.9
43	HIP CIRCUMFERENCE	33.5	34.3	33.7	42.1	42.7	41.8
44	HIP CIRCUMFERENCE, SITTING		38.2	34.5		47.0	43.6
45	VERTICAL TRUNK CIRCUMFERENCE, STANDING	59.3	61.6	56.0	70.3	71.6	65.5
46	VERTICAL TRUNK CIRCUMFERENCE, SITTING		59.2	53.1		68.9	63.4
47	ARM SCYE CIRCUMFERENCE	15.6	15.7	13.2	19.8	20.9	16.4
48	BICEPS CIRCUMFERENCE, FLEXED	10.6	11.0	9.1	14.6	14.5	12.1
49	ELBOW CIRCUMFERENCE, FLEXED		11.2	9.2		13.5	11.8
50	FOREARM CIRCUMFERENCE, FLEXED	10.3	10.4	8.7	13.0	13.0	10.8
51	WRIST CIRCUMFERENCE	6.2	6.0	5.4	7.3	7.6	6.4
52	UPPER THIGH CIRCUMFERENCE	18.9	19.5	19.2	25.1	26.3	25.4
53	CALF CIRCUMFERENCE	12.4	13.1	12.0	16.2	16.3	15.4
54	ANKLE CIRCUMFERENCE	7.6	7.9	7.4	9.9	9.7	9.2
55	WAIST BACK LENGTH	15.4	16.7	14.4	20.0	20.0	17.9
56	WAIST FRONT LENGTH	14.2	14.1	12.0	18.2	17.4	16.3

*BUST CIRCUMFERENCE FOR WOMEN

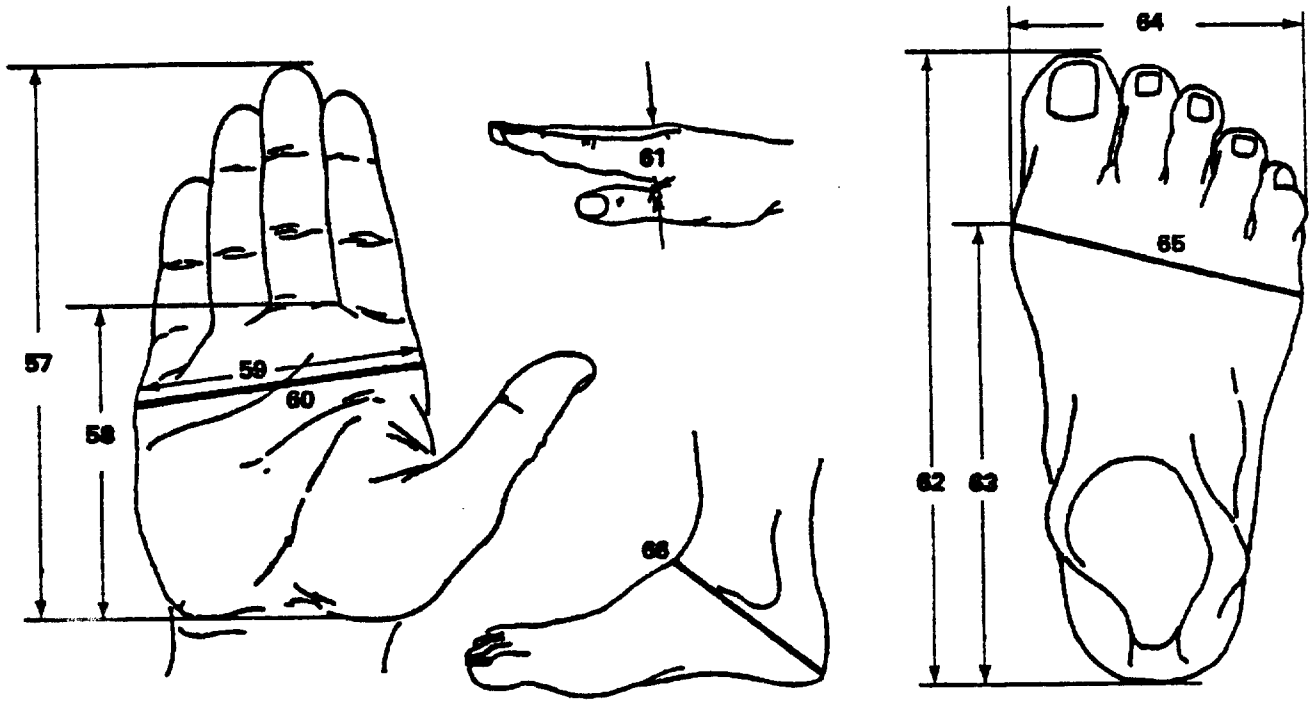


FIGURE 27. HAND AND FOOT DIMENSIONS

TABLE XVII. HAND AND FOOT DIMENSIONS

	PERCENTILE VALUES IN CENTIMETERS					
	5th PERCENTILE			95th PERCENTILE		
	GROUND TROOPS	AVIATORS	WOMEN	GROUND TROOPS	AVIATORS	WOMEN
HAND DIMENSIONS						
57 HAND LENGTH	17.4	17.7	16.1	20.7	20.7	20.0
58 PALM LENGTH	9.6	10.0	9.0	11.7	11.9	10.8
59 HAND BREADTH	8.1	8.2	6.9	9.7	9.7	8.5
60 HAND CIRCUMFERENCE	19.5	19.6	16.8	23.6	23.1	19.9
61 HAND THICKNESS		2.4			3.5	
FOOT DIMENSIONS						
62 FOOT LENGTH	24.5	24.4	22.2	29.0	29.0	26.5
63 INSTEP LENGTH	17.7	17.5	16.3	21.7	21.4	19.6
64 FOOT BREADTH	9.0	9.0	8.0	10.9	11.6	9.8
65 FOOT CIRCUMFERENCE	22.5	22.6	20.8	27.4	27.0	24.5
66 HEEL–ANKLE CIRCUMFERENCE	31.3	30.7	28.5	37.0	36.3	33.3
	PERCENTILE VALUES IN INCHES					
HAND DIMENSIONS						
57 HAND LENGTH	6.85	6.98	6.32	8.13	8.14	7.89
58 PALM LENGTH	3.77	3.92	3.56	4.61	4.69	4.24
59 HAND BREADTH	3.20	3.22	2.72	3.83	3.80	3.33
60 HAND CIRCUMFERENCE	7.68	7.71	6.62	9.28	9.11	7.82
61 HAND THICKNESS		0.95			1.37	
FOOT DIMENSIONS						
62 FOOT LENGTH	9.65	9.62	8.74	11.41	11.42	10.42
63 INSTEP LENGTH	6.97	6.88	6.41	8.54	8.42	7.70
64 FOOT BREADTH	3.53	3.54	3.16	4.29	4.58	3.84
65 FOOT CIRCUMFERENCE	8.86	8.91	8.17	10.79	10.62	9.65
66 HEEL–ANGLE CIRCUMFERENCE	12.32	12.08	11.21	14.57	14.30	13.11

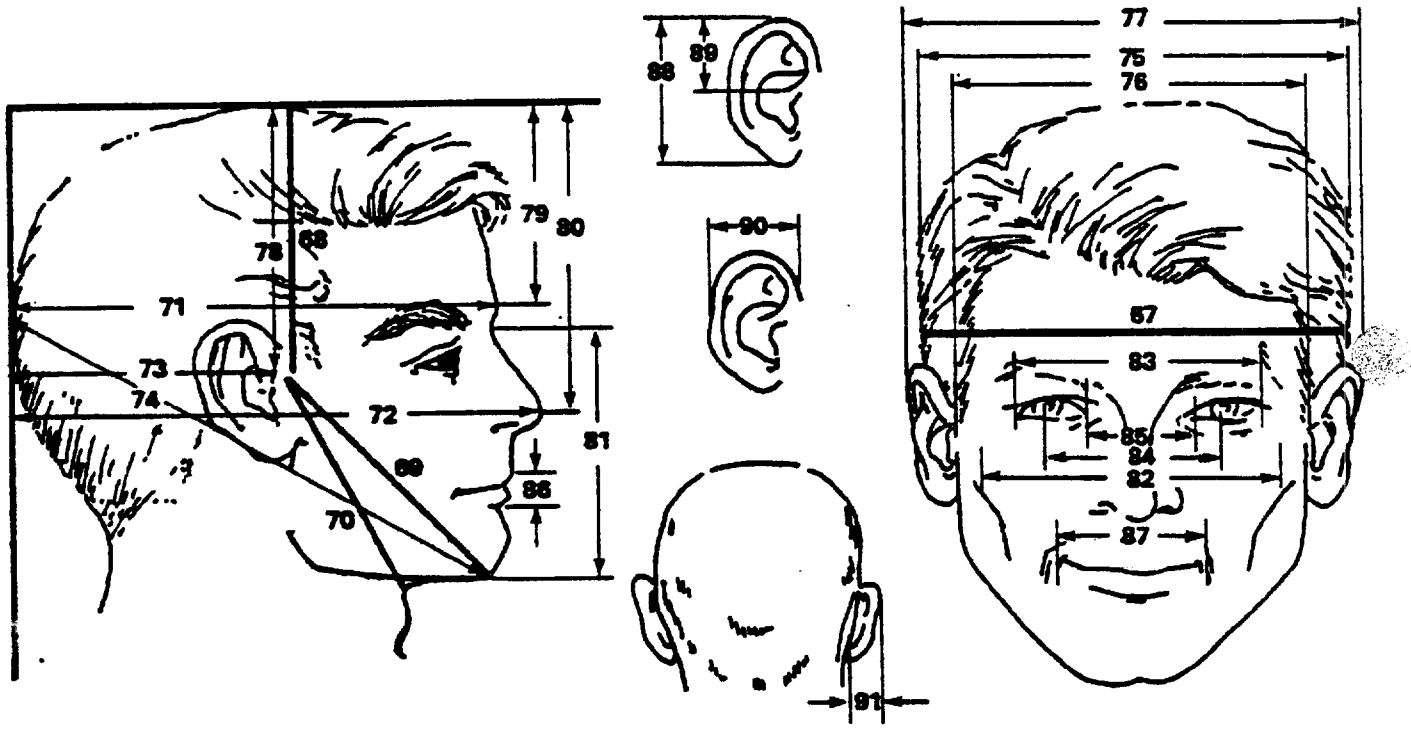


FIGURE 28. HEAD AND FACE DIMENSIONS

TABLE XVIII. HEAD AND FACE DIMENSIONS

HEAD AND FACE DIMENSIONS	PERCENTILE VALUES IN CENTIMETERS					
	5th PERCENTILE			95th PERCENTILE		
	GROUND TROOPS	AVIATORS	WOMEN	GROUND TROOPS	AVIATORS	WOMEN
67 HEAD CIRCUMFERENCE	53.2	53.8	52.2	58.8	59.9	57.7
68 BITRAGION-CORONAL CURVATURE	31.9	33.4	31.3	36.1	37.8	36.3
69 BITRAGION-MENTON CURVATURE	29.0	30.1	27.3	33.1	34.7	31.6
70 BITRAGION-SUBMANDIBULAR CURVATURE	26.7	28.4	24.5	30.7	33.6	28.9
71 HEAD LENGTH	18.2	18.6	17.3	20.7	21.0	19.8
72 PRONASALE TO WALL	20.8	21.4	19.7	23.5	24.1	23.2
73 TRAGION TO WALL	8.5	9.2	8.8	12.6	12.1	11.8
74 HEAD DIAGONAL (MENTON-OCCIPUT)		24.4			26.9	
75 HEAD BREADTH	14.2	14.4	13.5	16.3	16.5	15.6
76 BITRAGION BREADTH	12.5	13.1	12.1	14.5	15.2	13.8
77 BIAURICULAR BREADTH	16.5	17.5	14.2	19.4	20.2	17.4
78 HEAD HEIGHT (TRAG.-TOP OF HEAD)	11.9	12.0	11.6	14.5	14.4	14.3
79 GLABELLA TO TOP OF HEAD	6.5	7.2	7.1	9.4	10.9	9.9
80 PRONASALE TO TOP OF HEAD	11.6	13.0	11.9	15.1	16.6	16.8
81 FACE LENGTH (MENTON-SELLION)	10.6	10.2	9.6	13.1	13.0	11.8
82 FACE (BIZYGOMATIC) BREADTH	12.8	12.4	11.9	14.9	15.1	14.0
83 BIOCULAR BREADTH	9.3	8.4	8.8	10.9	10.1	10.5
84 INTERPUPILLARY BREADTH	5.1	5.3	5.1	6.8	7.0	6.5
85 INTEROCULAR BREADTH		2.7	2.7		3.8	3.7
86 LIP TO LIP LENGTH		1.1			2.3	
87 LIP-LENGTH (MOUTH BREADTH)		4.5	3.7		5.9	5.1
88 EAR LENGTH	5.5	5.9	4.5	6.9	7.3	6.0
89 EAR LENGTH ABOVE TRAGION		2.5			3.4	
90 EAR BREADTH	3.8	3.0	2.4	5.0	4.3	3.5
91 EAR PROTRUSION		1.6			2.8	

(Continued)

TABLE XVIII. HEAD AND FACE DIMENSIONS (CONCLUDED)

HEAD AND FACE DIMENSIONS	PERCENTILE VALUES IN INCHES					
	5th PERCENTILE			95th PERCENTILE		
	GROUND TROOPS	AVIATORS	WOMEN	GROUND TROOPS	AVIATORS	WOMEN
67 HEAD CIRCUMFERENCE	20.94	21.18	20.57	23.16	23.59	22.73
68 BITRAGION-CORONAL CURVATURE	12.56	13.14	12.31	14.21	14.90	14.29
69 BITRAGION-MENTON CURVATURE	11.42	11.86	10.74	13.03	13.66	12.45
70 BITRAGION-SUBMANDIBULAR CURVATURE	10.51	11.18	9.63	12.09	13.23	11.37
71 HEAD LENGTH	7.19	7.32	6.80	8.14	8.27	7.80
72 PRONASALE TO WALL	8.18	8.42	7.88	9.27	9.50	9.15
73 TRAGION TO WALL	3.33	3.62	3.47	4.95	4.77	4.64
74 HEAD DIAGONAL (MENTON-OCCIPUT)		9.60			10.59	
75 HEAD BREADTH	5.59	5.67	5.33	6.40	6.50	6.12
76 BITRAGION BREADTH	4.92	5.17	4.76	5.71	5.98	5.45
77 BIAURICULAR BREADTH	6.50	6.89	5.61	7.84	7.95	6.84
78 HEAD HEIGHT (TRAG.-TOP OF HEAD)	4.69	4.74	4.56	5.72	5.69	5.62
79 GLABELLA TO TOP OF HEAD	2.56	2.81	2.79	3.70	4.30	3.88
80 PRONASALE TO TOP OF HEAD	4.57	5.12	4.70	5.94	6.54	6.61
81 FACE LENGTH (MENTON-SELLION)	4.17	4.04	3.79	5.17	5.13	4.63
82 FACE (BIZYGOMATIC) BREADTH	5.04	4.87	4.69	5.88	5.94	5.53
83 BIOCULAR BREADTH	3.66	3.31	3.47	4.29	3.99	4.14
84 INTERPUPILLARY BREADTH	2.01	2.10	2.00	2.67	2.75	2.57
85 INTEROCULAR BREADTH		1.08	1.05		1.50	1.45
86 LIP TO LIP LENGTH		0.41			0.92	
87 LIP LENGTH (MOUTH BREADTH)		1.76	1.46		2.30	2.01
88 EAR LENGTH	2.17	2.31	1.77	2.72	2.88	2.34
89 EAR LENGTH ABOVE TRAGION		0.97			1.36	
90 EAR BREADTH	1.50	1.19	0.95	1.97	1.70	1.38
91 EAR PROTRUSION		0.65			1.09	

more detailed anthropometric data; definitive or more specific data should be obtained from the service agency responsible for anthropometry.

5.6.3 Use of data.

5.6.3.1 Data limitations. Because the anthropometric data presented here represent nude body measurements, suitable allowances shall be made for light or heavy clothing, flying suits, helmets, boots, body armor, load-carrying equipment, protective equipment, and other worn or carried items, when utilizing these data for design criteria.

5.6.3.2 Clearance dimensions. Clearance dimensions (e.g., for passageways and accesses), which must accommodate or allow passage of the body or parts of the body, shall be based upon the 95th percentile values for applicable body dimensions.

5.6.3.3 Limiting dimensions. Limiting dimensions (reaching distance, control movement, displays, test points, handrails, etc.) which restrict or are limited by extensions of the body shall be based upon the 5th percentile values for applicable body dimensions.

5.6.3.4 Adjustable 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 5th to 95th percentile values for the applicable body member(s).

5.6.3.5 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 5th through the 95th percentile values of body dimensions. Pertinent dimensions of essential or critical equipment (e.g., aviators' helmets) shall be based on the 1st and 99th percentile values. Where two or more dimensions are used simultaneously as design parameters, appropriate multivariate data and techniques shall be utilized. (See appendix for representative references.)

5.6.4 Special populations. Where equipment will be used, inclusively or exclusively, by selected or specialized segments of the military population (e.g., Army tank crews, Navy divers, etc.) or population ranges other than the 5 -.95th percentiles (e.g., disproportionate anthropometric accommodation test cases), appropriate available anthropometric data on these specialized populations, contained in DOD-HDBK-743, shall be utilized for design and sizing criteria. Where equipment is intended for use by foreign military personnel, appropriate anthropometric data on such populations shall be utilized for design and sizing criteria. (See appendix for representative references.)

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5.7 Workspace design.

5.7.1 General. Unless otherwise noted, the following criteria apply to ground installations and, as practical, to airborne and shipboard installations.

5.7.1.1 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 inches) deep and 100 mm (4 inches) high to allow for protective or specialized apparel.

5.7.1.2 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.

5.7.1.3 Work space. Whenever feasible, free floor space of at least 1.220 m (4 feet) shall be provided in front of each console. For equipment racks that require maintenance, free floor space shall be provided in accordance with the following criteria.

5.7.1.3.1 Depth of work area. Clearance from the front of the rack to the nearest facing surface or obstacle shall not be less than 1.070 m (42 inches). The minimum space between rows of cabinets shall be 200 mm (8 inches) greater than the depth of the deepest drawer (equipment).

5.7.1.3.2 Lateral work space. The minimum lateral workspace 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 pounds): 460 mm (18 inches) on one side and 100 mm (4 inches) on the other.

b. For racks having drawers or removable items weighing over 20 kg (44 pounds): 460 mm (18 inches) on each side.

5.7.1.3.3 Space between rows of cabinets. The minimum space between rows of cabinets shall be 200 mm (8 inches) greater than the depth of the deepest drawer or cabinet.

5.7.1.3.4 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.

5.7.2 Standing operations

5.7.2.1 Work surface. Unless otherwise specified, work surfaces to support job instruction manuals, worksheets, etc., shall be 915 $\pm$15 mm (36 $\pm$0.6 inches) above the floor.

5.7.2.2 Display placement, normal. Visual displays mounted on vertical panels and used in normal equipment operation shall be placed between 1.040 m (41 inches) and 1.780 m (70 inches) above the standing surface.

5.7.2.3 Display placement, special. Displays requiring precise and frequent reading shall be placed between 1.270 m (50 inches) and 1.650 m (65 inches) above the standing surface.

5.7.2.4 Control placement, normal. All controls mounted on a vertical surface and used in normal equipment operation shall be located between 860 mm and 1.780 m (34 and 70 inches) above the standing surface.

5.7.2.5 Control placement, special. Controls requiring precise or frequent operation and emergency controls shall be mounted between 860 mm and 1.350 m (34 and 53 inches) above the standing surface and no farther than 530 mm (21 inches) laterally from the centerline.

5.7.3 Seated operations.

5.7.3.1 Work surface width and depth. A lateral workspace of at least 760 mm (30 inches) wide and 400 mm (16 inches) deep shall be provided whenever practicable.

5.7.3.2 Work surface height. Desk tops and writing tables shall be 740 to 790 mm (29 to 31 inches) above the floor, unless otherwise specified.

5.7.3.3 Writing surfaces. Where a writing surface is required on equipment consoles, it shall be at least 400 mm (16 inches) deep and should be 610 mm (24 inches) wide, when consistent with operator reach requirements.

5.7.3.4 Seating.

5.7.3.4.1 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 to be operationally compatible with the console configuration.

5.7.3.4.2 Vertical adjustment. Provision shall be made for vertical seat adjustment from 380 to 535 mm (15 to 21 inches) in increments of no more than 25 mm (1 inch) each.

5.7.3.4.3 Backrest. A supporting backrest that reclines between 1745 and 2005 mrad (100 and 115 degrees) shall be provided. 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 brought to the "Eye Line" with no more than 75 mm (3 inches) of forward body movement.

5.7.3.4.4 Cushioning. Where applicable, both the backrest and seat shall be cushioned with at least 25 mm (1 inch) of compressible material and provided with a smooth surface.

5.7.3.4.5 Armrests. Unless otherwise specified, armrests shall be provided. Armrests that are integral with operators' chairs shall be at least 50 mm (2 inches) wide and 200 mm (8 inches) long. Modified or retractable armrests shall be provided when necessary to maintain compatibility with an associated console and shall be adjustable from 190 to 280 mm (7.5 to 11 inches) above the compressed sitting surface.

5.7.3.5 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 inches). If a fixed footrest or a foot-operated control is provided, this dimension shall be increased accordingly.

b. Width: 510 mm (20 inches)

c. Depth: 460 mm (18 inches)

5.7.3.6 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 inches) above the sitting surface.

5.7.3.7 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 inches) above the sitting surface, and no further than 530 mm (21 inches) laterally from the centerline.

5.7.3.8 Warning displays. For "sit" consoles requiring horizontal vision over the top, critical visual warning displays shall be mounted at least 570 mm (22.5 inches) above the sitting surface.

5.7.3.9 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 inches) above the sitting surface.

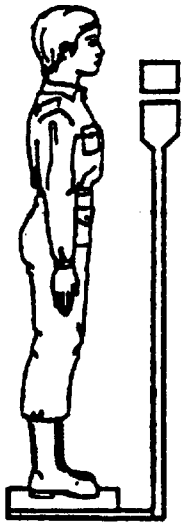
5.7.3.10 Control placement, special. Controls requiring precise or frequent operation shall be mounted between 200 and 740 mm (8 and 29 inches) above the sitting surface.

5.7.4 Common working positions. Anthropometric data for the design and sizing of workspaces involving standing, sitting, stooping, kneeling and supine positions are presented in Table XIX and illustrated in Figure 29. Fifth and 95th percentile values for men and women are given for various body dimensions in both centimeters and inches. (The data are based on measurements of 300 Army women and 106 Army men in 1977; therefore, differences in several measurements common to Table XIX and tables of para 5.6 should be resolved in favor of the latter tables. Information on other "Anthropometry of Common Working Positions" may be found in the reference so titled in the Appendix.) Suitable allowances should be made for heavy clothing or protective equipment when required. In no case shall clearance dimensions be less than the 95th percentile values for men or limiting dimensions be more than the 5th percentile values for women, shown in Table XIX.

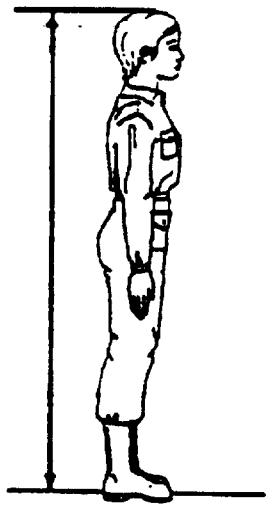
TABLE XIX. ANTHROPOMETRIC DATA FOR COMMON WORKING POSITIONS

*	PERCENTILE VALUES IN CENTIMETERS			
	5th PERCENTILE		95th PERCENTILE	
	MEN	WOMEN	MEN	WOMEN
1. WEIGHT – CLOTHED (KILOGRAMS)	58.6	48.8	90.2	74.6
2. STATURE – CLOTHED	168.5	156.8	189.0	178.7
3. FUNCTIONAL REACH	72.6	64.0	86.4	79.0
4. FUNCTIONAL REACH, EXTENDED	84.2	73.5	101.2	92.7
5. OVERHEAD REACH HEIGHT	200.4	185.3	230.5	215.1
6. OVERHEAD REACH BREADTH	35.2	31.5	41.9	37.9
7. BENT TORSO HEIGHT	125.6	112.7	149.8	138.6
8. BENT TORSO BREADTH	40.9	36.8	48.3	43.5
9. OVERHEAD REACH, SITTING	127.9	117.4	146.9	139.4
10. FUNCTIONAL LEG LENGTH	110.6	99.6	127.7	118.6
11. KNEELING HEIGHT	121.9	114.5	136.9	130.3
12. KNEELING LEG LENGTH	63.9	59.2	75.5	70.5
13. BENT KNEE HEIGHT, SUPINE	44.7	41.3	53.5	49.6
14. HORIZONTAL LENGTH, KNEES BENT	150.8	140.3	173.0	163.8
	PERCENTILE VALUES IN INCHES			
1. WEIGHT – CLOTHED (POUNDS)	129.1	107.6	198.8	164.5
2. STATURE – CLOTHED	66.4	61.8	74.4	70.3
3. FUNCTIONAL REACH	28.6	25.2	34.0	31.1
4. FUNCTIONAL REACH, EXTENDED	33.2	28.9	39.8	36.5
5. OVERHEAD REACH HEIGHT	78.9	73.0	90.8	84.7
6. OVERHEAD REACH BREADTH	13.9	12.4	16.5	14.9
7. BENT TORSO HEIGHT	49.4	44.4	59.0	54.6
8. BENT TORSO BREADTH	16.1	14.5	19.0	17.1
9. OVERHEAD REACH, SITTING	50.3	46.2	57.9	54.9
10. FUNCTIONAL LEG LENGTH	43.5	39.2	50.3	46.7
11. KNEELING HEIGHT	48.0	45.1	53.9	51.3
12. KNEELING LEG LENGTH	25.2	23.3	29.7	27.8
13. BENT KNEE HEIGHT, SUPINE	17.6	16.3	21.1	19.5
14. HORIZONTAL LENGTH, KNEES BENT	59.4	55.2	68.1	64.5

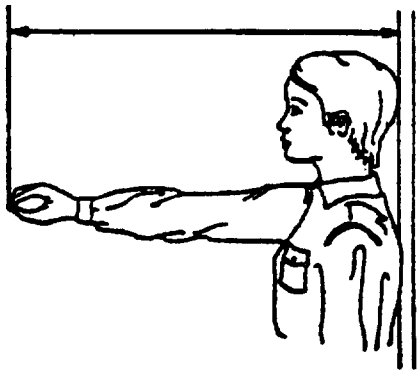
*See Figure 29 for illustration of each measurement.



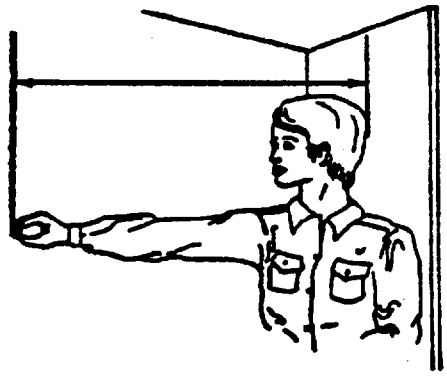
① WEIGHT (CLOTHED) WEARING FATIGUES & COMBAT BOOTS; STANDING IN CENTER OF SCALE



② STATURE (CLOTHED) STANDING ERECT; HEELS TOGETHER; WEIGHT DISTRIBUTED EQUALLY ON BOTH FEET. MEASURED FROM STANDING SURFACE TO TOP OF HEAD.

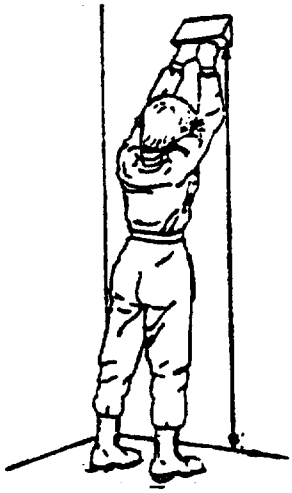


③ FUNCTIONAL REACH – STANDING ERECT; LOOKING STRAIGHT AHEAD; BOTH SHOULDERS AGAINST WALL; RIGHT ARM HORIZONTAL. MEASURED FROM WALL TO TIP OF INDEX FINGER

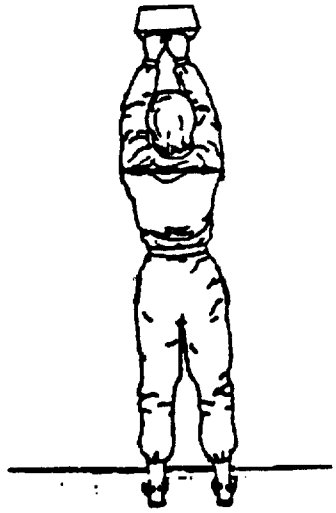


④ FUNCTIONAL REACH, EXTENDED– STANDING ERECT; LOOKING STRAIGHT AHEAD; RIGHT SHOULDER EXTENDED AS FAR FORWARD AS POSSIBLE WHILE BACK OF LEFT SHOULDER FIRMLY AGAINST WALL; ARM HORIZONTAL. MEASURED FROM WALL TO TIP OF INDEX FINGER.

FIGURE 29. ANTHROPOMETRIC DATA FOR WORKSPACES

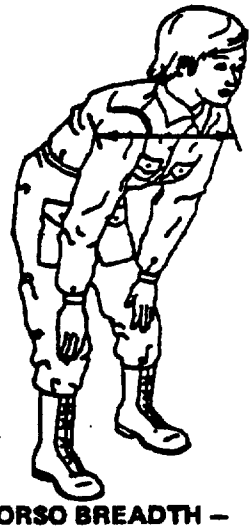


⑤ OVERHEAD REACH HEIGHT – STANDING WITH HEELS 23 cm APART AND TOES 15 cm FROM WALL; ARMS EXTENDED OVERHEAD WITH FISTS TOUCHING AND AGAINST WALL; 1st PHALANGES HORIZONTAL. MEASURED FROM FLOOR TO HIGHEST POINT ON 1st PHALANGES



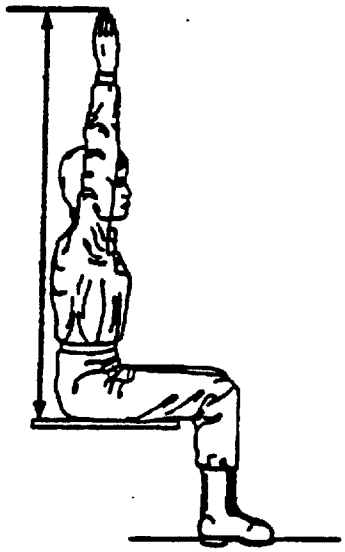
⑥ OVERHEAD REACH BREADTH – STANDING WITH HEELS 23 cm APART AND TOES 15 cm FROM WALL; ARMS EXTENDED OVERHEAD WITH FISTS TOUCHING AND AGAINST WALL; 1st PHALANGES HORIZONTAL. MEASURED HORIZONTALLY ACROSS ARMS OR SHOULDERS, WHICHEVER IS WIDER.

⑦ BENT TORSO HEIGHT – STANDING WITH FEET 30 cm APART; BENDING OVER AND PLACING PALMS OF THE HANDS ON KNEECAPS; ELBOWS AND KNEES LOCKED; LOOKING FORWARD; HEAD TILTED AS FAR BACK AS POSSIBLE. MEASURED FROM FLOOR TO TOP OF HEAD.

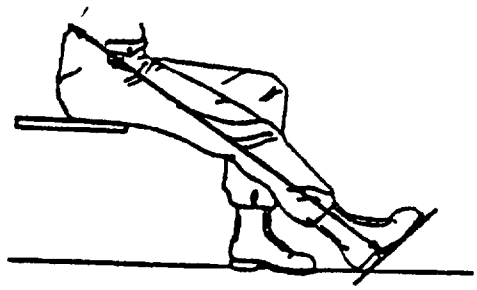


⑧ BENT TORSO BREADTH – STANDING WITH FEET 30 cm APART; BENDING OVER AND PLACING THE PALMS OF THE HANDS ON KNEECAPS; ELBOWS AND KNEES LOCKED; LOOKING FORWARD; HEAD TILTED AS FAR BACK AS POSSIBLE. MEASURED AS MAXIMUM HORIZONTAL DISTANCE ACROSS SHOULDERS.

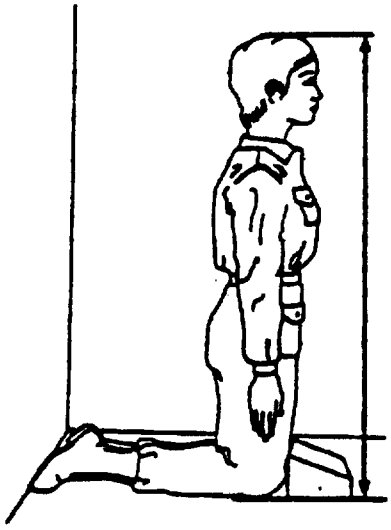
FIGURE 29. ANTHROPOMETRIC DATA FOR WORKSPACES (CONTINUED)



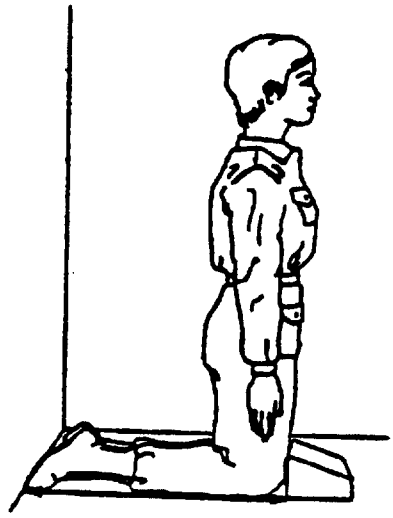
(9) OVERHEAD REACH, SITTING – SITTING ERECT; RIGHT SIDE AGAINST WALL; RIGHT ARM EXTENDED UPWARD WITH PALM FLAT AGAINST WALL AND FINGERS EXTENDED. MEASURED FROM SITTING SURFACE TO TIP OF MIDDLE FINGER.



(10) FUNCTIONAL LEG LENGTH – SITTING ERECT ON EDGE OF CHAIR; RIGHT LEG EXTENDED FORWARD WITH KNEE STRAIGHTENED. MEASURED FROM HEEL ALONG AXIS OF LEG TO POSTERIOR WAIST.

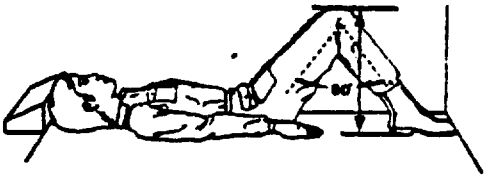


(11) KNEELING HEIGHT – KNEELING WITH TOES EXTENDED AND LIGHTLY TOUCHING REAR WALL; TORSO ERECT WITH ARMS HANGING LOOSELY AT SIDES. MEASURED FROM FLOOR TO TOP OF HEAD.

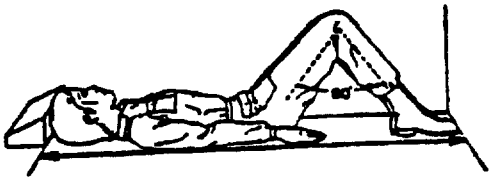


(12) KNEELING LEG LENGTH – KNEELING WITH TOES EXTENDED AND LIGHTLY TOUCHING REAR WALL; TORSO ERECT WITH ARMS HANGING LOOSELY AT SIDES. MEASURED FROM WALL TO ANTERIOR PORTION OF BOTH KNEES.

FIGURE 29. ANTHROPOMETRIC DATA FOR WORKSPACES (CONTINUED)



(13) BENT KNEE HEIGHT, SUPINE – LYING SUPINE; KNEES RAISED UNTIL ANGLE BETWEEN UPPER AND LOWER LEGS APPROXIMATES 60°; TOES LIGHTLY TOUCHING WALL. MEASURED FROM FLOOR TO HIGHEST POINT ON KNEES.



(14) HORIZONTAL LENGTH, KNEES BENT – LYING SUPINE; KNEES RAISED UNTIL ANGLE BETWEEN UPPER AND LOWER LEGS APPROXIMATES 60°; TOES LIGHTLY TOUCHING WALL. MEASURED FROM WALL TO TOP OF HEAD.

FIGURE 29. ANTHROPOMETRIC DATA FOR WORKSPACES (CONCLUDED)

5.7.5 Standard console design.

5.7.5.1 Dimensions. For purposes of standardization, consoles and the units and racks which constitute operator work stations should be designed to conform with the dimensions shown in Table XX and Figure 30.

5.7.5.2 Configurations. The configurations represented in Table XX and Figure 30 may not be applicable to all design situations. In some cases, however, operational requirements may necessitate unique design solutions. Because of the benefits and economies inherent in a standard console, design should conform with the standard configurations.

5.7.5.3 Variables. The selected console design should accommodate the following requirements, as applicable:

a. Visibility over the top of the console.

b. Operator mobility (e.g., "sit", "stand", or "sit-stand" requirements).

c. Panel space. (Note columns "B" and "E", Table XX)

d. Volume in the area below the writing surface.

5.7.5.4 Console selection. On the basis of the considerations in 5.7.5.3, the particular configuration that will best meet the requirements should be selected from among the five console types represented in Table XX.

5.7.6 Special-purpose console design.

5.7.6.1 Horizontal wrap-around. (Figure 31)

5.7.6.1.1 Panel width. When requirements for preferred panel space for a single seated operator exceed a panel width of 1.120 m (44 inches), a flat-surface, segmented, wrap-around console should be provided, so as to place all controls within the reach of the 5th percentile stationary operator.

5.7.6.1.2 Panel angle. The left and right segments should be placed at an angle, measured from the frontal plane of the central segment, such that they can be reached by the 5th percentile stationary operator.

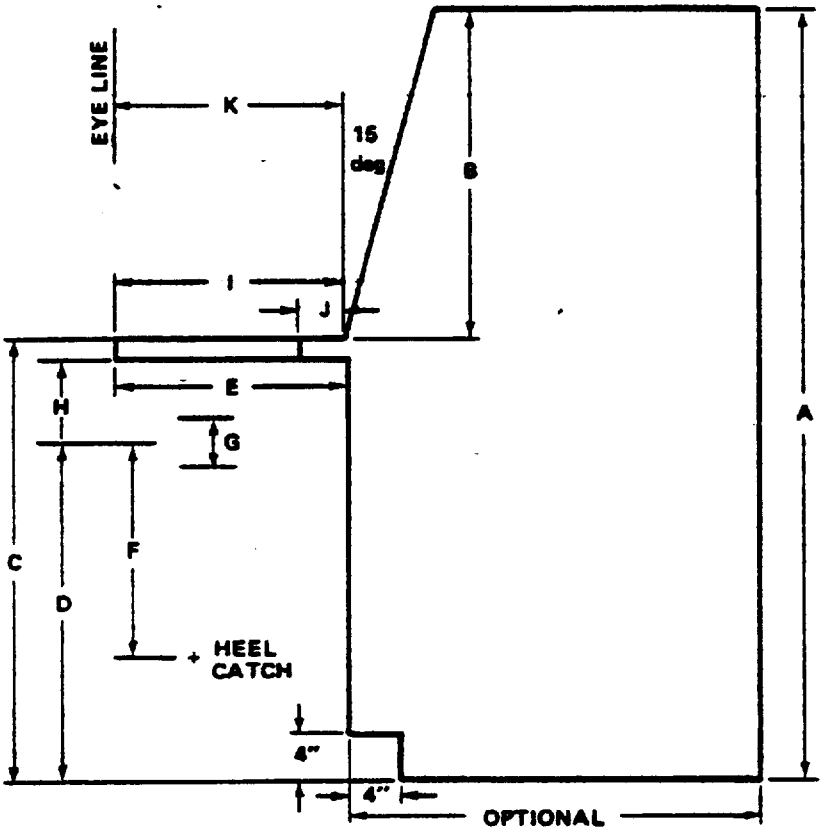
5.7.6.1.3 Dimensions (vision over top). Where vision over the top is required (thereby limiting vertical panel space), the width of the central segment shall not exceed 1.120 m (44 inches), and that of the left and right segments shall not exceed 610 mm (24 inches).

5.7.6.1.4 Dimensions. Where vision over the top is not required, i.e., the total console height may exceed the seat height by more than 685 mm (27 inches), the width of the central segment shall not exceed 860 mm (34 inches), and that of the left and right segments should not exceed 610 mm (24 inches).

TABLE XX. 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	
1. SIT (W/VISION OVER TOP)*	1.170 m (46 in.)	520 mm (20.5 in.)	650 mm (25.5 in.)	435 mm (17 in.)	1.120 m (44 in.)
	1.335 m (52.5 in.)	520 mm (20.5 in.)	810 mm (32 in.)	595 mm (23.5 in.)	1.120 m (44 in.)
	1.435 m (56.5 in.)	520 mm (20.5 in.)	910 mm (36 in.)	695 mm (27.5 in.)	1.120 m (44 in.)
2. SIT (W/O VISION OVER TOP)	1.310 m (51.5 in.)	660 mm (26 in.)	650 mm (25.5 in.)	435 mm (17 in.)	910 mm (36 in.)
	1.470 m (58.0 in.)	660 mm (26 in.)	810 mm (32 in.)	595 mm (23.5 in.)	910 mm (36 in.)
	1.570 m (62.0 in.)	660 mm (26 in.)	910 mm (36 in.)	695 mm (27.5 in.)	910 mm (36 in.)
3. SIT-STAND (W/STANDING VISION OVER TOP)	1.535 m (60.5 in.)	620 mm (24.5 in.)	910 mm (36 in.)	695 mm (27.5 in.)	910 mm (36 in.)
4. STAND (W/VISION OVER TOP)	1.535 m (60.5 in.)	620 mm (24.5 in.)	910 mm (36 in.)	NA	1.120 m (44 in.)
5. STAND (W/O VISION OVER TOP)	1.830 m (72 in.)	910 mm (36 in.)	910 mm (36 in.)	NA	910 mm (36 in.)

*THE RANGE IN "A" IS PROVIDED TO ALLOW LATITUDE IN THE VOLUME OF THE LOWER PART OF THE CONSOLE; NOTE RELATIONSHIP TO "C" AND "D".



KEY	DIMENSIONS	mm	(in.)
A	MAXIMUM TOTAL CONSOLE HEIGHT FROM STANDING SURFACE	SEE TABLE XX	SEE TABLE XX
B	SUGGESTED VERTICAL DIMENSION OF PANEL, INCL SILLS		
C	WRITING SURFACE: SHELF HEIGHT FROM STANDING SURFACE		
D	SEAT HEIGHT FROM STANDING SURFACE AT MIDPOINT OF "G"		
E*	MINIMUM KNEE CLEARANCE	(460)	18
F*	FOOT SUPPORT TO SITTING SURFACE **	(460)	18
G*	SEAT ADJUSTABILITY	(150)	6
H*	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

*NOT APPLICABLE TO CONSOLE TYPES 4 AND 5 OF TABLE XX.
**SINCE THIS DIMENSION MUST NOT BE EXCEEDED, A HEEL CATCH MUST BE ADDED TO THE CHAIR IF "D" EXCEEDS 460 mm (18 in.).

NOTE: A SHELF THICKNESS OF 25 mm (1 in.) IS ASSUMED. FOR OTHER SHELF THICKNESSES, SUITABLE ADJUSTMENTS SHOULD BE MADE.

FIGURE 30. STANDARD CONSOLE DIMENSIONS KEY

5.7.6.1.5 Viewing angle. The total required left-to-right viewing angle shall not exceed 190 degrees (see Figure 2). This angle should be reduced whenever possible through appropriate control-display layout.

5.7.6.2 Vertical/stacked segments. (See Figure 32 for example.)

5.7.6.2.1 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 shall be divided into three vertical/stacked segments whose surfaces should be perpendicular to the operator's line of sight with little or no head movement.

5.7.6.2.2 Height. The center of the central segment should be 800 mm (31.5 inches) above the seat reference point. The height of this segment shall not exceed 530 mm (21 inches).

5.7.6.3 Sit-stand consoles. Where personnel will work from standing or seated positions, console dimensions should conform to those of Table XX.

5.7.7 Stairs, stair-ladders, fixed ladders, and ramps.

5.7.7.1 General criteria.

5.7.7.1.1 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 Figure 33.

5.7.7.1.2 Provision for hand-carrying equipment. Ramps, elevators, or equivalent means should be provided when equipment must be hand carried. Ladders shall not be selected in such cases, since both hands should be free to grasp the ladder. Stairs and steps should not be used where hand-carrying bulky loads or loads in excess of 13 kg (29 lbs) is required.

5.7.7.1.3 Handrails and guardrails. Stairs, stair-ladders, fixed ladders, and ramps should be equipped with a handrail on each side. Where one or both sides are open, appropriate intermediate guardrails shall be provided to prevent personnel injury. Non-fixed vehicular-boarding ladders are neither stair ladders nor fixed ladders and are exempt from this requirement. Ladders shall not be selected in such cases, since both hands should be free to grasp the ladder. Stairs and steps should not be used where hand-carrying bulky loads or loads in excess of 13 kg (29 lbs) is required.

5.7.7.2 Stairs. Stair dimensions should conform with the recommended values and shall be within the minimum and maximum limits of Figure 34.

5.7.7.3 Stair ladders. Stair ladder dimensions should conform with the recommended values and shall be within the specified minimum and maximum limits of Figure 35. The tread rise shall be open at the rear. Landings should be provided every tenth or twelfth tread. The surface of treads on exterior stair ladders should be constructed of open grating material or should be treated with nonskid material conforming with specification