METRIC
MIL-STD-1472H
15 September 2020
SUPERSEDING
MIL-STD-1472G
w/CHANGE 1
17 January 2019

DEPARTMENT OF DEFENSE
DESIGN CRITERIA STANDARD

HUMAN ENGINEERING

AMSC N/A AREA HFAC

FOREWORD

1. This standard is approved for use by all Departments and Agencies of the Department of Defense.

2. This standard establishes general human engineering criteria for design and development of military systems, equipment, and facilities. Human engineering is one of seven domains of human-systems integration (as defined in the DoD 5000 series) and is synonymous with human factors engineering. The purpose of this standard 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. Achieve required manpower readiness for system performance.

c. Achieve required reliability of personnel-equipment combinations.

d. Foster design standardization within and among systems.

3. 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 that arise and are not specifically covered herein.

4. 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 degrees unless it is necessary to specify fractions of a degree where milliradians are used.

5. MIL-STD-1472G represented a major revision where the organizational structure of the standard was revamped to group similar material in the same section of the document. While much of the structure remains, additional sections in MIL-STD-1472H addressing habitability, cybersecurity, information presentation, and handheld devices have been added along with a section on ship bridge design that was recently issued under a Change 1 to MIL-STD-1472G.

One of the most significant changes to the "H" revision is addressing gender accommodation to meet the direction from Secretary of Defense Ashton Carter's memorandum, Implementation Guidance for the Full Integration of Women in the Armed Forces (3 December 2015), addressing the accommodation of female populations. Secretary Carter's memo states, "The Services will begin to execute the implementation of their approved plans to open all military occupational specialties, career fields, and branches for accession by women as soon as practicable." This revision to MIL-STD-1472 provides design criteria to remove unnecessary barriers to military service for men and women. For example, with respect to lifting requirements, equipment must conform to the mixed-gender lift requirements and be labeled accordingly. As a result, implications may be for increasing the number of lifters required for certain gear and equipment or require redesign or modification to reduce weight or increase lift points or handles. The goal of achieving truly "operationally relevant and gender neutral standards" reflects a balance between operational requirements (such as operationally validated military occupational specialty [MOS]-related lifting standards) and a reasonable accommodation for the broadest user possible. One must ensure that the criteria outlined herein to inform the design of military systems, equipment, and facilities is written such that it will not be applied in ways that are potentially career-limiting to military service members. It is the procuring activity's responsibility to consider all factors, including user population attributes, in design. To that end, military physical fitness testing standards are not appropriate for use in design criteria or to quantify human performance limits. The interpretation and use of this design standard should not create circumstances where a procuring activity accidently or deliberately defines its target user population such that a disproportionate number of men or women in the military that are assigned to tasks will not be able to interact and use certain equipment effectively to achieve the mission. The requirements generation, developmental process, production, and end item procurement should all be aligned to address the gender neutral directive.

It is recognized that there may be situations in which system designs cannot meet the MIL-STD-1472H anthropometry or lifting and strength requirements for some valid operational, technical, or programmatic reason. In these cases, the following should be provided:

a. A clear operational need for the design to exceed the anthropometric or lifting requirements for an identified task and duty position.

b. Explanation as to why there is either no viable design alternative or a listing of the impacts of any mitigation strategies describing why such alternatives are cost prohibitive or not operationally feasible (e.g., unacceptable adverse cost or performance impact to comply).

c. Clearly articulate evidence-based rationale as to why not accommodating a certain user population does not differentially discriminate by gender so as to not impact career advancement or what actions will be taken to mitigate that impact.

6. Comments, suggestions, or questions on this document should be addressed to Commander, Naval Sea Systems Command, ATTN: SEA 05S, 1333 Isaac Hull Avenue, SE, Stop 5160, Washington Navy Yard D.C. 20376-5160 or emailed to CommandStandards@navy mil, with the subject line “Document Comment”. Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at https://assist.dla mil.

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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 optimize system performance with full consideration of inherent human capabilities and limitations as part of the total system design trade space to more effectively integrate the human as part of the system, subsystems, equipment, and facilities to achieve mission success.

1.3 Application. This standard is applicable to the design of all systems, subsystems, equipment, and facilities, except where provisions relating to aircraft design conflict with crew system design requirements or guidelines of JSSG-2010. Unless otherwise stated in specific provisions, this standard applies to design of systems, subsystems, equipment, and facilities for use by both men and women. While this standard provides design criteria with respect to human capabilities and limitations, it is not intended to limit innovation in the design or selection of specific hardware, software, materials, and processes. This standard should be tailored by the Government as part of the contract. If it is not tailored by the Government, the contractor should determine any appropriate tailoring for the applicability to the system and recommend tailoring to the Government for approval.

1.4 Manufacturing tolerances. When manufacturing tolerances are not perceptible to the user, this standard will 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 General. The documents listed in this section are specified in sections 3, 4, or 5 of this standard. This section does not include documents cited in other sections of this standard or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3, 4, or 5 of this standard, whether or not they are listed.

2.2 Government documents.

2.2.1 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 cited in the solicitation or contract.

COMMERCIAL ITEM DESCRIPTIONS

A-A-55308 - Cloth and Strip, Laminated or Coated, Vinyl Nylon or Polyester, High Strength, Flexible

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-G-2874 - Gloves, Anti-Flash, Flame Resistant

MIL-DTL-7788 - Panels, Information, Integrally Illuminated

MIL-PRF-20696 - Cloth, Waterproof, Weather Resistant

MIL-PRF-32383 - Batteries, Rechargeable, Sealed General Specification for

MIL-PRF-38039 - Systems, Illuminated, Warning, Caution, and Advisory, General Specification for

MIL-L-85762 - Lighting, Aircraft, Interior, Night Vision Imaging System (NVIS) Compatible

DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-411 - Aircrew Station Alerting Systems

MIL-STD-882	-	System Safety
MIL-STD-1179	-	Lamps, Reflectors and Associated Signaling Equipment for Military Vehicles
MIL-STD-1425	-	Safety Design Requirements for Military Lasers and Associated Support Equipment
MIL-STD-1474	-	Noise Limits
MIL-STD-1787	-	Aircraft Display Symbology
MIL-STD-2525	-	Joint Military Symbology
MIL-STD-3009	-	Lighting, Aircraft, Night Vision Imaging System (NVIS) Compatible
MIL-STD-3050	-	Aircraft Crew Breathing Systems Using On-Board Oxygen Generating System (OBOGS)
MIL-STD-38784	-	General Style and Format Requirements for Technical Manuals
MIL-STD-46855	-	Human Engineering Requirements for Military Systems, Equipment, and Facilities

DEPARTMENT OF DEFENSE HANDBOOKS

MIL-HDBK-454	-	General Guidelines for Electronic Equipment
MIL-HDBK-472	-	Maintainability Prediction
MIL-HDBK-516	-	Airworthiness Certification Criteria
DOD-HDBK-743	-	Anthropometry of U.S. Military Personnel
MIL-HDBK-1473	-	Color and Marking of Army Materiel
MIL-HDBK-1908	-	Definitions of Human Factors Terms
MIL-HDBK-87213	-	Electronically/Optically Generated Airborne Displays

(Copies of these documents are available online at https://quicksearch.dla.mil/.)

2.2.2 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 of these documents are those cited in the solicitation or contract.

AIR FORCE INSTRUCTIONS

AFI 33-332	-	Air Force Privacy and Civil Liberties Programs
AFI 44-102	-	Medical Care Management

AIR FORCE MANUAL

AFM 41-210	-	Tricare Operations and Patient Administration

(Copies of these documents are available online at https://www.e-publishing.af mil.)

AIR FORCE INTEROPERABILITY COUNCIL (AFIC)

ADV-PUB-4048	-	Ejection Acceleration Limits

(Copies of this document are available online at https://quicksearch.dla.mil/.)

AIR FORCE PAMPHLETS

AFI 48-151 - Thermal Injury Prevention Program

(Copies of this document are available online at https://www.e-publishing.af.mil.)

AIR FORCE RESEARCH LABORATORY

AFRL-HE-WP-TR-2007-0016 - A Methodology for Evaluating Advanced Operator Workstation Accommodation

AFRL-RH-WP-TR-2014-0113 - Aircrew Sizing Survey 2011

(Copies of these documents are available online at https://www.dtic mil.)

ARMY MEDCOM

Release of Protected Health Information to Commanders Webpage - https://www.army mil/article/46296/release_of_protected_health_information_to_commanders

(Copies of this document are available online at www.army.mil.)

ARMY PUBLIC HEALTH CENTER (APHC)

Fact Sheet 88-009-0311 - You Can Arrange Your Desk So That It's Right For You

Fact Sheet 88-024-0318 - Sit/Stand Workstations

Fact Sheet 88-024-0711 - Pros and Cons of a Sit-Stand Workstation

Sit/Stand Set-Up Webpage - https://phc.amedd.army.mil/topics/workplacehealth/ergo/Pages/Sit-Stand-Set-up.aspx

(Copies of these documents are available online at http://phc.amedd.army.mil.)

ARMY REGULATIONS

AR 40-10 - Health Hazard Assessment Program in Support of the Army Acquisition Process

AR 40-66 - Medical Record Administration and Healthcare Documentation

AR 70-38 - Research, Development, Test, and Evaluation of Materiel for Worldwide Use

(Copies of these documents are available online at https://armypubs.army.mil/.)

ARMY TECHNICAL BULLETIN

TB MED 507/AFPAM 48-152 - Heat Stress Control and Heat Casualty Management

(Copies of this document are available online at https://armypubs.army.mil/.)

ARMY TECHNICAL REPORTS

USAAVSCOM TR 89-D-22A - Aircraft Crash Survival Design Guide Volume 1. Design Criteria and Checklists

USAAVSCOM TR 89-D-22B - Aircraft Crash Survival Design Guide Volume 2. Aircraft Design Crash Impact Conditions and Human Tolerance

USAAVSCOM TR 89-D-22C - Aircraft Crash Survival Design Guide Volume 3. Aircraft Structural Crash Resistance

USAAVSCOM TR 89-D-22D - Aircraft Crash Survival Design Guide Volume 4. Aircraft Seats, Restraints, Litters, and Cockpit/Cabin Delethalization

USAAVSCOM TR 89-D-22E	-	Aircraft Crash Survival Design Guide Volume 5. Aircraft Postcrash Survival

(Copies of these documents are available online at https://www.dtic mil.)

CODE OF FEDERAL REGULATIONS (CFR)

10 CFR 20	-	Standards for Protection Against Radiation
21 CFR 1040	-	Performance Standards for Light-Emitting Products
29 CFR 1910	-	Occupational Safety and Health Standards
29 CFR 1910.25	-	Stairways
29 CFR 1910.26	-	Dockboards
29 CFR 1910.27	-	Scaffolds and Rope Descent Systems
29 CFR 1910.28	-	Duty to Have Fall Protection and Falling Object Protection
29 CFR 1910.29	-	Fall Protection Systems and Falling Object Protection-Criteria and Practices
29 CFR 1910.36	-	Design and Construction Requirements for Exit Routes
29 CFR 1910.37	-	Maintenance, Safeguards, and Operational Features for Exit Routes
29 CFR 1910.101	-	Compressed Gases (General Requirements)
29 CFR 1910.102	-	Acetylene
29 CFR 1910.103	-	Hydrogen
29 CFR 1910.104	-	Oxygen
29 CFR 1910.105	-	Nitrous Oxide
29 CFR 1910.106	-	Flammable Liquids
29 CFR 1910.107	-	Spray Finishing Using Flammable and Combustible Materials
29 CFR 1910.108	-	Dip Tanks Containing Flammable or Combustible Liquids
29 CFR 1910.109	-	Explosives and Blasting Agents
29 CFR 1910.110	-	Storage and Handling of Liquefied Petroleum Gases
29 CFR 1910.111	-	Storage and Handling of Anhydrous Ammonia
29 CFR 1926	-	Safety and Health Regulations for Construction
29 CFR 1926.102	-	Eye and Face Protection
33 CFR 83	-	Inland Navigation Rules
47 CFR 1.1307	-	Actions that May Have a Significant Environmental Effect, for which Environmental Assessments (EAs) Must be Prepared
47 CFR 1.1310	-	Radiofrequency Radiation Exposure Limits
47 CFR 2.1091	-	Radiofrequency Radiation Exposure Evaluation: Mobile Devices
47 CFR 2.1093	-	Radiofrequency Radiation Exposure Evaluation: Portable Devices
49 CFR 571.101	-	Standard No. 101; Controls and Displays

49 CFR 571.108 - Standard No. 108; Lamps, Reflective Devices, and Associated Equipment

(Copies of these documents are available online at www.ecfr.gov.)

COMMITTEE ON NATIONAL SECURITY SYSTEMS

CNSSI 1253 - Security Categorization and Control Selection for National Security Systems

(Copies of this document are available online at http://www.cnss.gov.)

DEPARTMENT OF DEFENSE ISSUANCES AND DIRECTIVES

DoDD 5400.7 - DoD Freedom of Information Act (FOIA) Program

DoDI 5400.11 - DoD Privacy and Civil Liberties Programs

DoDI 6025.18 Health Insurance Portability and Accountability Act (HIPPA) Privacy Rule Compliance in DoD Health Care Programs

DoDI 6055.01 - DoD Safety and Occupational Health (SOH) Program

DoDI 6055.15 - DoD Laser Protection Program

DoDI 8510.01 - Risk Management Framework (RMF) for DoD Information Technology (IT)

DoDI 8580.02 - Security of Individually Identifiable Health Information in DoD Health Care Programs

(Copies of these documents are available online at www.esd.whs mil/DD/.)

EUROPEAN AGENCY FOR SAFETY AND HEALTH AT WORK

European Parliament Directive 2002/44/EC - Vibration

(Copies of this document are available online at https://osha.europa.eu.)

FEDERAL COMMUNICATIONS COMMISSION OFFICE OF ENGINEERING & TECHNOLOGY

FCC 96-326 - Guidelines for Evaluating the Environmental Effects of Radiofrequency Radiation

OET Bulletin 56 - Questions and Answers about Biological Effects and Potential Hazards of Radiofrequency Electromagnetic Fields

(Copies of these documents are available online at www.fcc.gov.)

INTER-GOVERNMENTAL MARITIME CONSULTATIVE ORGANIZATION (IMCO)

Resolution MSC.337 - Adoption of the Code on Noise Levels on Board Ships

(Copies of this document are available online at www.imo.org.)

JOINT SERVICE SPECIFICATION GUIDE (JSSG)

JSSG-2010 - Crew Systems

JSSG-2010-7 - Crew Systems Crash Protection Handbook

(Copies of these documents are available online at https://quicksearch.dla.mil/.)

NATICK AND SURVIAC TECHNICAL REPORTS

NATICK/TR-13/018	-	2010 Anthropometric Survey of U.S. Marine Corps Personnel: Methods and Summary Statistics
NATICK/TR-13/033		Standard Methodology for Assessment of Range of Motion While Wearing Body Armor
NATICK/TR-14/019	-	Characterizing the Size of the Encumbered Soldier
NATICK/TR-15/007	-	2012 Anthropometric Survey of U.S. Army Personnel: Methods and Summary Statistics
NATICK/TR-16/013	-	2012 Anthropometric Survey of U.S. Army Pilot Personnel: Methods and Summary Statistics
NATICK/TR-17/010	-	Anthropometry and Range of Motion of the Encumbered Soldier
SURVIAC-TR-12-169	-	Joint Software Systems Safety Engineering Handbook

(Copies of these documents are available online at https://www.dtic mil.)

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

NIST SP 800-53 - Security and Privacy Controls for Information Systems and Organizations

(Copies of this document are available online at https://nvl.nist.gov/.)

NAVAL SEA SYSTEMS COMMAND (NAVSEA) PUBLICATIONS

T9640-AC-DSP-010/HAB - Shipboard Habitability Design Criteria and Practices Manual (Surface Ships) for New Ship Designs and Modernization

(Copies of this document are available online via Technical Data Management Information System (TDMIS) at https://mercury.tdmis navy mil/. Refer questions, inquiries, or problems to: DSN 296-0669, Commercial (805) 228-0669. These documents are available for ordering (hard copy) via the Naval Logistics Library (NLL) at https://nll.navsup.navy.mil. For questions regarding the NLL, contact the NLL Customer Service at nllhelpdesk@navy mil, (866) 817-3130, or (215) 697-2626/DSN 442-2626.)

NAVY MEDICINE AND NAVY ENVIRONMENTAL HEALTH CENTER

NEHC-TM-OEM-6260.6	-	Prevention and Treatment of Heat and Cold Stress Injuries
Policy 8-005		E-Mailing Personally Identifiable Information (PII) and Protected Health Information (PHI)

(Copies of this document are available online at https://www.med.navy mil.)

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH)

Applications Manual for the Revised NIOSH Lifting Equation

(Copies of this document are available online at www.cdc.gov/niosh.)

SECNAV INSTRUCTIONS

SECNAVINST 5211.5	-	Department of the Navy Privacy Program
SECNAV M-5210.1	-	Department of the Navy Records Management Program

(Copies of these documents are available online at https://www.secnav navy mil/doni/default.aspx.)

UNITED STATES COAST GUARD

Navigation Rules and Regulations Handbook

72 COLREGS - International Regulations for Preventing Collisions at Sea

(Copies of these documents are available online at http://navcen.uscg.gov.)

UNITED STATES GOVERNMENT

Public Law 104-191	-	Health Insurance Portability and Accountability Act of 1996
Public Law 111-5	-	American Recovery and Reinvestment Act of 2009
5 USC 552	-	Public Information; Agency Rules, Opinions, Orders, Records, and Proceedings

(Copies of these documents are available online at http://www.govinfo.gov.)

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

ACOUSTICAL SOCIETY OF AMERICA (ASA)

ANSI/ASA S1.4 Part 1	-	Electroacoustics – Sound Level Meters – Part 1: Specifications
ANSI/ASA S2.70	-	Guide for the Measurement and Evaluation of Human Exposure to Vibration Transmitted to the Hand
ANSI/ASA S3.2	-	Method for Measuring the Intelligibility of Speech Over Communication Systems

(Copies of these documents are available online at www.acousticalsociety.org.)

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH)

Industrial Ventilation: A Manual of Recommended Practice for Design

Documentation of the Threshold Limit Values of Physical Agents (TLVs)

(Copies of these documents are available online at https://www.acgih.org.)

AMERICAN INDUSTRIAL HYGIENE ASSOCIATION (AIHA)

The Occupational Environment: Its Evaluation, Control, and Management – "The White Book"
Stock #: BIHT10-566

(Copies of this document are available online at https://online-ams.aiha.org)

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI/ASC A14	-	Ladder Standards Package
ANSI/ASME A13.1	-	Scheme for the Identification of Piping Systems
ANSI Z136.1	-	Safe Use of Lasers
ANSI Z136.3	-	Safe Use of Lasers in Health Care
ANSI/ASSP Z359	-	Fall Protection Code (Series)
ANSI Z535.2	-	Environmental and Facility Safety Signs

ANSI Z535.4 - Product Safety Signs and Labels

(Copies of these documents are available online at www.ansi.org.)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM F3323 - Standard Terminology for Exoskeletons and Exosuits

ASTM F3444/F3444M - Standard Practice for Training Exoskeleton Users

ASTM F3358 - Standard Practice for Labeling and Information for Exoskeletons

ASTM F3392 - Standard Practice for Exoskeleton Wearing, Care, and Maintenance Instructions

ASTM F3427 - Standard Practice for Documenting Environmental Conditions for Utilization with Exoskeleton Test Methods

(Copies of these documents are available online at www.astm.org.)

ASSOCIATION FOR THE ADVANCEMENT OF MEDICAL INSTRUMENTATION (AAMI)

AAMI 62366-1 - Medical Devices – Part 1: Application of Usability Engineering to Medical Devices

AAMI HE75 - Human Factors Engineering – Design of Medical Devices

(Copies of these documents are available online at www.aami.org.)

COMPRESSED GAS ASSOCIATION

CGA S-1.1 - Pressure Relief Device Standards Part 1 – Cylinders for Compressed Gases

CGA G-8.1 - Standard for Nitrous Oxide Systems at Customer Sites

(Copies of these documents are available online at https://portal.cganet.com.)

ELECTRONIC COMPONENTS INDUSTRY ASSOCIATION

EIA TEB 26 - CIE-UCS Chromaticity Diagram with Color Boundaries

(Copies of this document are available online at www.ecianow.org.)

HUMAN FACTORS AND ERGONOMICS SOCIETY

ANSI/HFES 100 - Human Factors Engineering of Computer Workstations

ANSI/HFES 200 - Human Factors Engineering of Software User Interfaces

ANSI/HFES 200.3 - Interaction Techniques

(Copies of these documents are available online at https://webstore.ansi.org.)

ILLUMINATING ENGINEERING SOCIETY

The Lighting Handbook

(Copies of this document are available online at www.ies.org.)

INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERS

IEEE C95.1 - IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz

IEEE 1584 - Guide for Performing Arc-Flash Hazard Calculations

(Copies of these documents are available online at https://standards.ieee.org.)

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

IEC 60601-1-2 - Medical Electrical Equipment – Part 1-2: General Requirements for Basic Safety and Essential Performance – Collateral Standard: Electromagnetic Disturbances - Requirements and Tests

(Copies of this document are available online at www.iec.ch.)

INTERNATIONAL MARITIME ORGANIZATION

MSC.333(90) - Adoption of Revised Performance Standards for Shipborne Voyage Data Recorders (VDRs)

(Copies of this document are available online at www.imo.org.)

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

ISO 2041 - Mechanical Vibration, Shock and Conditioning Monitoring – Vocabulary

ISO 2631-1 - Mechanical Vibration and Shock – Evaluation of Human Exposure to Whole-Body Vibration – Part 1: General Requirements

ISO 2631-2 - Mechanical Vibration and Shock – Evaluation of Human Exposure to Whole-Body Vibration – Part 2: Vibration in Buildings (1 Hz to 80 Hz)

ISO 2631-5 - Mechanical Vibration and Shock – Evaluation of Human Exposure to Whole-Body Vibration – Part 5: Method for Evaluation of Vibration Containing Multiple Shocks

ISO 5348 - Mechanical Vibration and Shock – Mechanical Mounting of Accelerometers

ISO 5349-1 - Mechanical Vibration – Measurement and Evaluation of Human Exposure to Hand-Transmitted Vibration – Part 1: General Requirements

ISO 5349-2 - Mechanical Vibration – Measurement and Evaluation of Human Exposure to Hand-Transmitted Vibration – Part 2: Practical Guidance for Measurement at the Workplace

ISO 5805 - Mechanical Vibration and Shock – Human Exposure – Vocabulary

ISO 8861 - Shipbuilding – Engine-Room Ventilation in Diesel-Engined Ships – Design Requirements and Basis of Calculations

ISO 8862 - Air-Conditioning and Ventilation of Machinery Control-Rooms on Board Ships - Design Conditions and Basis of Calculations

ISO 9241-210 - Ergonomics of Human-System Interaction – Part 210: Human-Centred Design for Interactive Systems

ISO 9241-400 - Ergonomics of Human-System Interaction – Part 400: Principles and Requirements for Physical Input Devices

ISO 14726 - Ships and Marine Technology – Identification Colours for the Content of Piping Systems

ISO 14971 - Medical Devices – Application of Risk Management to Medical Devices

ISO 20283-5 - Mechanical Vibration – Measurement of Vibration on Ships – Part 5: Guidelines for Measurement, Evaluation and Reporting of Vibration with Regard to Habitability on Passenger and Merchant Ships

(Copies of these documents are available online at www.iso.org.)

NATIONAL FIRE PROTECTION ASSOCIATION

NFPA 70 - National Electrical Code

NFPA 91 - Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Particulate Solids

NFPA 101 - Life Safety Code

(Copies of these documents are available online at www.nfpa.org.)

SAE INTERNATIONAL

SAE AMS-STD-595 - Colors Used in Government Procurement

SAE AMS-STD-595/11105 - Red, Gloss

SAE AMS-STD-595/13538 - Yellow, Gloss

SAE AMS-STD-595/14187 - Green, Gloss

SAE AMS-STD-595/15123 - Blue, Gloss

SAE AMS-STD-595/17038 - Miscellaneous, Gloss

SAE AMS-STD-595/17875 - Miscellaneous, Gloss

SAE AMS-STD-595/21105 - Red, Semigloss

SAE AMS-STD-595/21136 - Red, Semigloss

SAE AMS-STD-595/23538 - Yellow, Semigloss

SAE AMS-STD-595/24300 - Green, Semigloss

SAE AMS-STD-595/26231 - Gray, Semigloss

SAE AMS-STD-595/26492 - Gray, Semigloss

SAE AMS-STD-595/26622 - Gray, Semigloss

SAE AMS-STD-595/27038 - Miscellaneous, Semigloss

SAE AMS-STD-595/27875 - Miscellaneous, Semigloss

SAE AMS-STD-595/33538 - Yellow, Flat or Lusterless

SAE AMS-STD-595/36231 - Dark Gull Gray

SAE AMS-STD-595/37038 - Black, Flat or Lusterless

SAE AMS-STD-595/37875 - Miscellaneous, Flat or Lusterless

SAE S6228 - Safety Requirements for Procurement, Maintenance and Use of Hand-Held Powered Tools

SAE AS18012 - Markings for Aircrew Station Displays Design and Configuration of

SAE AS25050	-	Colors, Aeronautical Lights and Lighting Equipment, General Requirements for
SAE J925	-	Minimum Service Access Dimensions for Off-Road Machines

(Copies of these documents are available online at www.sae.org.)

2.4 Order of precedence. Unless otherwise noted herein or in the contract, 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.

3. DEFINITIONS

3.1 Abbreviations and acronyms.

Acronym/ Abbreviation	Meaning
ΔE	Delta "E" or the "color difference"
µrad	Microradian
3-D	3-Dimensional
$a_{hv(rms)}$	Frequency-weighted vibration total value
ACGIH TLV	American Conference of Governmental Industrial Hygienists Threshold Limit Value
AI	Articulation index
ANSI	American National Standards Institute
APHC	Army Public Health Center
AR	Army Regulation
BIT	Built-in test
BITE	Built-in test equipment
CAC	Common access card
CBM+	Condition Based Maintenance Plus
CBRNE	Chemical, biological, radiological, nuclear, and high-yield explosive
cd/m^2	Candela per square meter
CIE	International Commission on Illumination (Commission Internationale de l'Eclairage)
CGA	Compressed Gas Association
cm	Centimeter
cm^3	Cubic centimeter
CO	Carbon monoxide
CO_2	Carbon dioxide
COHb	Carboxyhemoglobin
CONOPS	Concept of operations
CR	Contrast ratio
dBA	A-weighted decibels
dBP	Decibel peak pressure
DEAV	Daily Exposure Action Value
DELV	Daily Exposure Limit Value
DMS	Degrees, minutes, seconds
DoD	Department of Defense (United States)
DOF	Degrees of freedom
EA	Energy attenuating
EMI	Electromagnetic interference
EMP	Electromagnetic pulse
fc	Footcandles

Acronym/ Abbreviation	Meaning
FITS	Fighter Index of Thermal Stress
fL	Footlambert
FOD	Foreign object damage
ft/min	Feet per minute
ft/s	Feet per second
ft	Foot
ft^2	Square foot
ft^3	Cubic foot
ft^3/min	Cubic feet per minute
g	Gram
GHz	Gigahertz
H_2S	Hydrogen sulfide
HCl	Hydrogen chloride
HCN	Hydrogen cyanide
HFES	Human Factors and Ergonomics Society
HMDs	Helmet-mounted displays
HSI	Human systems integration
HUDs	Head-up displays
HVAC	Heating, ventilating, or air-conditioning
Hz	Hertz
in	Inch
in Hg	Inches of mercury
in^2	Square inch
in^3	Cubic inch
IP	Internet protocol
IS	Information system
ISO	International Organization for Standardization
ISSO	Information System Security Officer
IT	Information technology
K	Kelvin (temperature)
kg	Kilogram
kHz	Kilohertz
KOS	Key-operated switch
lb	Pound
lbf	Pounds-force
LCD	Liquid crystal display
LED	Light-emitting diode
LEP	Laser eye protection

Acronym/ Abbreviation	Meaning
Leq(24)	24-hour equivalent continuous sound level
LRU	Line replaceable unit
lx	Lux
m	Meter
m/min	Meters per minute
m/s	Meters per second
m/s^2	Meters per second squared (acceleration) – equivalent to ms^{-2}
m^2	Square meter
m^3	Cubic meter
m^3/min	Cubic meters per minute
mA	Milliamps
MGRS	Military grid reference system
MIL-HDBK	Military Handbook
MIL-STD	Military Standard
min	Minute
mm	Millimeter
mm Hg	Millimeters of Mercury
mm^2	Square millimeter
MOPP	Mission-oriented protective posture
MOS	Military occupational specialty
MPCD	Minimum perceptible color difference
mrad	Milliradian
MRT	Modified rhyme test
ms	Millisecond
ms^{-2}	Meters per second squared (acceleration) – equivalent to m/s^2
MSDV	Motion sickness dose value
MTBF	Mean time between failure
MTTR	Mean time to repair
N	Newtons
NH3	Ammonia
nm	Nanometer
N•m	Newton meters
NO	Nitrous oxide
NOHD	Nominal ocular hazard distance
NOHD-M	Nominal ocular hazard distance with magnifying optics
NSHD	Nominal skin hazard distance
NVD	Night vision device
OOD	Officer on deck

Acronym/ Abbreviation	Meaning
OOW	Officer of the navigation watch
OSH	Occupational safety and health
OSHA	Occupational Safety and Health Administration
ozf	Ounces of force
Pb	Lead
PC	Printed circuit
PED	Portable electronic device
PHEL	Physiological heat exposure limits
PHI	Protected health information
PII	Personally identifiable information
PIN	Personal identification number
PKI	Public key infrastructure
POA	Point-of-aim
PPE	Personal protective equipment
PSF	Performance shaping factor
RABC	Role-based access control
rad	Radian
RFI	Radio-frequency interference
RMS	Root mean square
RPG	Rocket-propelled grenade
RPM	Revolutions per minute
s	Second
SA	System administrator
SAE	SAE International, previously known as the Society of Automotive Engineers
SAR	Specific absorption rate
SECDEF	Secretary of Defense
SEP	Systems engineering plan
SME	Subject matter expert
SO_2	Sulfur dioxide
SPL	Sound pressure level
SRP	Seat reference point
STI	Speech transmission index
UAV	Unmanned aerial vehicle
UxV	Unmanned vehicle
VAC	Alternating current voltage
VDC	Direct current voltage
VE	Virtual environment
VOC	Volatile organic compound

Acronym/ Abbreviation	Meaning
WBGT	Web bulb globe temperature
$WBGT_{eff}$	Maximum effective wet bulb globe temperature
WL	Weight limit
WMSD	Workplace musculoskeletal disorder
Z	Vertical

3.2 Definitions. Definitions for terms used in this standard are as follows. All other terms are defined in accordance with MIL-HDBK-1908. Definitions herein and in MIL-HDBK-1908 are notionally provided for clarity of understanding. Specific approved functional requirements for any particular platform and system that vary from these definitions must be specified by the procuring activity (see 6.2).

3.2.1 Access control. The selective restriction of permissions within an information system (IS) and the rules that govern the access. Identification and authentication is the process of verifying the identity of a user, process, or device through the use of unique identifiers (e.g., passwords, tokens, and biometrics) as a prerequisite for granting access to resources in an information technology (IT) system.

3.2.2 Alarm. An alarm is the equivalent of a warning (see MIL-HDBK-1908 for definition of “warning”).

3.2.3 Alert. An alert is the equivalent of a caution (see MIL-HDBK-1908 for definition of “caution”). In some aviation contexts, an “alert” may simply refer to any signal that alerts the aircrew to the existence of a warning, caution, or advisory condition, but it is not used as such in this standard. Systems should defer to MIL-STD-411 for definitions and application in aviation context.

3.2.4 Anthropometric accommodation. Having sufficient reach, movement, clearance, and visibility to safely perform all required tasks while wearing the appropriate mission ensemble and equipment. Required tasks include adequate clearance for movement, the ability to ingress and egress work areas, internal and external visibility to perform the required operations, and proper reach and actuation of controls through their full range of travel.

3.2.5 Automation surprise. An action that is performed by an automated system and is unexpected by the user. A mode error can be a common cause of an automation surprise. Automation surprise can be dangerous when it upsets the situation awareness of a control operator.

3.2.6 Battle-short switch. A switch (or terminals for connecting one) that bypasses all interlocks. The battle-short switch circuit consists of a single switch wired in parallel with the interlock system. Closing the battle-short switch thus short circuits all of the interlock switches, which turns power on regardless of whether interlocks have been opened.

3.2.7 Binaural. Of, relating to, affecting, or designed for use with two ears.

3.2.8 Boresight (weapon). Adjustments made to an optical sight to align the barrel of a weapon with the sights.

3.2.9 Caution signal. A signal that alerts the operator to an impending dangerous condition requiring attention but not necessarily immediate action (in accordance with MIL-HDBK-1908 definition).

3.2.10 Central 90 percent accommodation. A design wherein the multivariate central 90 percent of suitably clothed and equipped males of the target user population and the multivariate central 90 percent of suitably clothed and equipped females of the target user population will be able to use and fit the system to accomplish required physical tasks under consideration. The distribution of the 10 percent not accommodated by the design, including range of adjustment of system features, should be evenly split between the smaller and larger portions of the population. When design of the system requires simultaneous accommodation on multiple measures of the population, multivariate analysis methods are required to properly determine accommodation of the central 90 percent of users. When design of the system requires only univariate accommodation, design for the central 90 percent of users is achievable by using the conventional 5^{th} to 95^{th} percentiles on a single dimension. Any other central percentage population would be similarly calculated and evaluated.

3.2.11 Clear eye distance. Minimum distance required to avoid eye impact injury due to recoil of weapon.

3.2.12 Coaxial cable. A type of electrical cable that has an inner conductor surrounded by a tubular insulating layer, which is encased by a tubular conducting shield. Many coaxial cables also have an insulating outer sheath or jacket.

3.2.13 Collimation. The process of aligning lenses along the line of sight to minimize divergence and convergence.

3.2.14 Contrast ratio (CR). The ratio of the target, icon, or character luminance to the surrounding field or background luminance. CR is expressed by the following:

$$CR = Lmax / Lmin$$

Contrast ratio is one greater than the luminance contrast (see 3.2.40) (i.e., CR = C + 1. For the purposes of this standard, contrast ratio will be expressed as a ratio [e.g., 3:1]).

3.2.15 Control. A device or coordinated arrangement of devices used to direct the actions of or to cause a system or subsystem to act or function in a certain way.

3.2.16 Corridors. Walkways that are physically restricted by walls, partitions, equipment, or other obstacles.

3.2.17 Dichotic. Related to the simultaneous stimulation of the right and left ear by different sounds.

3.2.18 Diffuse reflection. The reflection from a rough surface. The reflected rays still behave in accordance with the law of reflection, but the roughness of the surface results in variation in the normals along the surface. With this variation, normals at neighboring points are no longer parallel to each other. The incident angles for a set of parallel rays will not be the same, and each reflected ray will have a different angle of reflection. In other words, the rays scatter.

3.2.19 Diopter. A unit of refractive power of a lens. The reciprocal of the focal length in meters (m) is the refractive power in diopters. For example, a lens with a focal length of 0.5 m has a diopter measure of 2.0 (1/0.5).

3.2.20 Display frame. The outermost edges of a display that contains images.

3.2.21 Drop loop. A downward loop. Examples include a wire entering a building to permit rainwater to drip off or a loop in a pipe to collect water condensed in the pipe system.

3.2.22 Egocentric perspective. An outlook that has the tendency to perceive, understand, and interpret information in terms of the self.

3.2.23 Elbow (dynamic). Clearance required for an elbow moving in all directions.

3.2.24 Elbow (static). Clearance required for an elbow in still position.

3.2.25 Eye relief. The distance from the last surface of an eyepiece at which the user's eye can obtain the full viewing angle. Generally, the higher the magnification and the larger the intended field of view, the shorter the eye relief.

3.2.26 Field of regard. All points of the physical environment that can be perceived through eye, head, and body movement.

3.2.27 Field of view. The area that is visible for viewing by a stable eye at a given moment.

3.2.28 Font size-to-character height. Fonts are sized in "points," which describes measure from the top of the capital letters to the bottom of lower case letters with descenders (e.g., "j" or "y"). One point is 0.35 millimeter (mm) (0.0139 inch [in]).

3.2.29 Fuse. A protection device in an electrical circuit.

3.2.30 Fuze. An arming device for a military munition.

3.2.31 Ganging (switches). A set of two or more switches in as many circuits operated simultaneously by a single control.

3.2.32 Geographic displays. A display that presents geo-referenced data over a map service.

3.2.33 Glad hands. A coupling device used to connect air hoses between a tractor or truck and a trailer or towed vehicle.

3.2.34 Headspace (weapon). The distance measured from the part of the chamber that stops forward motion of the cartridge to the face of the bolt. If the headspace is too short, the ammunition may not chamber correctly. If the headspace is too large, the ammunition may not fit as intended and the cartridge may rupture, possibly damaging the weapon and injuring the user.

3.2.35 Health hazard. Exposure to an agent or condition inherent to the normal use and operation, training, maintenance, movement, transport, storage, or disposal of the materiel item or materiel system that can cause acute or chronic injury, acute or chronic illness, death, impairment, disability, reduced job performance (performance degradation), or reduced personnel readiness due to exposure to various physical (i.e., environmental) or physiological (i.e., biological) stressors.

3.2.36 Human performance. The demonstrated capability of the user to operate, maintain, and support the components of the system, equipment, or facility under all expected operational, environmental, and tactical conditions such that the outcome of the task(s) meets performance criteria for those specified conditions as executed by trained and qualified users.

3.2.37 Information system. The rendered elements of a computer application or operating system through which a user may interact with the software. Interaction styles include various modalities to include vision, auditory, and motor (gesture, tactile, braille, and speech). It includes the means by which commands are given to the computer or the program and how information is presented to the user.

3.2.38 Interaction (crew or team). Act of communicating or performing tasks and activities with other people.

3.2.39 Interlocks. Devices connected with a cover, shield, or case that disable the associated internal hazard (usually electrical) when the cover, shield, or case is opened. These devices are ordinarily wired into the "hot" lead to the power supply and operate whenever an access cover is opened, which breaks the circuit whenever personnel enter the enclosure. Similarly, software interlocks are logical conditions used to prevent execution of software-controlled actions unless certain logical conditions are met.

3.2.40 Ionizing radiation. Radiation that carries enough energy to detach electrons from atoms, thereby ionizing them. Exposure to ionizing radiation causes damage to living tissue and can result in radiation burns, cell damage, radiation sickness, cancer, and death.

3.2.41 Isolation switches. Switches used in electrical systems to allow isolation of apparatus such as circuit breakers, transformers, and transmission lines for maintenance. Isolation switches are usually not intended for normal control of the circuit, but only for safety isolation.

3.2.42 Limit stops. Mechanical mechanisms designed to restrict a moving object or part by stopping it at a predetermined (limit) position(s).

3.2.43 Lockout. A mechanical means to disable a control or switch in its safe position (e.g., electricity disconnected) and to prevent its activation without the use of undue force or tools.

3.2.44 Luminance contrast. The contrast between a figure (e.g., target, icon, or character) and its background equals the difference between the higher luminance (Lmax) and the lower luminance (Lmin) divided by the lower luminance (Lmin). Luminance contrast is expressed by the following:

$$C = (L_{max} - L_{min}) / L_{min}$$

For the purposes of this standard, luminance contrast will be expressed as a ratio (e.g., 3:1).

3.2.45 Maximum allowable torque. The highest torque that must be applied in order for the valve to be opened and operated. It is acceptable for the valve to be opened and operated at any lower torque.

3.2.46 Multivariate accommodation. (See 3.2.10, Central 90 percent accommodation).

3.2.47 Neutral posture. A posture in which the muscles are at their resting length and the joint is naturally aligned. Joints in neutral postures have maximum control and force production. Working with the body in a neutral posture reduces stress and strain on the muscles, tendons, and the skeletal system and reduces the risk of developing a workplace musculoskeletal disorder.

3.2.48 Non-ionizing radiation. Any type of electromagnetic radiation that does not carry enough energy to ionize atoms. Instead of producing charged ions when passing through matter, non-ionizing electromagnetic radiation has only enough energy for excitation, or the movement of an electron to a higher energy state. Exposure to non-ionizing radiation can cause burns, radiation sickness, cancer, and genetic damage.

3.2.49 Non-standard tool. A tool that is typically not found in the technician's toolbox.

3.2.50 Occlusion. An obstruction that prohibits one from viewing the image that should be displayed.

3.2.51 Open hatch. An operational condition in which the hatch of a combat vehicle is open 90 degrees or greater.

3.2.52 Open protected. An operational condition in which the hatch of a combat vehicle is open less than 90 degrees.

3.2.53 Optical density. The logarithmic ratio of the intensity of transmitted light to the intensity of the incident light passing through the substance. Optical density refers to the absorbance of a substance.

3.2.54 Parallax. A displacement or difference in the apparent position of an object viewed along two different lines of sight. As an example, when viewing a needle-style speedometer in a vehicle from directly in front, the exact speed will be shown. But when viewed from the passenger seat, the needle may appear to show a slightly different speed due to the angle of viewing.

3.2.55 Passageways. Areas across which people must pass for work purposes.

3.2.56 Performance shaping factors (PSFs). All factors that influence human performance. A PSF is an aspect of the human's individual characteristics, environment, organization, or task that specifically decrements or improves human performance and influences the likelihood of human error or mission success. Examples of PSFs include complexity, ergonomics, experience and training, stress and stressors, available time, work processes, fatigue, environmental stressors (e.g., heat, vibration, motion, or noise), and fitness for duty.

3.2.57 Personal protective equipment (PPE). Personal protective equipment, commonly referred to as "PPE", is equipment worn to minimize exposure to hazards that can cause workplace injuries and illnesses. These injuries and illnesses may result from contact with chemical, radiological, directed energy, physical, electrical, mechanical, or other workplace hazards. Personal protective equipment may include items such as LASER-protective eyewear, gloves, safety glasses and shoes, earplugs or muffs, hard hats, respirators, or coveralls, vests, and full-body suits.

3.2.58 Pintle. A pin or bolt that is used as part of a pivot or hinge. In transportation, a pintle-hitch is a type of tow hitch that uses a tow ring configuration to secure to a hook or a ball combination for the purpose of towing an unpowered vehicle or trailer. As a weapon mount, a pintle-mount is used as the mounting hardware that mates the weapon to a vehicle or tripod.

3.2.59 Portable electronic device (PED). A small, non-stationary electronic apparatus with the capability of processing, sensing, displaying, recording, storing, or transmitting information. Some PEDs can be held or worn, depending on the application.

3.2.59.1 Handheld PEDs. Devices that are intended for use by an individual holding the device in one or both hands. A smartphone and radio are examples of a handheld PED.

3.2.59.2 Two-handed PEDs. Handheld PEDs that require the use of two hands to achieve the intended purpose. A tablet computer is an example of a two-handed PED.

3.2.59.3 Wearable PEDs. PEDs that are primarily intended to be worn on the body. Wearable devices can be user-passive (such as sensors) or user-active (such as radios or control devices). Smart watches, sensors (radiological or biological), and smart glasses are examples of wearable PEDs.

3.2.60 Portlet. Pluggable user interface software components that are managed and displayed in a web or enterprise portal.

3.2.61 Public entrances. Any entrances that are not loading or service entrances.

3.2.62 Query language. A type of dialogue in which users compose entries for searching a database and returning specified data.

3.2.63 Quick release. A mechanism by which a single dedicated movement of the operator's unaided hand permits removal and installation of an object, device, or a related accessory requiring no tools and minimal hand movements.

3.2.64 Recoil. Backwards force and resultant movement caused by momentum, such as when a weapon is discharged.

3.2.65 Role-based access control (RABC). RABC is an access control policy that utilizes roles, permissions, and users to establish a method to restrict access. The organization defines roles with specific permissions to obtain established access levels. Users are assigned to roles and inherit the role's permissions to gain access to perform defined functions.

3.2.66 Solenoid. A coil that is "pipe-like" in the sense that its length is substantially greater than its diameter. A solenoid is a type of electromagnet whose purpose is to generate a controlled magnetic field in a volume of space when an electric current is passed through it.

3.2.67 Special tool. A tool that is developed for a specific application within a particular system.

3.2.68 Specular reflection. The reflection from a very smooth surface. A set of parallel incident rays encountering a smooth surface will reflect so that the angles of reflection are all the same. During specular reflection, the reflected rays will be parallel if the incident rays are.

3.2.69 Stereo headset. A headset that has independent inputs for the left and right channels.

3.2.70 Stereography. The depiction or representation of three-dimensional objects on to a two-dimensional surface.

3.2.71 Stereoscopic. Relating to or denoting a process by which two images of the same object taken at slightly different angles are viewed together, creating an impression of depth and solidity.

3.2.72 Tactor. Small actuators that vibrate against the skin to provide a physical stimulus in response to an electrical input.

3.2.73 Tagouts. Tags that are attached to a control or place of hazard associated with an ongoing mode of operation or maintenance. They are generally used to prevent equipment activation during maintenance of equipment.

3.2.74 User. A person who directly uses or is intended to directly use a product for its primary purpose. A user also includes a person who supports or maintains the product such as an installer, maintainer, sustainer, system administrator, or repair technician.

3.2.75 Visible, visibility (of display). The capacity of display content to be seen, discernable, readable, manifested, usable, or legible in the intended application under the prevailing operational conditions.

3.2.76 Visual display. Any device that presents graphical information, textual information, or images in a static or dynamic format that is electronically, electrically, or naturally illuminated.

3.2.76.1 Electronic displays. A display device that uses raster graphics or bitmap (pixel) data structure to display visual information that does not produce a permanent record. Electronic displays include video displays, PEDs, heads-up and helmet-mounted displays, segmented displays, and some stereographic displays.

3.2.76.2 Non-electronic displays. Graphical media illuminated by an electrical or natural light source. Non-electronic displays include illuminated panels, legends, scales, and indicator lights.

3.2.77 Walkways. Areas designated for walking.

3.2.78 Warning signal. A signal that alerts the operator to a dangerous condition requiring immediate action (per MIL-HDBK-1908 definition).

3.2.79 Web portals. A collection of web pages where each web page consists of one or more portlets.

3.2.80 Workplace. An area room or establishment where work is done.

3.2.81 Workstation. A place designed for a specific task or activity from where work is conducted or operations are directed. It is the collection of physical items required where a task or work of a particular nature is carried out. It may be a simple flat surface (e.g., desk or table top) to conduct manual or precision assembly work, or it may be a combination of input (e.g., keyboard, mouse, switches, and knobs) and output (e.g., display or monitor) devices as found with information technologies. Workstations often have supporting elements (e.g., chair, stool, or table desk) and may be independently assembled from input and output devices combined with supporting elements or implemented as an integrated unit such as a console or instrument panel. Workstations can be designed as areas for one or more users to accomplish purposeful tasks or jobs.

4. GENERAL REQUIREMENTS

4.1 Recycled, recovered, environmentally preferable, or biobased materials. Recycled, recovered, environmentally preferable, or biobased materials should be used to the maximum extent possible, provided that the material meets or exceeds the operational and maintenance requirements, and promotes economically advantageous life cycle costs.

4.2 Design objectives.

4.2.1 Work environment. Military systems, equipment, and facilities shall provide work and living environments that foster effective procedures, work patterns, and personnel safety, health, and survivability.

4.2.2 Performance degradation. Military systems, equipment, and facilities should minimize factors that degrade human performance or increase error.

4.2.3 User capabilities. The system design-induced requirements for user workload, accuracy, time, cognitive processing, and communication shall not exceed user capabilities.

4.2.4 Task performance. The system design shall meet the user capability requirements to permit accurate and efficient task performance thereby enabling system performance, measures of effectiveness, and measures of performance to be met.

4.2.5 Personnel, training, and skill requirements. The system design shall meet all defined personnel, training, and skill requirements for the system. The resultant design should be consistent with system complexity, operational availability, human performance requirements, and safety requirements within the designated measures of effectiveness, measures of performance, schedule, and cost constraints.

4.2.6 System manpower. The system design should optimize system manpower by identifying the minimum number and type of personnel required consistent with system complexity, human performance requirements, workload and safety requirements, and reliability, affordability, and risk constraints.

4.3 Standardization. Controls, displays, marking, coding, labeling, and arrangement schemes (equipment and panel layout) shall be uniform to the greatest extent possible for common functions of all equipment and systems.

4.4 Off-the-shelf equipment.

4.4.1 Selection. Criteria for selecting off-the-shelf commercial or Government equipment shall include the degree to which the equipment conforms to this standard.

4.4.2 Modification. 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.

4.5 Human engineering design.

4.5.1 Compliance. Compliance with the design criteria presented in this standard should be included as part of a program's human engineering effort as a best practice. Demonstration of suitability or task performance may be used to constitute compliance when approved by the procuring activity.

4.5.2 Application. Criteria identified in this standard shall be applied to the design of hardware, software, systems, equipment, and facilities in which there is a human interface or interaction including operation, maintenance, training, and support activities.

4.5.3 Accommodation. Unless otherwise specified elsewhere in this standard or by the procuring activity (see 6.2), equipment, systems, and subsystems shall be designed to accommodate both the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped males of the target user population, and the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped females of the target user population. The requirements generation, developmental process, production, and end item procurement should all be aligned to address the gender neutral Secretary of Defense (SECDEF) directive.

4.5.4 Human engineering requirements. As a best practice, human engineering design requirements should be established to develop effective human interfaces and preclude system characteristics that require extensive cognitive, physical, or sensory skills; complex manpower or training-intensive tasks; or may result in frequent or critical errors.

4.5.5 Human engineering activities. Human engineering activities shall be identified and executed according to a Human Engineering Program Plan or equivalent document (e.g., human factors section of a Human Systems Integration Plan, or the equivalent section in an integrated Systems Engineering Plan [SEP]) to ensure that systems are designed to account for human capabilities and limitations. Specific human factors analyses and activities are outlined in MIL-STD-46855.

4.5.6 Design factors. Design should reflect human engineering, life support, and biomedical factors that affect human performance. When applicable, this includes the following:

a. Atmospheric conditions including composition, pressure, temperature, and humidity. This includes safeguards against exceeding safe limits beyond which human performance will be degraded and personnel may be put at risk or harm. For aircrew systems, also see MIL-STD-3050.

b. Range of acoustic noise, vibration, acceleration, shock, blast, and impact forces. This includes safeguards against exceeding safe limits beyond which human performance will be degraded and personnel may be put at risk or harm.

c. Protection from thermal, biological, toxicological, chemical, radiological, nuclear, mechanical, electrical, electromagnetic, pyrotechnic, and other hazards.

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

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

f. Arrangement of operation and maintenance workplaces, equipment, controls, and displays.

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

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

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

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

k. Provision of nonrestrictive personal life support and protective equipment.

l. Provisions for minimizing psycho-physiological stress effects of mission duration and fatigue under normal, adverse, and emergency conditions.

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

n. Remote handling provisions and tools.

o. 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, passenger compartments, allocated tasks, and control movements with the clothing and personal equipment to be worn by personnel operating, riding in, or maintaining military systems or equipment.

q. Design of workstations in all human-system interactions for mobile operations.

r. Sufficient time, resources, and training are allocated to meet the “mean time to repair” required for operational availability or maintainability requirements such that operators are capable of isolating and implementing corrective action tasks in the time allocated.

s. The design for reliability is sufficient as to not place additional burden on the operators to perform diagnostics and corrective maintenance above that which has been deemed adequate to support the mission concept of operations (CONOPS).

t. Condition Based Maintenance Plus (CBM+) technologies have been considered and integrated wherever feasible to reduce the maintenance burden on operators and maintainers.

4.6 Failure modes.

4.6.1 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.

4.6.2 Remote and local control. For critical control and monitoring functions, there shall be normal and backup control functions so that the function can be executed even if normal control equipment fails or the operator that normally executes the function is incapacitated. The backup function shall be enabled to take control at any time and vice versa according to a defined control protocol (see 6.2). There shall be indication of the station that has control at both the normal and backup station.

4.7 Simplicity of design.

4.7.1 Equipment simplicity. The equipment shall represent the simplest design consistent with functional requirements and expected operational conditions.

4.7.2 Training. The equipment shall be capable of being operated and maintained in the intended operational environment to meet the systems operational availability requirements (i.e., mean time to repair, diagnostic time, isolation, and repair time) by personnel with the requisite technical training as prescribed for the system under design.

4.8 Interaction. The design of the system shall reflect the interaction requirements of crew-served equipment.

4.9 Safety.

4.9.1 System and personnel safety factors. Design shall reflect applicable system and personnel safety factors. This includes minimizing 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.

4.9.2 Design of nonmilitary-unique workplaces and equipment. Design of nonmilitary-unique workplaces and equipment shall conform to Occupational Safety and Health Administration (OSHA) standards unless military applications require more stringent limits (e.g., maximum steady-state noise in personnel-occupied areas).

4.9.3 Fall protection for operations and maintenance. Design for operations and maintenance evolutions shall provide protection or prevention of falls from elevated work surfaces in accordance with the ANSI/ASSP Z359 Fall Protection Code series. Design of systems and support equipment shall limit risk of fall from elevated work locations, considered to be 4 feet in general industry and 5 feet in maritime industry, through application of a hierarchy of controls to reduce or mitigate the hazard(s). Optimal measures will eliminate the hazard through process change or relocation of controls/equipment requiring inspection/maintenance to ground level. Alternative approaches will prevent falls through isolation or separation of workers by fixed barriers such as handrails, or by providing engineering controls such as aerial lifts, mobile scaffolding, or other design to allow guarded access. These measures may be augmented by administrative controls such as warning lines, signs, or designation of safe areas. When work at heights is necessary and fixed barriers are not feasible, designs shall provide for a personal fall arrest system (including personal fall protection devices [see 4.9.3.1]) and the engineering, management, and training components required for their application. Engineering, analysis, and documentation are needed to implement fall prevention programs including:

a. Analysis/description of how work at height will be accomplished.

b. Providing certified anchor points (5,000-pound [lb] test) for harnesses and other support equipment in accessible locations.

c. Use of certified full-body fall protection harnesses and associated lanyards (attached between harness and anchor points). Belts do not meet fall protection requirements and shall not be used (except for positioning).

d. Fall distance calculation accommodating the expansion of fall lanyards (with body harnesses) when a person falls plus allowance for height of the person (typically 15 feet [ft] total).

e. Proactively determining how to rescue workers after they fall before such events occur.

f. Ensuring that anchor points are placed such that the individual will not pendulum into harm's way should a fall occur.

4.9.3.1 Personal fall arrest system. A personal fall arrest system includes an approved full-body harness and other equipment designed to provide controlled expansion that limits the impact forces created by a the fall on the victim (to 1,800 pounds) and certified anchorages (> 3,600 lbs). The device providing controlled deceleration may include a lanyard, deceleration device, lifeline, or combinations of these.

4.10 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.

4.11 Chemical, biological, radiological, nuclear, and high-yield explosive (CBRNE) survivability. The required protection is likely to be different for the hazards to which an individual will be exposed in each of the CBRNE environments. As such, the system design shall provide individual PPE for the CBRNE, directed energy, or other mission environments in which the system will be operated and maintained as specified (see 6.2).

4.11.1 CBRNE PPE compatibility. As applicable, equipment design shall be compatible with CBRNE, directed energy, or other mission-required PPE.

4.11.2 Performance of mission-essential operations. Equipment design 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 CBRNE environments specified (see 6.2).

4.11.3 Susceptibility to reduction of inherent CBRNE hardness. Equipment design shall minimize susceptibility to reduction of inherent CBRNE hardness as a result of operator- or maintainer-induced errors or damage.

4.11.3.1 CBRNE hardness verification. CBRNE hardness shall be verifiable by maintenance personnel after maintenance actions (hardness surveillance).

4.11.3.2 CBRNE hardness and maintenance. CBRNE hardness shall not be degraded when routine (scheduled) and corrective (unscheduled) maintenance is performed.

4.11.4 CBRNE hardness and maintenance personnel expertise. Maintenance of the equipment's inherent CBRNE hardness shall not be dependent on maintenance personnel expertise, critical alignments, and maintenance actions.

4.11.5 CBRNE PPE ventilation requirements. For CBRNE or other mission-required PPE ventilation requirements, see 5.5.2.1.3.5.

4.11.6 Anthropometric accommodation. Anthropometric accommodation and design of CBRNE, directed energy protection, or other mission-required PPE systems shall be in accordance with section 5.8.

4.11.7 Human systems integration (HSI). HSI of CBRNE, directed energy, or other mission-required PPE systems shall be in accordance with applicable DoDI 5000 series.

4.12 Electromagnetic pulse (EMP) hardening.

4.12.1 EMP hardening requirements. 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.

4.12.2 Access to EMP-hardened facilities. Access to EMP-hardened facilities or spaces shall be provided without compromising the electromagnetic barrier protecting the space.

4.12.3 Electromagnetic barrier accessibility. Items such as surge arrestors, terminal protection devices, and filters, which form part of an electromagnetic barrier for protection against EMP effects, shall be readily accessible.

4.13 Automation.

4.13.1 Automation of functions. Functions shall be automated only to attain greater overall effectiveness, efficiency, reliability, simplicity, economy, and system safety rather than relying on human performance alone.

4.13.2 Human involvement. Irrespective of the level of automation, system and task design shall ensure that the human user is in command, involved in ongoing operations, and appropriately informed to maintain awareness of the situation and other status of automated functions.

4.13.3 Automated function characteristics. When used, automated functions shall minimize automation surprise; offer the user an appropriate range of options; monitor user actions to minimize, resist, and tolerate errors; and be capable of being overridden by the user.

4.13.4 Indication of operating mode. A clear indication of the currently selected operating mode shall be provided to the user at all times.

4.14 Functional use of color. Where not in conflict with color codes specified herein, colors used for functional purposes (e.g., visual displays, controls, workspaces, and equipment connections) shall accommodate users with color-deficient vision.

4.15 Design of aircrew systems. Aircrew systems shall be designed as specified (see 6.2). Refer to JSSG-2010 for further guidance. Additional aircrew system design guidance can be found in MIL-DTL-7788.

4.16 System integration. The design shall be compatible with all systems the user is expected to operate, maintain, or support.

4.17 Stealth and covert operations. Systems and equipment for use in combat may require stealth for covert operations. The need for low-observable exterior and camouflage may preclude the use of brightly colored warning signs, warning lights, or auditory warnings. For such systems and equipment, techniques such as barriers and interlocks shall be used to ensure safe and effective operations.

4.18 Technical documentation. For human engineering guidance on the preparation of technical documentation, see MIL-STD-38784.

4.19 Aircraft emergency escape systems.

4.19.1 Ejection acceleration limits. For guidance on the exposure of military personnel to short-duration (less than one second), linear, and angular acceleration occurring during the operation of ejection seats, see ADV-PUB-4048. Guidance for acceleration occurring during parachute opening after the ejection seat occupant has separated from the seat is excluded.

4.19.2 Crash protection. For guidance on occupant crash protection and crash-protective aspects of seating, restraint, and crewstation and passenger/troop station design, see JSSG-2010-7 and USAAVSCOM TR 89-D-22 (A through E), Aircraft Crash Survival Design Guide Volumes 1 through 5.

4.19.3 Escape and egress systems. For guidance on escape and egress systems, see MIL-HDBK-516.

4.20 Human performance.

4.20.1 Human performance requirements. Design should be based on an understanding of the human performance requirements, capabilities, and limitations as it relates to the human tasks and activities necessary to operate, maintain, support, and train the system, equipment, or facility.

4.20.2 Measuring human performance. Programs should measure human performance (and PSFs) throughout the early pre-design and design phases and in test and evaluation efforts so the program can be informed of human performance issues that may impact mission success.

5. DETAILED REQUIREMENTS

5.1 Controls.

5.1.1 General criteria.

5.1.1.1 Selection of mechanical controls. The criteria in table I should be used in determining the best type of mechanical control to be used on control panels. Table II shows recommended controls in relation to control function and actuation force required.

5.1.1.1.1 Compatibility with users.

5.1.1.1.1.1 Accommodation of user population. Unless otherwise specified (see 6.2), the type of control selected and the location of the motion envelopes shall accommodate the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped males of the target user population and the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped females of the target user population for body dimensions.

5.1.1.1.1.2 Two-dimensional design elements. Fifth percentile strength values and 5th or 95th percentile univariate physical dimension values shall be used for two-dimensional design elements (see figures 22 and 23).

5.1.1.1.1.3 Handedness accommodation. Equipment design shall accommodate both right- and left-handed users.

5.1.1.1.1.4 Handedness accommodation for majority of user population. If constraints permit only one group of users (right- or left-handed) to be accommodated, the majority of the target user population shall receive priority.

5.1.1.1.1.5 Compatibility with handwear. Controls shall be compatible with handwear to be utilized in the anticipated environment. Unless specified for glove use, all dimensions cited herein are for bare hands and shall be adjusted for use with gloves or mittens (see language regarding gloves in table VII).

5.1.1.1.2 Distribution of workload. Controls should be selected and distributed so that none of the user's limbs will be overburdened.

5.1.1.1.3 Multirotation controls. Multirotation controls should be used when precision is required over a wide range of adjustment.

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

5.1.1.1.5 Stops. Stops shall be provided at the beginning and end of the range-of-control positions if the control is not to be operated beyond the indicated end positions or within specified limits.

5.1.1.1.6 Power assist. Power assist may be used to reduce the magnitude of force inputs required to adjust or actuate controls. When servo-amplifier devices are used, appropriate proportional resistance or force feedback shall be provided to give the user the feel of unpowered control.

5.1.1.2 Direction of movement.

5.1.1.2.1 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, 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 excluded (see 5.1.1.2.5).

5.1.1.2.2 Multidimensional operation. When the vehicle, equipment, or components may move in more than two dimensions, an exception to 5.1.1.2.1 shall be made if necessary to ensure consistency of anticipated response (e.g., forward motion of a directional control causes some vehicles to dive or otherwise descend rather than simply move forward).

TABLE I. Mechanical control criteria. 1/

Function	Control									
	Selector Switch	**Round Knob**	**Discrete Thumb Wheel**	**Cont. Thumb Wheel**	**Crank**	**Push Button**	**Toggle Switch**	**Rocker Switch**	**Lever**	**Joystick, Lever, Ball, Mouse**
Select power state ON-OFF	3	--	--	--	--	1	2	2	1a	--
3-state (OFF-STBY-ON)	1	2	--	--	--	--	2	3	--	--
Select between OFF/prime mode/secondary mode(s)	1	--	--	--	--	2	3	3	1a	--
Select one or more of N-related functions	--	--	--	--	--	1	2	2	--	--
Select one of N mutually exclusive functions of any order	--	--	--	--	--	1	--	--	--	--
Select one of 3 to 24 discrete alternatives – sequential order	1	--	--	--	--	--	--	--	--	--
Select digit – discrete	2b	--	2b	--	--	1c	--	--	--	--
Set value on – continuous scale	--	1	--	2	3	--	--	--	3	--
Select value in – discrete steps	1	--	1	--	--	1	--	--	--	--
Select operating condition	2	--	--	--	--	1	1	1	2	--
Enter alphanumeric data	--	--	--	--	--	1c	--	--	--	--
Initiate test subfunction (momentary)	3	--	--	--	--	1	1	2	--	--
Initiate directional function	3	--	--	3	--	2d	1	1d	1	2
Generate stepping impulse (momentary hold)	--	--	--	--	--	1	1	2	--	--
Slew counters or other numeric readout	--	1e	--	--	1f	1	1	--	--	--
Reset mechanical counter, manual	--	1	3	1	--	--	--	--	--	--
Interrupt sequence, “hold”	--	--	--	--	--	1	2	2	--	--
Engage – disengage mechanical function	--	--	--	--	--	--	--	--	1	--
Adjust light level, continuous	--	1	3	1	--	--	--	2	3	--
Adjust sound level, continuous	--	1	3	1	--	--	--	2	3	--

TABLE I. Mechanical control criteria – Continued.

Function	Control									
	Selector Switch	**Round Knob**	**Discrete Thumb Wheel**	**Cont. Thumb Wheel**	**Crank**	**Push Button**	**Toggle Switch**	**Rocker Switch**	**Lever**	**Joystick, Lever, Ball, Mouse**
Coarse adjustment	--	1g	--	2h	2i	--	--	--	2j	2
Fine adjustment	--	1k	--	2l	2m	--	--	--	3n	2
Adjust to null position	--	1	--	2	3	--	--	--	3	2
Single-coordinate tracking	--	3	--	--	2	--	--	--	1	--
Two-coordinate tracking	--	--	--	--	3	--	--	--	--	1

NOTE:

[1/] Key:

1 = most preferred	2 = secondary preference	3 = least preferred
a – Lever for heavy duty power circuits	h – Small motion	
b – Only if sequential selection is acceptable	i – Few turns	
c – Keyboard	j – Short throw	
d – Multiple controls	k – Large diameter	
e – Rate control	l – Large motion	
f – Manual only	m – Many turns	
g – Small diameter	n – Long throw	

TABLE II. Recommended manual controls.

Control Function	Control Type
Small Actuation Force Required	
2 discrete positions	Key lock Legend switch Push button Slide switch Toggle switch
3 discrete positions	Push button Rotary selector switch Toggle switch
4 to 24 discrete positions	Rotary selector switch
Continuous setting (linear and less than 360°)	Continuous rotary knob Joystick or lever
Continuous slewing and fine adjustment	Continuous rotary knob Crank Joystick or lever
Large Actuation Force Required	
2 discrete positions	Detent lever Foot push button Hand push button
3 to 24 discrete positions	Detent lever Rotary selector switch
Continuous setting (linear and less than 360°)	Crank Handwheel Joystick or lever Two-axis grip handle
Continuous setting (greater than 360°)	Crank Handwheel Two-axis grip handle Valve

5.1.1.2.3 Combined controls. When several controls are combined in one device, responses shall be compatible with control movement (e.g., control motion to the right is compatible with clockwise roll, right turn, and direct movement to the right).

5.1.1.2.4 User-control orientation. Controls shall be oriented with respect to the user. Where a vehicle user may use two or more stations, the controls shall cause movement oriented to the user at the effecting station unless remote visual reference is used.

5.1.1.2.5 Valve controls. Rotary valve controls shall open the valve with a counterclockwise motion.

5.1.1.2.6 Labeling of valve controls. 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).

5.1.1.2.7 Ball valve controls. Ball valves with lever handles shall be provided with valve position indication with respect to the open and closed positions and double-ended arrows showing the direction of operation between the two positions.

5.1.1.3 Grouping and arrangement.

5.1.1.3.1 Grouping. Controls that are operated in a task-driven sequence or that are operated together shall be grouped together along with their associated displays.

5.1.1.3.1.1 Multiple steps selected by a single control. 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.

5.1.1.3.1.2 Cycling through ON/OFF position. Unnecessary cycling through the control's ON/OFF position shall be avoided.

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

5.1.1.3.3 Location of primary controls. The most important and frequently used controls (particularly rotary controls and those requiring fine settings) shall have the most favorable position for ease of reaching and grasping.

5.1.1.3.4 Consistency. The arrangement of functionally similar or identical primary controls shall be consistent from panel to panel throughout the system, equipment, vehicle, and other systems expected to be operated by the user (e.g., a movement of a control to the right or left shall result in a corresponding movement of a displayed element to the right or left).

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

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

5.1.1.3.7 Spacing. Minimum spacing between controls shall comply with table III. Spacing between a control and any adjacent obstruction shall be as shown by the figures referenced in table III. Minimum spacing shown shall be increased for operation with gloves, mittens, or CBRNE or other mission-required PPE when such operation is a system requirement (see 5.1.1.1.1.5 and table VII).

TABLE III. Minimum edge-to-edge separation distances for mechanical controls [1/].

	Toggle Switches	**Push Buttons [2/]**	**Continuous Rotary Controls**	**Rotary Selector Switches**	**Discrete Thumbwheel Controls**
Toggle Switches	See figure 16	13 mm (0.5 in)	19 mm (0.75 in)	19 mm (0.75 in)	13 mm (0.5 in)
Push Buttons [2/]	13 mm (0.5 in)	See figure 14	13 mm (0.5 in)	13 mm (0.5 in)	13 mm (0.5 in)
Continuous Rotary Controls	19 mm (0.75 in)	13 mm (0.5 in)	See figure 12	25 mm (1 in)	19 mm (0.75 in)
Rotary Selector Switches	19 mm (0.75 in)	13 mm (0.5 in)	25 mm (1 in)	See figure 6	19 mm (0.75 in)
Discrete Thumbwheel Controls	13 mm (0.5 in)	13 mm (0.5 in)	19 mm (0.75 in)	19 mm (0.75 in)	See figure 8

NOTES:

[1/] All values are for one-hand operation. All values are for bare-handed operation.

[2/] For push buttons not separated by barriers.

5.1.1.3.8 Control interference. The size, shape, and location of controls shall be designed to ensure that the operation of any one control does not interfere with the user's ability to use other controls and perform other duties.

5.1.1.3.9 Emergency shutoff controls. Emergency shutoff controls shall be accessible, not hidden, located to prevent accidental activation, and positioned within easy reach of the user (see 5.1.1.1.1.5, 5.1.1.6, and 5.1.1.7).

5.1.1.4 Coding. 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 (see table IV).

TABLE IV. Advantages and disadvantages of various types of manual control coding.

Advantages	**Type of Coding**					
	Location	**Shape**	**Size**	**Mode of Operation**	**Labeling**	**Color**
Improves visual identification	X	X	X		X	X
Improves nonvisual identification (tactile 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	X
Requires little (if any) training; is not subject to forgetting					X	

TABLE IV. Advantages and disadvantages of various types of manual control coding – Continued.

Advantages	Type of Coding					
	Location	Shape	Size	Mode of Operation	Labeling	Color
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 user wears gloves		X	X	X		
Controls must be viewed (i.e., must be within visual areas and illuminated)					X	X

5.1.1.4.1 Consistent application. Where coding is used to differentiate among controls, application of the code shall be uniform throughout the system and other systems expected to be operated by the user.

5.1.1.4.2 Location-coding.

5.1.1.4.2.1 Controls beside or behind the user. When controls are beside or behind the user, they shall be a minimum of 250 mm (10 in) apart for location coding.

5.1.1.4.2.2 Similar functions. Controls associated with similar functions shall be in the same relative location from workstation to workstation, from panel to panel, and other systems expected to be operated by the user.

5.1.1.4.3 Size-coding. No more than three different sizes shall be used to code controls for discrimination by absolute size.

5.1.1.4.3.1 Same function. Controls used for performing the same function on different items of equipment shall be the same size.

5.1.1.4.3.2 Knob diameter. When knob diameter is used as the coding parameter, the differences between diameters shall be not less than 13 mm (0.5 in).

5.1.1.4.3.3 Knob thickness. When knob thickness is the coding parameter, the differences between thicknesses shall be not less than 10 mm (0.4 in).

5.1.1.4.4 Shape coding. Shape coding designs shall meet the criteria in 5.1.1.4.4.1 through 5.1.1.4.4.2.

5.1.1.4.4.1 Use. Shape coding may be used to ensure identification of control knobs or handles by "feel" where visual identification is not possible, diversion of user visual attention to identify the proper control would detract from mission accomplishment, or where the consequences of incorrect control selection would be severe. The criteria of 5.1.1.4.4.1.1 through 5.1.1.4.4.1.7 shall be met when shape coding is used:

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

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

5.1.1.4.4.1.3 Identifiable with gloves. Shapes shall be tactually identifiable when gloves must be worn.

5.1.1.4.4.1.4 Number of shapes. The number of shapes to be identified by each user based on absolute discrimination shall be not more than 10.

5.1.1.4.4.1.5 Attached to shaft. Shape-coded knobs and handles shall be positively and non-reversibly attached to their shafts to preclude incorrect attachment when replacement is required.

5.1.1.4.4.1.6 Touch alone. For knobs that must be recognized by touch alone, easily recognizable knob shapes shall be used (see figure 1).

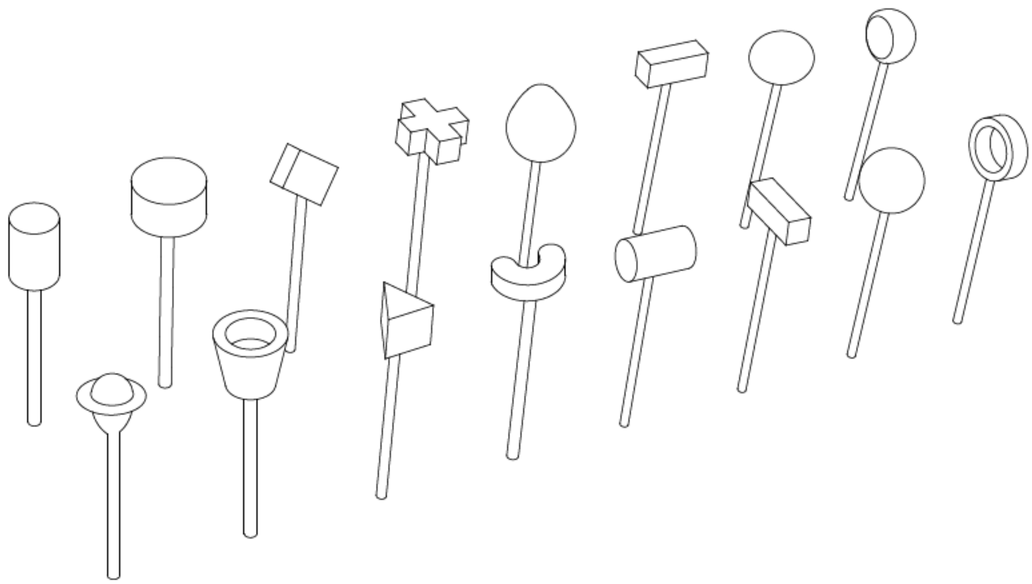


FIGURE 1. Easily recognizable knob shapes.

5.1.1.4.4.1.7 Control function. Shapes shall be assessed to ensure that they are clearly associated with the intended control function and have no reasonable association to any of the alternate functions available.

5.1.1.4.4.2 Control dimensions. Minimum control dimensions when users must distinguish controls by shape alone shall be as follows:

a. Height: 13 mm (0.5 in) or larger.

b. Width: 13 mm (0.5 in) or larger.

c. Depth: 6.5 mm (0.25 in) or larger.

5.1.1.4.5 Color coding. Colors shall not be the sole means to control coding.

5.1.1.4.5.1 Number of colors. When used for color coding, not more than five colors shall be used.

5.1.1.4.5.2 Choice of colors. Controls shall be black in accordance with SAE AMS-STD-595 (17038, 27038, 37038) or gray in accordance with SAE AMS-STD-595 (26231 or 36231).

5.1.1.4.5.3 Choice of colors for color coding. If color coding is required, only the following colors identified in SAE AMS-STD-595 shall be selected for control coding:

a. Red: 11105 or 21105.

b. Green: 14187.

c. Orange-yellow: 13538, 23538, or 33538.

d. White: 17875, 27875, or 37875.

e. Blue: 15123 (if an additional color is absolutely necessary).

5.1.1.4.5.4 Specular reflection. Gloss finishes shall not be used on controls where specular reflection (glare) or reduced friction could degrade task performance (10000-series in SAE AMS-STD-595).

5.1.1.4.5.5 Gloss finishes. Gloss finishes shall not be used in areas subject to darkened conditions for night operations.

5.1.1.4.5.6 Immediate action controls. Immediate action controls are those that need to be rapidly landmarked and activated in emergency situations. Color coding of immediate action controls for aircraft shall be in accordance with SAE AS18012.

5.1.1.4.5.7 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.

5.1.1.4.5.8 Control to background contrast. Sufficient color/brightness contrast between the control and its background shall be provided to ensure prompt and accurate identification of the control by the user.

5.1.1.4.5.9 Ambient lighting and color coding exclusion. Color coding shall be compatible with anticipated ambient light during the mission.

5.1.1.4.5.9.1 Primary identification means. Color coding shall not be used as the primary identification medium if the spectral characteristics of the ambient light or the user's adaptation to that light varies as the result of factors such as solar glare, filtration of light, and variation from natural to artificial light.

5.1.1.4.5.9.2 Red lighting. If red lighting is to be used during a portion of the mission, controls that would otherwise be coded red shall be coded by orange-yellow and black striping in accordance with SAE AMS-STD-595.

5.1.1.5 Labeling of controls. Control labeling shall be in accordance with 5.4.

5.1.1.6 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) (see 5.1.1.4.2 and 5.1.1.4.4).

5.1.1.7 Prevention of accidental actuation.

5.1.1.7.1 Location and design. Controls shall be designed and located so that they are not susceptible to being moved accidentally or inadvertently, particularly critical controls where such operation might cause equipment damage, personnel injury, system performance degradation, or system shutdown of mission-critical equipment where a reboot period is necessary to restart the equipment.

5.1.1.7.2 Internal controls. Internal or hidden controls shall be protected from inadvertent actuation or movement.

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

5.1.1.7.4 Methods. If a control must be protected from accidental actuation, one or more of the following methods shall be used:

a. Locate and orient the control so that the user is not likely to strike or move it accidentally in the normal sequence of control movements.

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

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

d. Interlock the control 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 control with movement resistance (e.g., viscous or coulomb friction, spring-loading, or inertia) so that definite or sustained effort is required for actuation.

f. Lock the control to prevent it from quickly passing through a position when strict sequential activation is necessary (i.e., the control is moved only to the next position, then delayed).

g. Design the control for operation by rotary action.

h. Design the control with spring loading requiring depress-to-turn rotary action.

5.1.1.7.5 Weapon control and actuation. The weapon (or directed energy) fire trigger (or switch) shall be clearly labeled for the intended function and shall be physically protected to prevent accidental activation.

5.1.1.7.6 Trigger. The trigger (or switch) shall be a guarded positive-action type control requiring continuous user intent to maintain activation.

5.1.1.7.7 Dead man controls. Dead man controls, which will result in system shutdown to a non-critical operating state when force or input is removed, shall be utilized wherever user incapacity can produce a critical system condition.

5.1.1.8 Feedback. There shall be no discernible time lag between a change in a system condition being controlled or monitored and its indication on a display.

5.1.1.8.1 Unavoidable time lag. If a time lag between control actuation and ultimate system state is unavoidable, the system shall provide immediate feedback to the user of the process and direction of parameter change.

5.1.1.8.2 Feedback indication. Feedback shall indicate (without ambiguity, uncertainty, or error) to the user that the control is properly actuated, that the desired response is achieved, and when the desired response is complete.

5.1.1.8.3 Critical control functions. Critical control functions, such as those entered by keyboard, shall provide feedback to the user prior to entry to ensure that the keyed entry is errorless and is the one that the user desires to enter.

5.1.1.9 Hazardous operations.

5.1.1.9.1 Interlocks and warnings. Unless otherwise contraindicated in this standard, the critical position of a control that initiates hazardous operations (e.g., ignition or crane movement) shall activate visible and audible warning signals in the affected work area.

5.1.1.9.2 Consistency of use. A control used for a critical or emergency use function shall be dedicated to that function only.

5.1.2 Control/display integration.

5.1.2.1 General criteria.

5.1.2.1.1 Relationship. The relationships of a control to its associated display and the display to the control shall be immediately apparent and unambiguous to the user.

5.1.2.1.2 Location. A control shall be located adjacent to (normally below or to the right of) its associated display and positioned so that neither the control nor the hand normally used for setting the control will obscure the display.

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

5.1.2.1.4 Complexity and precision. The complexity and precision required for manipulating controls and monitoring displays shall be consistent with the precision required of the system.

5.1.2.1.5 User ability. Control/display complexity and precision shall not exceed the user's ability to discriminate display detail or manipulate controls (in terms of manual dexterity, coordination, or reaction time) under the dynamic conditions and environment in which human performance is expected to occur.

5.1.2.1.6 Feedback.

5.1.2.1.6.1 Use. Feedback shall be provided that presents status information, confirmation, and verification of input throughout system interaction.

5.1.2.1.6.2 System status. Users shall always be provided with system status information regarding operational modes and availability, either automatically or by request as needed.

5.1.2.1.6.3 Computer response. Every input by a user shall produce a consistent, perceptible response output from the computer. In applications where the system intentionally produces no visual feedback as an indicator of invalid user input, an alternative form of feedback (e.g., different audio sound) shall be produced to ensure the invalid action is recognized by the user.

5.1.2.1.6.4 System response time. Maximum system response times for real-time systems (e.g., fire control systems or command and control systems) shall not exceed the values of table V. For teleoperations (e.g., remotely controlled systems, such as unmanned systems), the operationally acceptable response times should be specified by the acquisition program (see 6.2).

TABLE V. Acceptable system response times.

System Interpretation	Response Time Definition	Time (Seconds)
Key response, including scroll wheels, optical wheels, mouse clicks	Key pressed until positive response (e.g., “click”)	0.1
Key print	Key pressed until appearance of character	0.2
Page turn	End of request until first few lines are visible	1.0
Page scan	End of request until text begins to scroll	0.5
XY entry	From selection of field until visual verification	0.2
Pointing	From input of point to display point	0.2
Sketching	From input of point to display of line	0.2
Local update	Change to image using local database (e.g., new menu list from display buffer)	0.5
Host update	Change where data is at host in readily accessible form (e.g., a scale change of existing image)	2.0
File update	Image update requires an access to a host file	10
Inquiry (simple)	From command until display of a commonly used message	2.0
Inquiry (complex)	Response message requires seldom used calculations in graphic form	10
Error feedback	From entry of input until error message appears	0.2

5.1.2.1.6.4.1 Non-real-time systems. Non-real-time systems may permit relaxed response times.

5.1.2.1.6.4.2 Existing or predecessor systems. System response times for real-time and non-real-time systems shall not exceed the response time of the equivalent existing or predecessor system.

5.1.2.1.6.4.3 Response time greater than 1 second. If computer response time will exceed 1 second, the user shall be given a message indicating that the system is processing. For remotely handled automated systems, see 5.12.

5.1.2.1.6.5 Task performance time. The time required to accurately complete a standard time-sensitive action or sequence of actions (including system response time) shall not exceed the time to complete the same action(s) on the equivalent existing or predecessor system.

5.1.2.1.6.6 Time-consuming processes. The system shall give warning information when a command is invoked that will be time-consuming or resource-intensive to process.

5.1.2.1.6.7 Aborting time-consuming processes. Users shall be provided with an option to abort time-consuming processes.

5.1.2.1.6.8 Stand-by. When system functioning requires the user to stand by, a message or appropriate icon shall be displayed until user interaction is possible again.

5.1.2.1.6.8.1 Delays in excess of 1 second. Where the delay exceeds 1 second, the user shall be informed.

5.1.2.1.6.8.2 Delays in excess of 10 seconds. For delays exceeding 10 seconds, a countdown display shall show the delay time remaining.

5.1.2.1.6.9 Startup. When the system is not immediately available after system startup, the system shall provide feedback to the user that indicates the average system response time or known periods of unavailability, and the keyboard and pointing device shall be disabled until startup is complete.

5.1.2.1.6.9.1 Disable pointing device. The shape of the pointing device display shall be altered to indicate that it is disabled.

5.1.2.1.6.9.2 System becomes available. When startup is complete and the system becomes available, the system shall remove any messages indicating that it is unavailable, return the pointer to its normal shape, and enable the keyboard and pointing device.

5.1.2.1.6.10 Input confirmation. Confirmation of inputs shall not cause displayed data to be removed.

5.1.2.1.6.11 User input rejection. If the system rejects a user input, feedback shall be provided to indicate the reason for rejection and the required corrective action.

5.1.2.1.6.12 Highlighted option selection. Any displayed message or datum selected as an option or input to the system shall be highlighted to indicate acknowledgment by the system.

5.1.2.1.6.13 Process outcome. When a control process or sequence is completed or aborted by the system, positive indication shall be presented to the user concerning the outcome of the process and the requirements for subsequent user action.

5.1.2.1.6.14 Feedback message content. Users shall not be required to translate feedback messages by use of reference system or code sheets.

5.1.2.1.6.15 Abbreviations. Abbreviations should be avoided in feedback messages unless they are well known by all potential users.

5.1.2.1.7 Error management.

5.1.2.1.7.1 Error correction. Where users are required to make entries into a system, an easy means shall be provided for correcting erroneous entries.

5.1.2.1.7.2 Correction of individual errors. The system shall permit correction of individual errors without requiring reentry of correctly entered commands or data elements.

5.1.2.1.7.3 Early detection. A capability shall be provided to facilitate detection and correction of errors after keying in, but before entering into the system. This may be done through automated error checking and then highlighting the suspect entries for the operator to assess.

5.1.2.1.7.4 Error checking. In order to avoid disrupting the user, error checking shall occur at logical data entry breaks, such as at the end of data fields rather than character-by-character.

5.1.2.1.7.5 Internal software checks. Software shall check user entries for validity of item, sequence of entry, completeness of entry, and range of value.

5.1.2.1.7.6 Critical entries. The system shall require the user to acknowledge critical entries prior to them being implemented by the system.

5.1.2.1.7.7 Error message content. See 5.17.10.7 through 5.17.10.10.

5.1.2.1.7.8 Diagnostic information. Error messages shall explicitly provide as much diagnostic information and remedial direction as can be inferred reliably from the error condition.

5.1.2.1.7.9 Correction entry and confirmation. When the user enters correction of an error, such corrections shall be implemented by an explicit action by the user (e.g., actuation of an ENTER key).

5.1.2.1.7.10 Error correction acknowledgement. The system shall acknowledge all error corrections by the user either by accepting the corrected entry or by providing a separate error message for an erroneous entry.

5.1.2.1.7.11 Spelling errors. Spelling and other common errors shall not produce valid system commands or initiate transactions.

5.1.2.1.7.11.1 Recognize common misspellings. The system shall recognize common misspellings of commands and inform users of unrecognized entries, provide a similar correct entry, and display the recommendation for revision and confirmation by the user.

5.1.2.1.7.11.2 Computer-corrected commands. Computer-corrected commands, values, and spellings shall be displayed and highlighted for user confirmation.

5.1.2.1.7.12 Errors in stacked commands. To prompt for corrections of an error in stacked commands, the system shall display the stacked command sequence with the error(s) highlighted. Where possible, a procedure shall be provided to correct the error and salvage the stack.

5.1.2.1.7.13 Display of erroneous entries. An error message shall be displayed continuously until either the error is corrected or the user dismisses the error message.

5.1.2.1.8 Illumination. Adjustable illumination shall be provided for controls (including labels and critical markings) that must be read in darkened conditions.

5.1.2.1.8.1 Continuously adjustable. Illumination shall be continuously adjustable or permit adjustment to a minimum of 30 increments throughout the full operational range from full bright to full off.

5.1.2.1.8.2 Intensity control. Continuous intensity control of the above lighting from full bright, to 0.02 percent of full bright, and "off" is required (for night vision imaging system compatible lighting, see MIL-STD-3009).

5.1.2.1.9 Simultaneous access. If more than one crewmember must have simultaneous access to a group of controls or displays to ensure proper functioning of a system or subsystem, each user assigned to control and monitor a function or group of related functions shall have physical and visual access to all controls, displays, and communication capability necessary to perform the assigned tasks.

5.1.2.1.9.1 Simultaneous read access. Where two or more users must have simultaneous read access to a computer program or data processing results from multiple personal equipment interfaces, the operation by one person shall not interfere with the operations of another person unless mission survival may be contingent upon preemption.

5.1.2.1.9.2 Preemption. When two or more users have simultaneous access and one preempts the other, provisions shall be made so that the preempted user can resume operations at the point of interference without information loss.

5.1.2.2 Position relationships.

5.1.2.2.1 Functional grouping. Functionally related controls and displays shall be located close to each other and arranged in functional groups (e.g., power, status, and test).

5.1.2.2.1.1 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.

5.1.2.2.1.2 Operational sequence. Arrangement of controls by operational sequence when not within the same functional group (e.g., location, time and date, and mission designation) shall be permitted when it is more efficient.

5.1.2.2.1.3 Access. Provided that the integrity of grouping by function and sequence is not compromised, the more frequently used groups and the most important groups shall be located in areas of easiest access.

5.1.2.2.1.4 Functional group marking. Functional group marking shall meet the criteria of 5.1.2.2.1.4.1 through 5.1.2.2.1.4.6.

5.1.2.2.1.4.1 Outlining. Functional groups may be set apart by outlining them with contrasting lines that completely encompass the groups.

5.1.2.2.1.4.2 Non-critical functional groups. Where functional group coding is specified (see 6.2) and where gray panels are used, non-critical functional groups (i.e., those not associated with critical or emergency operations) shall be outlined with a black border measuring 1.5 mm (0.0625 in) in accordance with SAE AMS-STD-595/27038.

5.1.2.2.1.4.3 Critical operations. Those panels involving emergency or extremely critical operations shall be outlined with a red border measuring 5 mm (0.1875 in) in accordance with SAE AMS-STD-595/21136 or designated by contrasting color pads or patches for both critical and non-critical functional areas, subject to approval by the procuring activity.

5.1.2.2.1.4.4 Red compartment lighting. When red compartment lighting is used, an orange-yellow (in accordance with SAE AMS-STD-595/23538) and black-striped (in accordance with SAE AMS-STD-595/27038) border shall be used to outline functional groups involving emergency or extremely critical operations.

5.1.2.2.1.4.5 Aircraft crewstations. Design requirements and configuration of letters, numerals, and identification for aircrew station displays and control panels shall be in accordance with SAE AS18012.

5.1.2.2.1.4.6 Night vision compatibility. If compatibility with night vision equipment is required, the compartment lighting shall be designed in accordance with MIL-STD-3009.

5.1.2.2.1.5 Consistency. The location of recurring functional groups and individual items shall be consistent from panel to panel.

5.1.2.2.1.5.1 Mirror images. Mirror image arrangements shall not be used.

5.1.2.2.1.5.2 Display commonality. When multiple displays and multiple display formats are used, nomenclature and symbology shall be common on all displays, as appropriate.

5.1.2.2.1.5.3 Text or readout fields. Text or readout fields common to all displays (e.g., system advisories) shall be in a standard location on all display panels and formats.

5.1.2.2.1.5.4 Commonality and consistency across systems. Where possible, criteria for consistency and display commonality shall be applied across other systems expected to be operated by the user.

5.1.2.2.1.6 Maintenance controls and displays. Control/display groups required solely for maintenance purposes shall be located in positions providing a lesser degree of access to the user relative to operating groups.

5.1.2.2.2 Location and arrangement. If an operator or maintainer is required to use many controls and displays, they shall be located and arranged to aid in identifying the controls used with each display, the equipment component affected by each control, and the equipment component described by each display.

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

5.1.2.2.3.1 No specific sequence. If the controls and displays within a functional group are not used in any specific operational sequence, they shall be arranged either in accordance with their importance or their frequency of use, with the most important or frequently used controls in the most accessible locations.

5.1.2.2.3.2 Horizontal arrays. Horizontal rows of displays shall be associated with horizontal controls.

5.1.2.2.3.3 Fewer rows than displays. If controls must be arranged in fewer rows than their associated displays, controls that affect the top row of displays shall be positioned at the left, with controls that affect the second row of displays placed immediately to the right of these.

5.1.2.2.3.4 Vertical arrays. Vertical columns of displays shall be associated with vertical controls.

5.1.2.2.3.5 Simultaneous use. To maintain legibility and avoid parallax errors, a visual display that must be monitored while a related control is manipulated shall be located so that the user is not required to observe the display from an extreme visual angle.

5.1.2.2.3.6 Multiple displays. If manipulating one control requires reading 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.

5.1.2.2.3.6.1 Selection by rotary selector switch. If one of a group of displays is selected for viewing with a rotary selector switch, the displays shall be arranged so that their sequence corresponds to the switch positions.

5.1.2.2.3.6.2 OFF position. If the switch includes an OFF position, the OFF position shall be to the left of the first active position (i.e., it shall be the most counterclockwise position).

5.1.2.2.3.6.3 Displays not selected. If applicable, displays that are not selected shall read off-scale, not zero.

5.1.2.2.3.7 Combined control. Separate displays that are affected by a combined control (e.g., concentrically ganged knobs) shall be arranged from left to right with the combined control underneath the center of the displays, but not in a location that will obscure the displays when manipulating the control.

5.1.2.2.3.8 Display remains visible. Controls shall be located so that the user's hand or arm does not obscure the associated display.

5.1.2.2.3.9 Separated controls and displays. When controls must be located on panels separate from their associated displays, the control and display panels shall be adjacent to each other and mounted at approximately the same direction relative to the user; the preferred arrangement is to place the display panel above the control panel.

5.1.2.2.3.9.1 Mounting. The separated control and display panels shall not be mounted facing each other.

5.1.2.2.3.9.2 Control positions. The control positions on one panel shall correspond to the associated display positions on the other panel.

5.1.2.2.3.10 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 for a user facing the normal direction of vehicle movement.

5.1.2.2.3.11 Emergency use. Emergency displays and controls shall be located where they can be seen and reached without delay. For example, warning lights should be within a 30-degree cone about the user's normal line of sight (the median direction of gaze when viewing a display surface) (see figure 2).

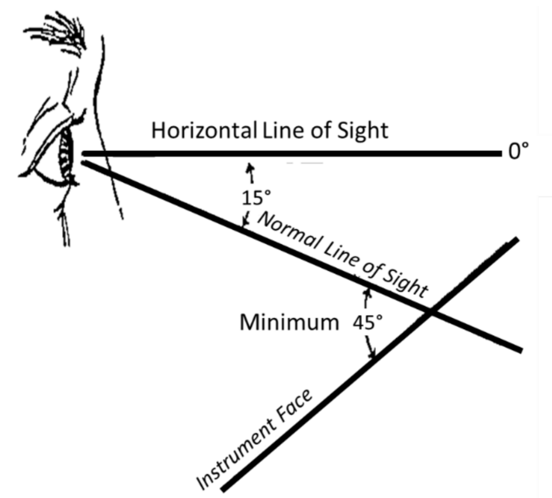


FIGURE 2. Lines of sight.

5.1.2.2.3.12 Emergency controls. An emergency control should be close to either its related warning display or the nearest available hand in its nominal operating position.

5.1.2.2.3.13 Correspondence with equipment arrangement. If applicable, the arrangement of controls and displays shall correspond to the physical arrangement of their associated units or equipment components.

5.1.2.3 Movement relationships.

5.1.2.3.1 Lack of ambiguity. Display indicators shall clearly and unambiguously direct and guide the appropriate control response.

5.1.2.3.2 Response to control movements. The response of a display to control movements shall be consistent, predictable, and compatible with the user's expectations.

5.1.2.3.3 Display response time. There shall be no discernible time lag between a change in a real-time system condition being controlled or monitored and its indication on a display (see 5.1.2.1.6.4).

5.1.2.3.4 Time lag. The time lag between system response to a control input and display presentation of that response shall be minimized, consistent with safe and effective system operation.

5.1.2.3.5 Moving-pointer circular scales. Clockwise movement of a rotary control or forward, upward, or rightward movement of a linear control shall produce a clockwise movement of circular scale pointers and an increase in the magnitude of the reading.

5.1.2.3.6 Moving-pointer tape scales. Tape scales shall have the larger value at the top (vertical) or the right side (horizontal). Clockwise movement of a rotary control or forward, upward, or rightward movement of a linear control shall produce a movement up or to the right for horizontal and vertical scale pointers and an increase in the magnitude of the reading.

5.1.2.3.7 Fixed-pointer circular scale. Displays with circular moving scales and fixed pointers or cursors shall be avoided.

5.1.2.3.8 Fixed-pointer circular scale necessary. When circular, fixed-pointer, moving-scale indicators are necessary, clockwise movement of a rotary control or forward, upward, or rightward movement of a linear control shall normally produce a counterclockwise movement of the scale and an increase in the magnitude of the reading.

5.1.2.3.9 Fixed-pointer tape scale. Tape scales shall have the larger value at the top (vertical) or the right (horizontal). When use of a vertical or horizontal fixed-pointer moving-scale indicator is necessary, clockwise movement of an associated rotary control or forward, upward, or rightward movement of a linear control shall normally produce a movement of the scale down or to the left and an increase in the magnitude of the reading.

5.1.2.3.10 Digital displays. Clockwise movement of a rotary control or movement of a linear control forward, up, or to the right shall produce increasing values in digital displays.

5.1.2.3.11 Direct linkage. When a control and display are directly linked (e.g., radio frequency selector and station pointer), a rotary control shall be used if the indicator moves through an arc of more than 180 degrees. If the indicator moves through an arc of less than 180 degrees, a linear control may be used, provided that the path of control movement parallels the average path of the indicator movement and that the indicator and control move in the same relative direction.

5.1.2.3.12 Common plane. Direction of control movements shall be consistent with related movements of associated displays, equipment components, or vehicles.

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

5.1.2.3.14 Labeling. When control/display relationships specified herein cannot be adhered to, controls shall be clearly labeled (see 5.4) to indicate the direction of control movement required.

5.1.2.3.15 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.

5.1.2.3.16 Arrays of indicator lights. A bottom-to-top or left-to-right movement in an array of indicator lights shall represent increasing values.

5.1.2.4 Control/display movement ratio.

5.1.2.4.1 Minimization of time. Control/display ratios for continuous adjustment controls shall minimize the time required to make desired control movements (slewing and fine adjusting) consistent with display size, tolerance requirements, viewing distance, and time delays.

5.1.2.4.2 Range of display movement. When a wide range of display-element movement is required, a 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 a small movement of the display consistent with the final accuracy required.

5.1.2.4.3 Knob, coarse setting. When a knob is provided for making coarse display-element settings on linear scales, one complete turn of the knob shall cause display-element movement equal to two-thirds the total length of the linear scale.

5.1.2.4.4 Knob, fine setting. For fine setting on linear scales, one complete turn of the knob shall cause display-element movement equal to between one-tenth and one-fifth the total length of the linear scale.

5.1.2.4.5 Bracketing. When bracketing is used to locate a maximum or minimum rather than a specific value, the control knob shall swing through an arc of not less than 10 degrees or more than 30 degrees on either side of the target value in order to make the peak or dip associated with that value clearly noticeable.

5.1.2.4.6 Lever, coarse setting. When a lever is provided for coarse settings, one unit of display-element movement shall be induced by three units of lever movement.

5.1.2.4.7 Lever, two-dimensional setting. When a lever is provided to make settings in two dimensions to coarse tolerances, one unit of display-element movement shall be induced by two and one-half units of lever movement.

5.1.2.4.8 Counter control/display ratio. One revolution of a counter knob shall produce approximately 50 counts (i.e., the drum representing the smallest decimal value completes five full revolutions. A mechanical counter (e.g., odometer) is normally a series of wheels that counts from zero to nine. If one turn of a counter knob produces 50 counts, that means the lowest (i.e., right hand) drum will have spun 5 times and the next lowest drum will have moved five positions (10, 20, 30, 40, 50).

5.1.3 Information system controls.

5.1.3.1 Touchscreen controls for displays.

5.1.3.1.1 Use. Touchscreen control may be used to provide an overlaying control function to a data display where direct visual reference access and optimum direct control access are desired. Touchscreens are appropriate for interactions involving the selection of devices or targets on position displays (e.g., radars), arrangement diagrams, piping diagrams, discrete-function controls, or opening and closing valves. Advantages and disadvantages of touchscreen use are provided in table VI.

TABLE VI. Advantages and disadvantages of touchscreen use.

Advantages	Disadvantages
• No separate input device	• Slower alphanumeric data entry
• Programmable interface	• Arm fatigue
• Fast access	• Finger may obstruct view
• Direct manipulation of targets	• Fingerprints or other debris may obscure screen
• Input/output in same location	• Larger buttons required for finger use
• Intuitive 1/	• Pointing is not very accurate
• Natural pointing action	• User must be within reach of screen
• Generally no additional desk space required 2/	• No tactile feedback provided 4/
• Generally no additional training required 3/	• Unable to rest finger on target without actuation 3/
	• Accuracy degraded by vehicle movement and vibration
	• Gloved operation may be incompatible with some touchscreen technology
	• Lack of physical landmarks forces users to look at display to use
	• Controls must be deactivated for cleaning

NOTES:
1/ If the underlying software is well designed to take advantage of the touch interface.
2/ If incorporated as part of an existing primary display.
3/ Application-dependent.
4/ If a tactile feedback membrane is not incorporated.

5.1.3.1.1.1 High frequency use. A touchscreen should not be the sole input means if the interface will be used to enter large amounts of data frequently.

5.1.3.1.1.2 Moving or vibration environments. A touchscreen should not be the sole input means if system movement or vibration might degrade user performance below the level required for mission accomplishment.

5.1.3.1.1.3 Mission-critical and safety-critical applications. A touchscreen shall not be the sole input device for mission critical or safety critical interfaces (such as flight control information).

5.1.3.1.2 Luminance transmission. Touchscreens shall have sufficient luminance transmission to allow the display to be clearly readable in the intended environment (including from the seated position for the full range of users, if applicable) and meet the display luminance requirements (see 5.2.1.2).

5.1.3.1.3 Positive indication. A positive indication of touchscreen actuation shall be provided to acknowledge the system response to the control action.

5.1.3.1.4 Display response time (latency). Display response time should not be more than 100 milliseconds (ms). A shorter display response time may be dictated by operational considerations. Any latency should be evaluated in a representative environment to ensure that it meets human performance requirements.

5.1.3.1.5 Impact on visual display. Characteristics of touch-interactive devices shall not degrade visual display quality in a manner that impairs user performance.

5.1.3.1.6 Spatial resolution. Touch-interactive devices shall provide sufficient spatial resolution for anticipated task performance.

5.1.3.1.7 Critical tasks. Where a touchscreen control is used for a critical task, system response shall require an additional confirmatory action to ensure that the control actuation is intended.

5.1.3.1.7.1 Confirmatory action impractical. Where confirmatory action is impractical for critical tasks, multiple touch actuations shall be incorporated to minimize the possibility of accidental actuation.

5.1.3.1.8 Repeat function delay. An initial delay of 500 to 750 ms shall be provided when a repeat delay is provided.

5.1.3.1.9 Sensitivity. Fingertip contact with the touchscreen shall be able to actuate the control or input function.

5.1.3.1.10 Match operational modes. Screen sensitivity shall match all expected operational modes including the use of gloves (such as gloved operations during flight or flash gear).

5.1.3.1.11 Parallax and glare. Touchscreen devices shall be mounted to minimize parallax issues and specular glare.

5.1.3.1.12 Touchscreen viewing angle. When possible, touchscreens shall be perpendicular to the user's line of sight while the user is in a normal operating position. A reduced viewing angle, less than 90 degrees from horizontal, may reduce arm fatigue for frequent actions; however, changes to viewing angle shall be evaluated in relation to the negative impact on parallax, specular glare, and readability.

5.1.3.1.13 Reach. Reach design for touchscreens shall meet the criteria in 5.1.3.1.13.1 through 5.1.3.1.13.5.

5.1.3.1.13.1 Accommodation. Touchscreens shall be mounted to ensure the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped males of the target user population and the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped females of the target user population are accommodated. Unless otherwise specified (see 6.2), users shall be able to reach and actuate all areas of the screen, including corners of the display.

5.1.3.1.13.2 Avoid full arm extension. Touchscreens shall be located to avoid full arm extension.

5.1.3.1.13.3 Emergency controls. If emergency controls are located on touchscreens, the emergency controls shall be able to be reached by crewmembers with their harness or seat belt locked even if full arm extension is necessary.

5.1.3.1.13.4 Avoid upward reach. Touchscreens shall be located to avoid upward reach.

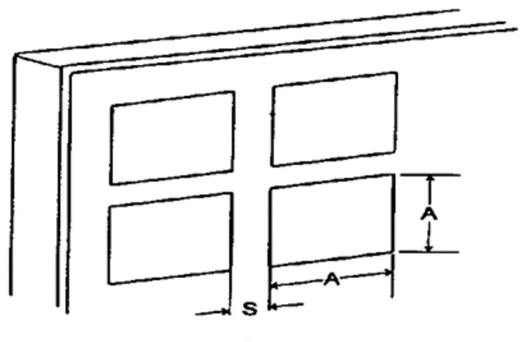
5.1.3.1.13.5 Elbow support. Where possible, elbow support shall be provided to minimize arm fatigue.

5.1.3.1.14 Sustained interaction. Touchscreens shall not be used for frequent actions over an extended duration of time (e.g., typing on a virtual keyboard or continuous target selection). This requirement does not apply to small hand-held devices.

5.1.3.1.15 Intermittent interaction. Touchscreens may be used to complete intermittent actions such as gross cursor navigation and communication panel selection.

5.1.3.1.16 Target shape and color. If color coding is used, it shall be redundant to another form of coding.

5.1.3.1.17 Dimensions, resistance, and separation. The dimensions, resistance, and separation of responsive areas of touch screens shall conform to figure 3.



	Alphanumeric/Numeric Keyboards [1/]		
	A (Actuation area) [2/]	**S (Separation) [3/]**	**Resistance**
Minimum	—	0	250 mN (0.9 oz)
Preferred	16 x 16 mm (0.6 x 0.6 in)	2 mm (0.08 in)	—
Maximum	—	6 mm (0.25 in)	1.5 N (5.3 oz)
	Other Applications		
	A (Actuation area) [2/]	**S (Separation) [3/]**	**Resistance**
Minimum	15 x 15 mm (0.6 x 0.6 in)	3 mm (0.12 in)	250 mN (0.9 oz)
Maximum	38 x 38 mm (1.5 x 1.5 in)	6 mm (0.25 in)	1.5 N (5.3 oz)

NOTES:

1/ Unless otherwise noted, the dimensions specified apply to ungloved finger touch.

2/ For standard cotton flame-resistant anti-flash gloves (i.e., Navy flash gloves [as defined in MIL-G-2874]) use, add 5 mm (0.2 in) to each dimension of the actuation area (A).

3/ For touchscreens that use a "first contact" actuation strategy, separation between targets shall be not less than 5 mm (0.2 in). For touchscreens that use a "last contact" strategy, separation between targets may be less than 5 mm (0.2 in), but not less than 3 mm (0.12 in) for applications other than alphanumeric/numeric keyboards.

FIGURE 3. Touchscreens.

5.1.3.2 Keyboards.

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

5.1.3.2.2 Layout and configuration. Alphanumeric keyboards and numeric keypads shall be in accordance with ANSI/HFES 100.

5.1.3.2.3 Dimensions, resistance, displacement, and separation. Dimensions, resistance, displacement, and separation between adjacent edges of the push buttons on keyboards shall be in accordance with the criteria in table VII. For a given keyboard, table VII criteria shall be uniformly met for all individual keys.

TABLE VII. Keyboards.

	Dimensions (Square)			**Resistance**		
	Bare Hand	**Arctic Mittens [1/]**	**[2/]**	**Numeric**	**Alphanumeric**	**Dual Function**
Minimum	10 mm (0.4 in)	19 mm (0.75 in)	15 mm (0.6 in)	1 N (3.5 oz)	0.25 N (0.9 oz)	0.25 N (0.9 oz)
Preferred	13 mm (0.5 in)	19 mm (0.75 in)	18 mm (0.7 in)	--	0.5to 0.6 N (1.8 to 2.2 oz)	--
Maximum	19 mm (0.75 in)	--	--	4 N (14 oz)	1.5 N (5.3 oz)	1.5 N (5.3 oz)

	Displacement [3/]			**Separation (Between Adjacent Key Tops)**
	Numeric	**Alphanumeric**	**Dual Function**	
Minimum	0.8 mm (0.03 in)	1.3 mm (0.05 in)	0.8 mm (0.03 in)	6.4 mm (0.25 in)
Preferred	--	--	--	6.4 mm (0.25 in)
Maximum	4.8 mm (0.19 in)	6.3 mm (0.25 in)	4.8 mm (0.19 in)	--

	Vehicle Applications			
	Dimensions		**Resistance**	**Separation**
	Bare Hand	**Gloved Hand**	**Numeric Input**	
Minimum	10 mm (0.4 in)	19 mm (0.75 in)	2.8 N (9.9 oz)	--
Preferred	--	--	--	13 mm (0.5 in)
Maximum	25 mm (1 in)	25 mm (1 in)	6.7 N (23.7 oz)	--

NOTES:

1/ Trigger finger type; other parameters are unchanged from those of bare-handed operation.

2/ Standard cotton flame-resistant anti-flash gloves (i.e., Navy flash gloves [as defined in MIL-G-2874]).

3/ For membrane keys, preferred displacement is 0.7 mm (0.03 in) and resistance shall be not less than 2.0 N (7.2 oz). Membrane keys shall also incorporate positive tactile feedback (e.g., "snap" action).

5.1.3.2.4 Slope of non-portable keyboards. The slope of non-portable keyboards shall be 0 to 25 degrees (0 to 15 degrees preferred) above the horizontal.

5.1.3.2.5 Multiple keyboards. Systems that include more than one keyboard shall maintain the same configuration for alphanumeric, numeric, and special function keys throughout the system and other systems the user is expected to operate.

5.1.3.2.6 Feedback. Tactile feedback shall be provided to inform the user that the intended key was pressed and that the next operation may be initiated, such as through the use of spring-loaded keys that click and return to prior height after being pressed and released.

5.1.3.2.7 Keyboard lighting. Keyboards that are used in darkened environments shall provide lighted keys that are dimmable to a minimum of 30 incremental positions from the full ON to OFF position.

5.1.3.2.7.1 Indicator lights. Indicator lights on the keyboard shall dim concurrently with the keyboard.

5.1.3.2.7.2 Individual key characters. Individual key characters and symbols shall be backlit to ensure readability in darkened conditions.

5.1.3.2.7.3 Keyboard backlighting. Low-level white light shall be used for keyboard backlighting in accordance with SAE AS25050.

5.1.3.2.7.4 Night vision compatibility. See 5.5.3.6 for night vision compatibility.

5.1.3.3 Mouse. Mouse (free-moving xy controller) designs shall meet the criteria in 5.1.3.3.1 through 5.1.3.3.6.

5.1.3.3.1 Application. A mouse may be used on any flat surface to generate x and y coordinate values that control the position of the cursor on the associated display. A mouse may be used for data pickoff or for entry of coordinate values.

5.1.3.3.1.1 Zero order control. A mouse shall be used for zero order control only (i.e., generation of x and y outputs by the controller results in proportional displacement of the cursor).

5.1.3.3.1.2 Free-drawn graphics. A mouse should not be used for generation of free-drawn graphics; a grid-and-stylus device (see 5.1.3.7) is better for such an application.

5.1.3.3.2 Dynamic characteristics. Dynamic characteristics shall meet the criteria in 5.1.3.3.2.1 through 5.1.3.3.2.6.

5.1.3.3.2.1 Orientation. The characteristics of the mouse and placement of the maneuvering surface shall allow the user to consistently orient the mouse to within 10 degrees of the correct orientation without visual reference to the controller (e.g., when the user grasps the mouse 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 cursor on the display shall be between 350 and 10 degrees).

5.1.3.3.2.2 Hand grasp. The mouse shall be easily movable in any direction without a change of hand grasp.

5.1.3.3.2.3 Smooth movement. The mouse shall result in smooth movement of the cursor in the same direction ±10 degrees.

5.1.3.3.2.4 Handedness. The mouse shall be operable with either the left or right hand.

5.1.3.3.2.5 Display-movement relationship. Unless expanded movement is selected for an automatic sequencing mode of operation, a complete excursion of the mouse from side-to-side of the maneuvering area shall move the cursor from side-to-side on the display regardless of scale setting or offset.

5.1.3.3.2.6 Off-edge indicator. If the mouse can drive the cursor off the edge of the display, indicators shall be provided to assist the user in bringing the cursor back onto the display.

5.1.3.3.3 Connection. Where the mouse is connected to the computer via a cable, the cable shall be long enough to maintain slack during use.

5.1.3.3.4 Buttons. A mouse shall have one or more buttons that provide features related to various functions and control actions.

5.1.3.3.4.1 Operable without diminishing control. The mouse buttons shall be operable without diminishing control of the mouse.

5.1.3.3.4.2 Finger actuation. The mouse design shall permit the finger to actuate the button surface from a neutral posture.

5.1.3.3.4.3 Contact surfaces. Mouse button contact surfaces shall be perpendicular to displacement direction and finger motion during actuation.

5.1.3.3.5 Shape. The mouse shall be shaped to allow the user to grasp it using either hand with the hand in a relaxed and neutral posture (i.e., minimal wrist deviation, flexion, or extension is required).

5.1.3.3.6 Dimensions, button resistance, and button displacement. Mouse dimensions, button resistance, and button displacement shall be in accordance with the criteria in table VIII.

TABLE VIII. Mouse characteristics.

	Dimensions			Button Characteristics	
	Width	**Length**	**Height**	**Resistance**	**Displacement**
Minimum	40 mm (1.6 in)	70 mm (2.8 in)	25 mm (1 in)	0.5 N (1.8 oz)	5 mm (0.20 in)
Maximum	70 mm (2.8 in)	120 mm (4.7 in)	40 mm (1.6 in)	1.5 N (5.4 oz)	6 mm (0.24 in)

5.1.3.4 Trackballs. Also known as ball control, ball tracker, joyball, and rolling ball.

5.1.3.4.1 Use. A trackball suspended on low-friction bearings may be used for various control functions such as selection of data on a display. Trackballs shall be used only as position controls (i.e., a given movement of a trackball makes a proportional movement of the cursor on the display).

5.1.3.4.2 Off-edge indicator. If an application allows the trackball to drive the cursor on the display off the edge of the display, indicators shall be provided to advise the user how to bring the cursor back onto the display.

5.1.3.4.3 Button placement. Trackball buttons and buttons near the trackball shall be located to prevent accidental actuation during trackball use (i.e., user hand placement while manipulating the trackball shall not accidentally actuate buttons).

5.1.3.4.4 Finger control. If the trackball is designed for finger control (i.e., roller manipulated using fingers), the primary actuation button shall be placed near the thumb position and permit thumb actuation.

5.1.3.4.5 Dynamic characteristics. The trackball shall be capable of rotation in any direction to generate any combination of x and y output values.

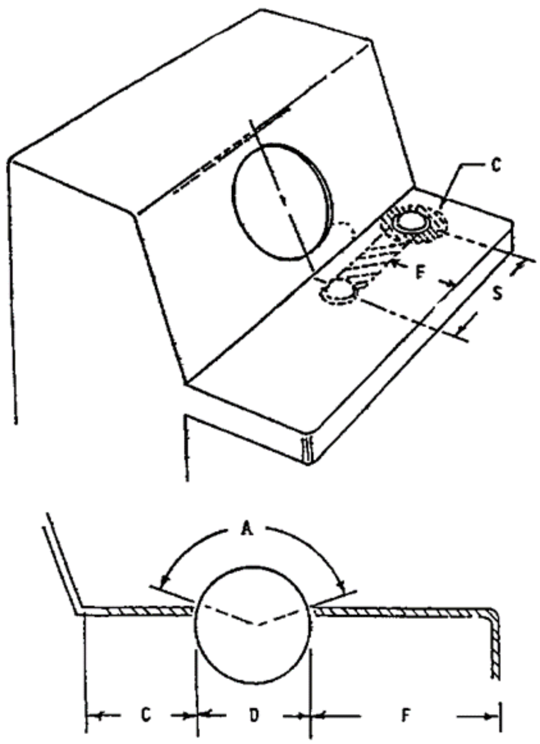
5.1.3.4.5.1 No cross-coupling. When the trackball is moved in either the x or y directions alone, there shall be no apparent cross-coupling (cursor movement in the orthogonal direction).

5.1.3.4.5.2 Backlash. While manipulating the trackball, neither backlash nor cross-coupling shall be apparent to the user.

5.1.3.4.5.3 Control ratios. Trackball control ratios and dynamic features shall meet the dual requirement of rapid gross positioning and smooth, precise fine positioning.

5.1.3.4.6 Limb support. When trackball controls are used to make precise or continuous adjustments, wrist support or arm support, or both, shall be provided.

5.1.3.4.7 Dimensions, resistance, and clearances. Trackball dimensions, resistance, and clearances shall be in accordance with the criteria on figure 4.



	Dimensions		Resistance [1]		Clearance		
	D; Diameter	**A; Surface Exposure**	**Precision Required**	**Vibration or Acceleration Conditions**	**S; Display CL to Ball CL**	**C; Around Ball**	**F; Ball to Shelf Front**
Minimum	50 mm (2 in)	100°	0.25 N (0.9 oz)	--	0	50 mm (2 in)	120 mm (4.75 in)
Preferred	100 mm (4 in)	120°	0.3 N (1.1 oz)	--	--	--	--
Maximum	150 mm (6 in)	140°	1.5 N (5.4 oz)	1.7 N (6 oz)	320 mm (12.6 in)	--	250 mm (10 in)

NOTE:
[1] Initial resistance shall range from 0.25 N (0.9 oz) to 0.4 N (1.4 oz).

FIGURE 4. Trackballs.

5.1.3.4.7.1 Small diameter trackballs. Smaller diameter trackballs may be acceptable where space availability is limited and when there is no need for precision.

5.1.3.4.7.2 Permanent mounting. If used, permanent trackball mounting shall be as shown on figure 4.

5.1.3.5 Displacement joysticks. Displacement joysticks shall meet the criteria in 5.1.3.5.1 through 5.1.3.5.4.6.2.

5.1.3.5.1 General.

5.1.3.5.1.1 Use. Joysticks may be used when the task requires precise or continuous control in two or more related dimensions. Displacement joysticks may also be used for various display functions such as selecting data from a display and generation of free-drawn graphics.

5.1.3.5.1.2 Positioning accuracy. When positioning accuracy is more critical than positioning speed, displacement joysticks (where resistance to movement increases with the distance the user displaces it from the center [null] position) shall be selected over isometric joysticks (see 5.1.3.6).

5.1.3.5.1.3 Off-edge indicator. In rate control applications, which allow the cursor to transit beyond the edge of the display, indicators shall be provided to aid the user in bringing the cursor back onto the display.

5.1.3.5.1.4 Return to center. Displacement joysticks used for rate control shall be spring-loaded for return to the center when the hand is removed.

5.1.3.5.1.5 Deadband. Displacement joysticks that have a deadband near the center or hysteresis shall not be used with automatic sequencing of a cursor unless they are instrumented for null return or zero-set to the instantaneous position of the stick at the time of sequencing.

5.1.3.5.1.6 Termination of automatic sequencing. Upon termination of an automatic sequencing routine, the joystick center shall again be registered to scope center.

5.1.3.5.2 Hand-operated displacement joysticks. In addition to general use, hand-operated displacement joysticks may be used to control vehicles and aim sensors. Such 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 a displacement hand grip than on an isometric handgrip.

5.1.3.5.2.1 Buttons.

5.1.3.5.2.1.1 Button location. When buttons are located on hand-operated joysticks, they shall be operable using a normal grip without diminishing control of the joystick.

5.1.3.5.2.1.2 Button placement. Joystick buttons shall be located to prevent accidental actuation during joystick use (i.e., buttons shall not be placed where the user would rest the heel of their hand to manipulate the joystick).

5.1.3.5.2.2 Dynamic characteristics.

5.1.3.5.2.2.1 Movement. Movement of a hand-operated joystick shall not exceed 45 degrees from the center position.

5.1.3.5.2.2.2 Smooth in all directions. Movement of a hand-operated joystick shall be smooth in all directions.

5.1.3.5.2.2.3 Positioning cursor. Positioning of a cursor shall be attainable without noticeable backlash, cross-coupling, or need for multiple corrective movements.

5.1.3.5.2.2.4 Control ratios. Control ratios, friction, and inertia shall meet the dual requirements of rapid gross positioning and precise fine positioning.

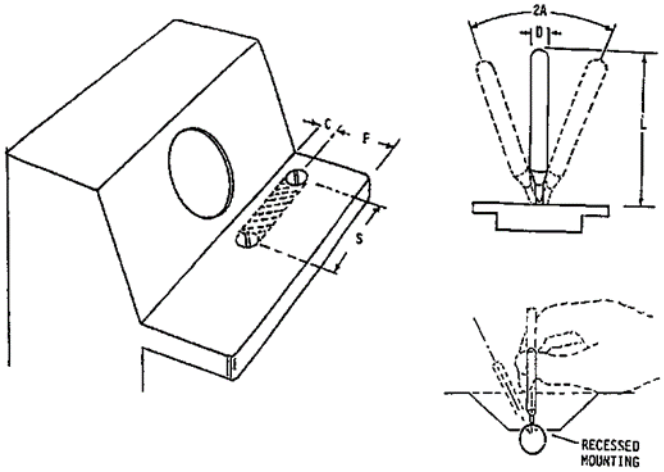
5.1.3.5.2.2.5 Free-drawn graphics. When a joystick is used for generating free-drawn graphics, the display refresh rate shall be sufficiently high to display the cursor as a continuous track.

5.1.3.5.2.2.6 Delays. Delay between control movement and the confirming display response shall be not greater than 0.1 second.

5.1.3.5.2.3 Trigger actuation. Inadvertent trigger actuation shall be minimized through proper use of trigger guards, safety latches, or other means.

5.1.3.5.2.4 Coding. Joystick buttons and other controls shall be coded by shape, size, location, texture, or other means to aid in non-visual identification.

5.1.3.5.2.5 Dimensions and clearance. Joystick dimensions and clearance shall be in accordance with the criteria on figure 5.



	Dimensions		Resistance	A, Displacement	Clearance		
	D, Diameter	L, Length			S, Display CL to Stick CL	C, Around Stick	F, Stick CL to Shelf Front
Minimum	6.5 mm (0.25 in)	75 mm (3 in)	3.3 N (12 oz)		0	1/	120 mm (4.75 in)
Maximum	16 mm (0.625 in)	150 mm (6 in)	8.9 N (32 oz)	45° (785 mrad)	400 mm (15.75 in)		250 mm (10 in)

NOTE:
1/ Maximum stick excursion plus 100 mm (4 in).

FIGURE 5. Displacement joysticks.

5.1.3.5.2.5.1 Hand grip length. The hand grip length shall be 110 to 180 mm (4.3 to 7.1 in).

5.1.3.5.2.5.2 Hand grip diameter. The hand grip diameter shall be not more than 50 mm (2 in).

5.1.3.5.2.5.3 Clearance. Clearances of 100 mm (4 in) to the side and 50 mm (2 in) to the rear shall be provided to allow for hand movement.

5.1.3.5.2.5.4 Full range of motion. Clearance shall be provided to allow for the full range of joystick motion.

5.1.3.5.2.5.5 Actuation of buttons. Clearance shall be provided to enable actuation of joystick buttons while in any position within the joystick range of motion.

5.1.3.5.2.5.6 Mounting. Joysticks shall be mounted to provide forearm or wrist support.

5.1.3.5.2.5.7 Modular devices. Modular devices shall be mounted to allow actuation of the joystick without slippage, movement, or tilting of the mounting base.

5.1.3.5.3 Finger-operated displacement joysticks.

5.1.3.5.3.1 Dynamic characteristics. Dynamic characteristics shall be in accordance with 5.1.3.5.2.2. Recessed mounting may be utilized as indicated on figure 5 to allow more precise control.

5.1.3.5.3.2 Button placement. Joystick and other nearby buttons shall be located to prevent accidental actuation during joystick use (i.e., buttons shall not be placed where the user would rest the heel of their hand to manipulate the joystick).

5.1.3.5.3.3 Mounting.

5.1.3.5.3.3.1 Mounting on desk. The joystick shall be mounted on a desk or shelf surface as shown on figure 5.

5.1.3.5.3.3.2 Arm or wrist support. Joysticks shall be mounted to provide forearm or wrist support.

5.1.3.5.3.4 Modular devices. Modular devices shall be mounted to allow actuation of the joystick without slippage, movement, or tilting of the mounting base.

5.1.3.5.3.5 Clearances.

5.1.3.5.3.5.1 Full range of motion. Clearance shall be provided to allow for the full range of joystick motion.

5.1.3.5.3.5.2 Actuation of buttons. Clearance shall be provided to enable actuation of joystick buttons while in any position within the joystick range of motion.

5.1.3.5.4 Thumbtip- or fingertip-operated displacement joysticks. Thumbtip- or fingertip-operated joysticks may be mounted on a hand grip, which serves as a steady rest to damp vibrations and increase precision.

5.1.3.5.4.1 Hand grip with mounted joystick. If a thumbtip- or fingertip-user joystick is mounted on a hand grip, the hand grip shall not simultaneously function as a joystick controller.

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

5.1.3.5.4.3 Button placement. Joystick buttons shall be located to prevent accidental actuation during joystick use.

5.1.3.5.4.4 Hand and wrist support. Joysticks shall be mounted to provide hand or wrist support.

5.1.3.5.4.5 Modular devices. Modular devices shall be mounted to allow actuation of the joystick without slippage, movement, or tilting of the mounting base.

5.1.3.5.4.6 Clearances.

5.1.3.5.4.6.1 Full range of motion. Clearance shall be provided to allow for the full range of joystick motion.

5.1.3.5.4.6.2 Actuation of buttons. Clearance shall be provided to enable actuation of joystick buttons while in any position within the joystick range of motion.

5.1.3.6 Isometric joysticks (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. Isometric joysticks shall meet the criteria in 5.1.3.6.1 through 5.1.3.6.4.2.

5.1.3.6.1 General.

5.1.3.6.1.1 Use. Isometric joysticks may be used for various display functions, such as data pickoff from a display. Isometric joysticks may also be used for tasks requiring precise or continuous control in two or more related dimensions and are particularly appropriate for the following types of applications:

a. Applications that require precise return to center after each use.
b. Applications in which user feedback is primarily visual rather than tactile feedback from the control itself.
c. Applications where there is minimal delay and tight coupling between control, input, and system reaction.

5.1.3.6.1.2 Applications to avoid. Isometric joysticks should not be used in applications that require the user to maintain a constant force on the controller for a long period of time or that provide no definitive feedback when maximum control inputs have been exceeded.

5.1.3.6.1.3 Positioning speed. When positioning speed is more critical than positioning accuracy, isometric joysticks shall be selected over displacement joysticks.

5.1.3.6.1.4 Off-edge indicator. In rate control applications that may allow the cursor to transit beyond the edge of the display, indicators shall be provided in order to aid the user in bringing the cursor back onto the display.

5.1.3.6.2 Hand-operated isometric joysticks.

5.1.3.6.2.1 Specific use. In addition to general use, hand-operated isometric joysticks may be used as vehicle controllers, aiming sensors, and mounting platforms for secondary controls, such as thumb- and finger-operated switches. Operation of secondary controls has greater induced error on isometric joysticks than on displacement joysticks.

5.1.3.6.2.2 Dynamic characteristics. Maximum force for full output shall be not more than 118 newtons (26.7 lbs).

5.1.3.6.2.3 Button placement. Joystick buttons shall be located to prevent accidental actuation during joystick use (i.e., buttons shall not be placed where the user would rest the heel of their hand to manipulate the joystick).

5.1.3.6.2.4 Trigger actuation. Inadvertent trigger actuation shall be minimized through proper use of trigger guards, safety latches, or other means.

5.1.3.6.2.5 Coding. Joystick buttons and other controls shall be coded by shape, size, location, texture, or other means to aid in non-visual identification.

5.1.3.6.2.6 Dimensions, resistance, and clearance. Dimensions, resistance, and clearance shall be in accordance with 5.1.3.5.2.5.

5.1.3.6.3 Finger-operated isometric joysticks. Dimensions, resistance, and clearance shall conform to 5.1.3.5.3.5.

5.1.3.6.4 Thumbtip- or fingertip-operated isometric joysticks. Thumbtip- or fingertip-operated joysticks may be mounted on a hand grip, which serves as a steady rest to damp vibrations or increase precision.

5.1.3.6.4.1 Simultaneous function. If a thumbtip- or fingertip-operated joystick is mounted on a hand grip, the hand grip shall not simultaneously function as a joystick controller.

5.1.3.6.4.2 Dimensions, resistance, and clearance. Dimensions, resistance, and clearance of thumbtip- and fingertip-operated joysticks shall be in accordance with 5.1.3.5.4.6.

5.1.3.7 Grid-and-stylus devices. The following provisions cover techniques that use a means of establishing an x and y grid and a stylus for designating specific points on that grid for control purposes. For dimensions and mounting, see 5.1.3.8.3.

5.1.3.7.1 Application. Grid and stylus devices may be used to select data from a display, enter points on a display, generate free-drawn 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.

5.1.3.7.1.1 Cursor. A cursor (bug, mark, hook) shall be presented on the display at the coordinate values selected by the stylus.

5.1.3.7.1.2 Feedback. Feedback (e.g., a click) shall be provided for control actions.

5.1.3.7.1.3 Control functions. Grid and stylus devices shall be used only for zero-order control functions (i.e., displacement of the stylus from the reference position causes a proportional displacement of the cursor).

5.1.3.7.2 Dynamic characteristics. Movement of the stylus in any direction on the grid surface or 3-dimensional (3-D) display volume shall result in smooth movement of the cursor in the same direction.

5.1.3.7.2.1 Stylus placement. Discrete placement of the stylus at any point on the grid shall cause the cursor to appear at the corresponding coordinates and to remain there as long as the stylus is not moved.

5.1.3.7.2.2 Refresh rate. The refresh rate for the cursor shall be high enough to ensure the appearance of a continuous track whenever the stylus is used for generation of free-drawn graphics.

5.1.3.7.3 Grids. Transparent grids that are used as display overlays shall conform to the size of the display.

5.1.3.7.3.1 Grids displaced from the display. Grids that are displaced from the display shall approximate the display size.

5.1.3.7.3.2 Grid mounting. Grids shall be mounted below the display in an orientation to preserve directional relationships to the maximum extent (i.e., vertical plane passing through the north-south axis on the grid shall pass through or be parallel to the north-south axis of the display).

5.1.3.8 Light pens and other styli. Light pens and other styli shall meet the criteria in 5.1.3.8.1 through 5.1.3.8.4.2.

5.1.3.8.1 Use. A light pen may be used as a track-oriented readout device. It may be positioned on the display screen to detect a computer-generated track by sensing its refresh pattern; the display system will then present a hook on the designed track. With additional circuitry, a cursor can be made to track the movement of the light pen across the screen surface, thus allowing it to function as a two-axis controller capable of serving the same purposes as the grid and stylus devices of 5.1.3.7.

5.1.3.8.2 Dynamic characteristics. When used as a two-axis controller, light pen dynamic characteristics shall be in accordance with 5.1.3.7.2

5.1.3.8.2.1 Force. The stylus force required to produce a continuous input on a tablet shall be not greater than 0.8 newtons (2.9 ounces of force [ozf]).

5.1.3.8.2.2 Use as a 3-axis controller. When used as a 3-axis controller, the light pen dynamic characteristics shall provide a natural sense of movement within a 3-dimensional image, even when the pen touches no physical surface.

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

5.1.3.8.3.1 Slip-resistant surface. The light pen shall have a slip-resistant surface.

5.1.3.8.3.2 Weight. The light pen shall weigh 0.1 to 0.25 newtons (0.35 to 0.875 ounces of force).

5.1.3.8.3.3 Stowage. A means shall be provided to stow or secure the light pen when it is not in use.

5.1.3.8.4 Buttons.

5.1.3.8.4.1 Diameter. The contact surface of a selector button that is mounted on a stylus or light pen shall have a diameter of not less than 0.05 mm (0.2 in).

5.1.3.8.4.2 Force to actuate a button. The force required to actuate a button mounted on a stylus or light pen shall be 0.3 to 0.8 newton (1 to 2.9 ounces of force).

5.1.3.9 Pucks. A puck is a non-keyboard input device shaped like a slice of a cylinder that is placed on or next to a display surface (see ANSI/HFES 100 for a detailed definition specific to computer workstations). Use and characteristics of pucks shall be in accordance with ISO 9241-400.

5.1.3.10 Hand-held controllers (free-moving x-y-z). A free-moving x-y-z controller shall involve a relative positional reference to the device being controlled in roll, pitch, and yaw axes; include at least one push button switch to provide a selection or activation method; and have a defined operating space and associated position accuracy as required by the application. If the reference relationship between the handheld controller and the entity controlled (machine, weapon system, or display) is lost, the user shall be alerted via an indicator (light, audio tone, or buzzer in the handheld device), and the handheld controller inputs shall be ignored until the reference relationship is re-established (see 5.19).

5.1.3.11 Data entry.

5.1.3.11.1 General. Data entry functions shall be designed to establish consistency of data entry transactions, minimize input actions and memory load on the user, ensure compatibility of data entry with data display, and provide flexibility of user control of data entry.

5.1.3.11.1.1 User pacing. Data entry shall be paced by the user rather than by the system.

5.1.3.11.1.2 Positive feedback. The system shall provide a positive feedback to the user of the acceptance or rejection of a data entry. Feedback response times shall be in accordance with 5.1.2.1.6.4.

5.1.3.11.1.3 Processing delay. Where system overload or other system conditions will result in a processing delay, the system shall acknowledge the data entry and provide an indication of the delay to the user. If possible, the system shall advise the user of the time remaining for the process or of the fraction of the process completed.

5.1.3.11.1.4 Explicit action. Data entry shall require an explicit completion action, such as pressing an ENTER key.

5.1.3.11.1.5 Validation. Data entries shall be validated by the system for completeness, correct format, legal value, or range of values.

5.1.3.11.1.6 Entry of data sets. Where repetitive entry of data sets is required, data validation for each set shall be completed before another transaction can begin (see 5.1.2.1.7.13).

5.1.3.11.1.7 Input units. Data should be input in units necessary for the system.

5.1.3.11.1.8 Abbreviations, acronyms, mnemonics, and codes. When abbreviations, acronyms, mnemonics, or codes are used to shorten data entry, they shall be distinctive and have an intuitive relationship or association to normal language or specific job-related terminology.

5.1.3.11.1.8.1 Length. An abbreviation shall be no longer than is necessary to ensure a clear and unambiguous meaning.

5.1.3.11.1.8.2 Reference. An easily accessible reference of abbreviation meanings shall be made available to the operator.

5.1.3.11.1.8.3 Consistency. Abbreviations, acronyms, mnemonics, and codes shall be consistent within and between systems and applications that are anticipated to be used by the same user population.

5.1.3.11.1.9 Explicit delete action. Data deletion or cancellation shall require an explicit action, such as pressing a DELETE key.

5.1.3.11.1.10 Permanent deletion. Permanent deletion (in absence of an “undo” function) of more than one character shall not be allowed without an affirmative response to an “Are you sure?” type of query.

5.1.3.11.1.11 Change of data. Where a user requests a change (or deletion) of a data item that is not currently being displayed, the option of displaying the old value before confirming the change shall be presented.

5.1.3.11.1.12 Single method of data entry. Data entry methods and data displays shall not require the user to shift between entry methods.

5.1.3.11.1.13 Data entry display. Where data entry on an electronic display is permitted only in prescribed areas, a clear visual definition of the entry fields shall be provided.

5.1.3.11.2 Cursors. Cursors shall meet the criteria in 5.1.3.11.2.1 through 5.1.3.11.2.8.3.

5.1.3.11.2.1 Control. Systems employing cursors shall provide cursor control capability.

5.1.3.11.2.1.1 Sensitivity adjustment. The user shall be able to adjust the sensitivity of the cursor movement to be compatible with the required task and user skills where appropriate.

5.1.3.11.2.1.2 Impact on mission and critical tasks. The ability for the user to adjust the sensitivity of the cursor movement shall only be provided where adjustment of this control could not adversely affect the ability to fulfill the mission and complete critical tasks.

5.1.3.11.2.2 Display. A movable cursor within the display shall have a distinctive visual attribute that does not obscure other displayed entities.

5.1.3.11.2.2.1 Fine positioning. When fine positioning accuracy is required, as in some forms of graphic and image processing applications, the displayed cursor shall include an appropriate point designation feature, such as crosshairs.

5.1.3.11.2.2.2 Display boundaries. The cursor shall not move beyond the display boundaries and disappear.

5.1.3.11.2.2.3 Key press. If the cursor is moved by pressing a key, releasing the key shall cause the cursor to stop moving.

5.1.3.11.2.3 Home position. The home position for the cursor shall be consistent across similar types of displays.

5.1.3.11.2.4 Explicit actuation. A separate explicit action distinct from cursor position shall be required for the actual entry (e.g., enabling or actuation) of a designated position.

5.1.3.11.2.5 Incremental cursor positioning. Where cursor positioning is incremental by discrete steps, the step size of cursor movement shall be consistent horizontally (in both right and left directions) and vertically (in both up and down directions). For 3-dimensional displays, cursor movement shall be consistent in depth in both fore and aft directions.

5.1.3.11.2.6 Keyboard cursor control. When position designation is required in a task emphasizing keyed data entry, cursor control shall be by some device integral to the keyboard.

5.1.3.11.2.7 Key location. If cursor movement is accomplished by pressing keys, the keys shall be located on the main keyboard.

5.1.3.11.2.8 Movement relationships. The response of a cursor to control movements shall be consistent, predictable, and compatible with the user's expectations.

5.1.3.11.2.8.1 Cursor control by key action. For cursor control by key action, the cursor shall move in the corresponding direction of the arrow key that was pressed (i.e., left arrow to left, right arrow to right, up arrow up, down arrow down).

5.1.3.11.2.8.2 Cursor control by joystick. For cursor control by joystick, movement of the joystick shall result in the cursor moving in the corresponding direction (i.e., left movement moves cursor to the left, right movement moves the cursor to the right, push movement moves the cursor upward, pull movement moves the cursor down).

5.1.3.11.2.8.3 Cursor responses to other controls. Cursor responses to movements of other controls shall be in accordance with 5.1.1.2.1 or to the movement-related provisions of the applicable control specified herein.

5.1.3.11.3 Data entry using keyboards. Keyboards shall be in accordance with the provisions below (also see 5.1.3.2).

5.1.3.11.3.1 Use. A keyboard shall be used to enter alphabetic, numeric, and other special characters into the system.

5.1.3.11.3.2 Characteristics. Keyboard characteristics shall be in accordance with ANSI/HFES 100.

5.1.3.11.3.3 Length. The length of individual data items shall be no more than necessary to accomplish the task.

5.1.3.11.3.4 Justification. When entering tabular data, the user shall not be required to right- or left-justify tabular data entries. The system shall automatically justify columnar data with respect to decimal point, left margin, or right margin, depending on the type of data.

5.1.3.11.3.5 Numeric keypads. Keyboards used in systems that require substantial numeric input shall be equipped with a numeric keypad.

5.1.3.11.3.6 Minimization of keying. The amount of keying required shall be no more than necessary to accomplish the task.

5.1.3.11.3.7 Minimization of shift keying. The use of key shifting functions shall be minimized during data entry transactions.

5.1.3.11.3.8 Data change. In keyed data entry, means shall be provided to allow users to change previous entries by either overtyping the existing text or inserting new text at any position within the data field.

5.1.3.11.4 Data entry using fixed function (dedicated) keys. Data entry using fixed function keys shall meet the criteria in 5.1.3.11.4.1 through 5.1.3.11.4.4.2.

5.1.3.11.4.1 Use. Fixed function keys (e.g., ENTER) shall be used for time-critical, error-critical, or frequently used control inputs.

5.1.3.11.4.2 Standardization. Fixed function keys shall be common throughout the system.

5.1.3.11.4.3 Functional consistency. Once a key has been assigned a given function, it shall not be reassigned to a different function for a given user.

5.1.3.11.4.4 Availability. Fixed function keys shall be selected to control functions that are continuously available (i.e., lockout of fixed function keys shall be minimized).

5.1.3.11.4.4.1 Function keys not currently used. At any step in a transaction sequence, function keys not used for current inputs shall be temporarily disabled under computer control.

5.1.3.11.4.4.2 Mechanical overlays. Mechanical overlays shall not be used to temporarily disable function keys.

5.1.3.11.4.5 Non-active keys. Non-active fixed function keys shall be replaced by a blank key or grayed-out.

5.1.3.11.4.6 Grouping. Fixed function keys shall be logically grouped and placed in distinctive locations on the keyboard.

5.1.3.11.4.7 Actuation. Except when used to toggle between two opposing states, a fixed function key shall require only a single actuation to accomplish its function.

5.1.3.11.4.8 Feedback. When fixed function key activation does not result in an immediately observable natural response, the user shall be given an indication of system acknowledgment.

5.1.3.11.4.9 Fixed function key labels. Fixed function key assignments shall always be displayed.

5.1.3.11.4.9.1 Direct marking. Fixed function key assignments shall be displayed by direct marking.

5.1.3.11.4.9.2 Abbreviations. Where abbreviations are necessary for fixed function keys, standard abbreviations shall be used.

5.1.3.11.4.10 Prolonged function key pressing. Except for the DELETE key, prolonged pressing of function keys shall not result in a repeat of the function.

5.1.3.11.5 Data entry using variable function keys. Data entry using variable function keys shall meet the criteria in 5.1.3.11.5.1 through 5.1.3.11.5.8.

5.1.3.11.5.1 Use. Variable function keys may be used for programmable menu selection and entry of control functions.

5.1.3.11.5.2 Critical action. A single entry on a variable function key shall not produce a critical action.

5.1.3.11.5.3 Critical action confirmation. Critical actions shall require confirmation when initiated with a variable action key.

5.1.3.11.5.4 Status display. When the effect of a function key varies, the status of the key shall be displayed.

5.1.3.11.5.5 Reprogrammable or inactive default functions. When keys with labeled default functions are reprogrammed or turned off, a visual warning shall alert the user that the standard function is not currently accessible via that key.

5.1.3.11.5.6 Relabeling. Provisions shall be made for easily relabeling variable function keys. Labels for variable function keys located along the perimeter of a display may be generated on the display face.

5.1.3.11.5.7 Shifted characters. Shift keys shall not be required to operate variable function keys.

5.1.3.11.5.8 Easy return to base-level functions. Where the functions assigned to a set of function keys change as a result of user selection, the user shall be given an easy means to return to the initial, base-level functions.

5.1.3.11.6 Data entry using a light pen. Data entry using a light pen shall meet the criteria in 5.1.3.11.6.1 through 5.1.3.11.6.4.2.

5.1.3.11.6.1 Use. Direct-pointing controls shall be used when item selection is the primary type of data entry.

5.1.3.11.6.2 Dimensions and mounting. See 5.1.3.8.3.

5.1.3.11.6.3 Actuation and deactuation. Light pens shall be equipped with a discrete actuating and deactuating mechanism.

5.1.3.11.6.4 Feedback. Position of the light pen, preferably in the form of a displayed cursor (e.g., circle, crosshair, or highlighting), that informs the user that the system is recognizing the presence of the light pen shall be provided.

5.1.3.11.6.4.1 See under the light pen tip. Feedback shall be large enough to be seen under the point of the light pen.

5.1.3.11.6.4.2 Receipt by system. Feedback shall be provided to indicate actuation of the light pen and receipt of the input by the system.

5.1.3.11.7 Data entry using directional controllers. A joystick, trackball, or similar device may be used when precise input functions are required. Trackballs, displacement joysticks, isometric joysticks, grid-and-stylus devices, and free-moving x-y-z controllers shall be in accordance with 5.1.3.4, 5.1.3.5, 5.1.3.6, 5.1.3.7, and 5.1.3.10, respectively. A discrete mechanism shall be provided to allow the user to actuate and deactuate the device.

5.1.3.11.8 Data entry using a touchscreen. See 5.1.3.1 for design criteria on touchscreens.

5.1.3.11.9 Data entry by voice or gesture. See 5.3.1 and 5.3.13.

5.1.3.12 Interactive control.

5.1.3.12.1 General.

5.1.3.12.1.1 Control actions. Control actions shall be minimized, consistent, make minimal memory demands of the user, and be sufficiently flexible to adapt to different user needs.

5.1.3.12.1.2 Dialog types. Dialog types shall be compatible with anticipated task requirements and user skills.

5.1.3.12.1.3 Response time compatibility with user. System response times shall be consistent with operational requirements and shall accommodate dialog type and requirements for user training.

5.1.3.12.1.3.1 Compatibility with system response times. Required user response times shall be compatible with required system response time.

5.1.3.12.1.3.2 Consistent with user tasking. Required user response times shall be within the limits imposed by total user tasking expected in the operational environment (see 5.1.2.1.6.4).

5.1.3.12.1.3.3 Response time-induced input device lockout. If computer processing time requires delay of concurrent user inputs and no keyboard buffer is available, input device lockout shall occur until the computer can accept the next transaction.

5.1.3.12.1.3.4 Lockout alert. An alert shall be displayed to indicate to the user that lockout has occurred.

5.1.3.12.1.3.5 Input device restoration. When the computer is ready to continue following a response time induced input device lockout, a signal to indicate such shall be presented (e.g., cursor changes back to normal shape).

5.1.3.12.1.3.6 Interrupt to end input device lockout. When input device lockout has occurred, the user shall be provided with a capability to abort a transaction that has resulted in an extended lockout. Any such capability shall act like an UNDO command that stops ongoing processing and does not RESET the computer, thereby losing prior processing.

5.1.3.12.1.4 Simplicity. Control and display relationships shall be straightforward and explicit.

5.1.3.12.1.5 Control actions. Control actions shall be simple and direct, whereas potentially destructive control actions shall require extended user attention such that they are not easily acted on (e.g., "Are you sure?" queries).

5.1.3.12.1.6 Accidental actuation. Provision shall be made to prevent accidental actuation of potentially destructive control actions, such as accidental erasure or memory dump.

5.1.3.12.1.7 Compatibility with user skill. Controls shall be compatible with the lowest anticipated user skill levels. Experienced users shall have options that shortcut intervening steps necessary for inexperienced users.

5.1.3.12.1.8 Availability of information. Information necessary to select or enter a specific control action shall be available to the user when selection of that control action is appropriate.

5.1.3.12.1.9 Concurrent display. Concurrent displays shall meet the criteria in 5.1.3.12.1.9.1 through 5.1.3.12.1.9.3.

5.1.3.12.1.9.1 Control actions. Control actions to be selected from a discrete set of alternatives shall have those alternatives displayed prior to the time of selection.

5.1.3.12.1.9.2 Current value. The current value of any parameter or variable with which the user is interacting shall be displayed.

5.1.3.12.1.9.3 User control inputs. User control inputs shall result in a positive feedback response displayed to indicate performance of requested actions.

5.1.3.12.1.10 Hierarchical process. The number of hierarchical levels used to control a process or sequence shall be minimized. No more than four hierarchical levels should be used.

5.1.3.12.1.10.1 Display and input formats. Display and input formats should be similar within hierarchical levels.

5.1.3.12.1.10.2 Current position. The system shall always indicate the current positions within the sequence.

5.1.3.12.1.11 User memorization. The system shall not require the user to learn mnemonics, codes, special or long sequences, or special instructions.

5.1.3.12.1.12 Dialog type. The choice of dialog type (e.g., form filling, menus, or command language) for interactive control shall be compatible with user characteristics and task requirements.

5.1.3.12.1.13 Number system. Number systems shall meet the criteria in 5.1.3.12.1.13.1 through 5.1.3.12.1.13.2.

5.1.3.12.1.13.1 Decimal system. When numeric data are displayed or required for control input, such data shall be in the decimal, rather than binary, octal, hexadecimal, or other number system unless it is operationally imperative to use an alternate number system.

5.1.3.12.1.13.2 Alternate number system. When numeric data is not displayed in the decimal format due to operational requirements, the alternate number system used shall be clear to the user.

5.1.3.12.1.14 Data manipulation. The system shall enable the user to manipulate data without specialized knowledge of the internal storage and retrieval mechanisms of the system.

5.1.3.12.1.15 Computer processing constraints. The sequence of transaction selection shall be dictated by user choices and not by internal computer processing constraints.

5.1.3.12.1.16 Feedback for correct input. Control feedback responses to correct user input shall consist of changes in state or value of those display elements that are being controlled and shall be presented in an expected and logically natural form.

5.1.3.12.1.17 Acknowledgement message. An acknowledgment message shall be provided only where control feedback responses as provided in 5.1.3.12.1.5 are not appropriate or where feedback response time exceeds 1 second.

5.1.3.12.1.18 Feedback for erroneous input. Where control input errors are detected by the system, error messages shall be available as provided in 5.17.10.7 and error recovery procedures shall be as provided in 5.1.2.1.7.1.

5.1.3.12.1.19 Control input data display. The presence and location of control input data entered by the user shall be clearly and appropriately indicated. Data displayed shall not mislead the user with regard to nomenclature, units of measure, sequence of task steps, or time phasing.

5.1.3.12.1.20 Originator identification. See 5.17.22.3.4.8.

5.1.3.12.2 Menu selection. Menu selection shall meet the criteria in 5.1.3.12.2.1 through 5.1.3.12.2.2.7.

5.1.3.12.2.1 Use. Interactive control through menu selection should be used for tasks that involve little or no entry of free-form data and where users may have relatively little training. Menu selection should be used when a command set is so large that users are not likely to be able to commit all the commands to memory.

5.1.3.12.2.2 Selection.

5.1.3.12.2.2.1 Mouse or other pointing device. A mouse or other pointing device (including touch technology) should be used for menu selection (see 5.1.3.3).

5.1.3.12.2.2.2 Design constraints. Where design constraints do not permit pointing devices, a standard window shall be provided for the user to key the selected option code.

5.1.3.12.2.2.3 Menu selection by pointing. If menu selection is accomplished by pointing, dual actions shall be provided. The first action shall designate the selected option. The selection for processing shall be followed by a separate action to enter the selection for processing.

5.1.3.12.2.2.4 Title. Each page of options (menu) shall have a title that clearly identifies the purpose of that menu.

5.1.3.12.2.2.5 Stack menu selections. Users shall be provided the capability to stack menu selections (i.e., to make several menu selections without having each menu displayed).

5.1.3.12.2.2.6 Multi-page options. A menu shall not consist of a long list of multi-page options.

5.1.3.12.2.2.7 Logically segmented. The menu shall be logically segmented to allow several sequential selections among a few alternatives.

5.1.3.12.2.3 Active option presentation. The system shall present only menu selections for actions that are currently available.

5.1.3.12.2.4 Format consistency. Menus of the same type (e.g., hierarchical or stack) shall be presented in a consistent format throughout the system and across other systems the user is expected to operate.

5.1.3.12.2.5 Availability. Menus shall always be readily available.

5.1.3.12.2.6 Option sequence. Menu selections shall be listed in a logical order, or, if no logical order exists, in the order of frequency of use.

5.1.3.12.2.7 Simple menus. If the number of selections can fit on one page in no more than two columns, a simple menu shall be used. If the selection options exceed two columns, hierarchical menus may be used.

5.1.3.12.2.8 Option presentation. Selection codes and associated descriptors shall be presented on single lines.

5.1.3.12.2.9 Direction function call. If several levels of hierarchical menus are provided, a direct function call capability shall be provided such that the experienced user does not have to step through multiple menu levels.

5.1.3.12.2.10 Option coding. When selections are indicated by coded entry, the code associated with each option shall be included on the display in some consistent manner.

5.1.3.12.2.11 Keyed codes. If menu selections must be made by keyed codes (mnemonics), the options shall be coded by the first several letters of their displayed labels rather than by more arbitrary numeric codes.

5.1.3.12.2.12 Function codes. Keyed codes shall not duplicate any other user function codes.

5.1.3.12.2.13 Position in structure. When menu traversal can be accomplished by clearly defined hierarchical paths, the user shall be given some indication of the displayed menu's current position in the overall or relevant structure (e.g., an optional display of "path" information or cascading menus). A menu tree showing the menu hierarchy shall be included in the user manual or online Help section.

5.1.3.12.2.14 Return to next higher level. When using hierarchical menus, the user shall be able to return to the next higher level by using single key action until the initial, top-level menu or display is reached. No more than three levels should be used in a hierarchical menu structure.

5.1.3.12.2.15 Return to top level. A function shall be provided to directly recall the initial, top-level menu or display without stepping through the menu or display hierarchy.

5.1.3.12.3 Form filling. Form filling shall meet the criteria in 5.1.3.12.3.1 through 5.1.3.12.3.19.

5.1.3.12.3.1 Use. Form filling interactive control may be used where some flexibility in data to be entered is needed and where the users will have moderate training. A form-filling dialog should not be used when the computer must handle multiple types of forms and the computer response is slow.

5.1.3.12.3.2 Grouping. Displayed forms shall be arranged to group related items together.

5.1.3.12.3.3 Format and content consistency. The format and content of displayed forms shall duplicate the (paper) form it is intended to represent in every major parameter.

5.1.3.12.3.4 Responses. The displayed form shall require a response for every data entry field; advancing through a field (i.e., leaving blank) for which no entry is desired shall require an explicit action such as TAB or ENTER keystrokes.

5.1.3.12.3.5 Distinctiveness of fields. Fields or groups of fields shall be separated by spaces, lines, or other delineation cues. Required fields shall be distinguished from optional fields.

5.1.3.12.3.6 Field labels. Field labels shall be distinctively presented such that they can be distinguished from data entry.

5.1.3.12.3.7 Additional cueing. Labels for data entry fields shall incorporate additional cueing of data format where the entry is made up of multiple inputs (e.g., "DATE (MM/DD/YYYY): _ _ / _ _ / _ _ _ _").

5.1.3.12.3.8 Cursor. A displayed cursor shall be positioned by the system at the first data entry field when the form is displayed.

5.1.3.12.3.8.1 Advancing cursor. The cursor shall be advanced by a TAB key to the next data entry field when the user has completed entry of the current field.

5.1.3.12.3.8.2 Automatic movement. The cursor shall automatically move to the next field when the end of the field is reached.

5.1.3.12.3.9 Entry length indication. The maximum acceptable length for variable length fields shall be indicated.

5.1.3.12.3.10 Overwriting. Data shall not be entered by overwriting a set of characters in a field (such as a default).

5.1.3.12.3.11 Unused underscores. When an item length is variable, the system shall not require the user to remove unused underscores.

5.1.3.12.3.12 Dimensional units. When a consistent dimensional unit is used in a given entry field, the dimensional unit shall be provided by the computer. When the dimensional unit varies for a given field, it shall be provided, or selected, by the user.

5.1.3.12.3.13 User omissions. When required data entries have not been input, the omission shall be indicated to the user and input of the missing items shall be allowed.

5.1.3.12.3.14 User input delayed. If user input will be delayed, the user shall have the ability to designate the field to indicate that the missing item is delayed, not overlooked.

5.1.3.12.3.15 Non-entry areas. Non-entry (protected) areas of the display shall be designated and made inaccessible to the user via the cursor.

5.1.3.12.3.16 Flexible data entry. When multiple data items are entered as a single transaction, the user shall be allowed to reenter, change, or cancel any item before taking a final ENTER action.

5.1.3.12.3.17 Informative labels. Descriptive wording shall be employed when labeling data fields. Use of arbitrary codes shall be avoided.

5.1.3.12.3.18 Logical order. Where no source document or external information is involved, forms shall be designed so that data items are ordered in a logical sequence for input.

5.1.3.12.3.19 Dialog boxes for control entry. Dialog boxes may be used as an aid for composing complex control entries. For example, for a print request, a displayed form might help a user invoke the various format controls that are available.

5.1.3.12.4 Fixed function keys. Fixed function key interactive control may be used for tasks that require only a limited number of control inputs or in conjunction with other dialog types (see 5.1.3.11.4).

5.1.3.12.5 Command language.

5.1.3.12.5.1 Use. Command language interactive control may be used for tasks that involve a wide range of user inputs and where user familiarity with the system can take advantage of the flexibility and speed of the control technique.

5.1.3.12.5.2 User viewpoint. A command language shall reflect the user's point of view such that the commands are logically related to the user's conception of what is being done.

5.1.3.12.5.3 Distinctiveness. Command names shall be distinctive from one another.

5.1.3.12.5.4 Punctuation. The command language shall contain a minimum amount of punctuation or other special characters.

5.1.3.12.5.5 Abbreviations. The user shall be permitted to enter the full command name or an abbreviation for any command of more than five characters.

5.1.3.12.5.6 Standardization. All commands and their abbreviations, if any, shall be standardized within and across other systems the user is expected to operate.

5.1.3.12.5.7 Displayed location. Commands shall be entered and displayed in a standard location on the display.

5.1.3.12.5.8 Command prompts. The user shall be able to request prompts, as necessary, to determine required parameters or available options for an appropriate command entry.

5.1.3.12.5.9 Complexity. The command language shall be programmed in layers of complexity such that the basic layer will allow the inexperienced user to control a transaction; experienced users shall be allowed to skip from basic to more advanced layers.

5.1.3.12.5.10 User definition of macro commands. The system shall not accept a user-designated macro name that is the same as an existing command name.

5.1.3.12.5.11 Standard techniques for command editing.

5.1.3.12.5.12 Destructive commands. If a command entry may have disruptive consequences, the user shall be required to review and confirm a displayed interpretation of the command before it is executed.

5.1.3.12.6 Question and answer. Question-and-answer designs shall meet the criteria in 5.1.3.12.6.1 through 5.1.3.12.6.5.

5.1.3.12.6.1 Use. Question-and-answer dialogs may be used for routine data entry tasks where data items are known and their ordering can be constrained, where users will have little or no training, and where the computer is expected to have medium response speed.

5.1.3.12.6.2 Questions displayed separately. Each question shall be displayed separately in question-and-answer dialogs.

5.1.3.12.6.3 Multiple questions. Users shall not be required to answer several questions at once.

5.1.3.12.6.4 Recapitulating prior answers. When a series of computer-posed questions are interrelated, answers to previous questions shall be displayed when they will provide context to help a user answer the current question.

5.1.3.12.6.5 Source document capability. When questions prompt entry of data from a source document, the question sequence shall match the data sequence in the source document.

5.1.3.12.7 Query language. Query language shall meet the criteria in 5.1.3.12.7.1 through 5.1.3.12.7.6.

5.1.3.12.7.1 Use. Query language dialog should be used for tasks emphasizing unpredictable information retrieval (as in many analysis and planning tasks) with moderately trained users.

5.1.3.12.7.2 Natural organization of data. Query languages shall reflect a data structure or organization perceived to be natural by users. For example, if a user supposes that all data about a particular topic is stored in one place, then the query language shall permit such data to be retrieved by a single query, even though various data may be stored in different computer files.

5.1.3.12.7.3 Coherent representation of data organization. A single representation of the data organization for use in query formulation shall be established (i.e., the user does not need to know if different queries will access different databases over different routes).

5.1.3.12.7.4 Task-oriented wording. The wording of a query shall simply specify the data being requested. Users shall not have to tell the computer how to find the data.

5.1.3.12.7.5 Logic to link queries. The query language shall be designed to include logic elements that permit users to link (e.g., “and”, “or”) sequential queries as a single entry.

5.1.3.12.7.6 Confirming large-scale data retrieval. If a query will result in a large-scale data retrieval, the user shall be required to confirm the transaction or take further action to narrow the query before processing.

5.1.3.12.8 Graphic interaction. Graphic interaction design shall meet the criteria in 5.1.3.12.8.1 through 5.1.3.12.8.3.

5.1.3.12.8.1 Use. Graphic interaction as a dialog may be considered for use by casual users to provide graphic aids as a supplement to other types of interactive control.

5.1.3.12.8.2 Iconic menus. When system users have different linguistic backgrounds, graphic menus that display icons to represent the control options may be used. Where the system is intended for use by foreign military personnel, icon design shall be consistent with applicable cultural and ethnic variables to ensure comprehension and to avoid potential offense.

5.1.3.12.8.3 Supplementary textual labels. Where icons are used to represent control actions in menus, textual labels shall be displayed, or made available for display, with each icon to help ensure that its intended meaning will be understood.

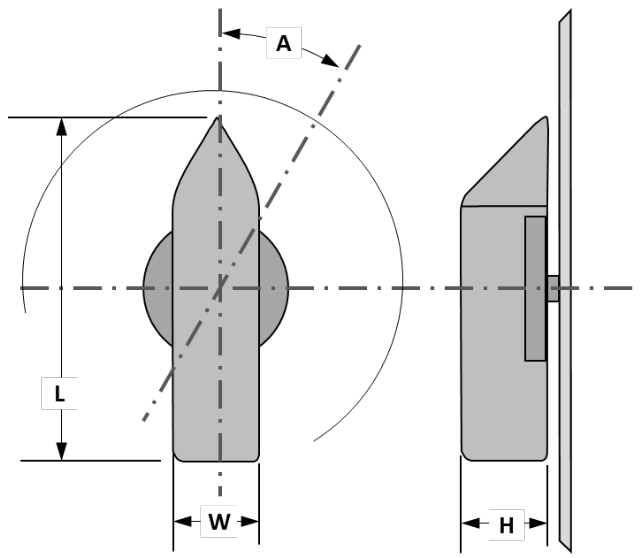
5.1.4 Mechanical controls. Mechanical controls (as opposed to information system controls of 5.1.3) are controls that are typically used for applications other than input to an information system. It is recognized that there may be situations where a mechanical control may provide input to an information system.

5.1.4.1 Rotary controls.

5.1.4.1.1 Discrete adjustment rotary controls.

5.1.4.1.1.1 Rotary selector switches. Rotary selector switches shall meet the criteria in 5.1.4.1.1.1.1 through 5.1.4.1.1.1.10.

5.1.4.1.1.1.1 Use. Rotary selector switches (see figure 6) should be used for discrete functions when three or more detented positions are required. Rotary selection 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.



	Dimensions			**Resistance**
	L, Length	**W, Width**	**H, Depth**	
Minimum	25 mm (1 in)	--	16 mm (0.625 in)	115 mN·m (1 in-lbf)
Maximum	100 mm (4 in)	25 mm (1 in)	75 mm (3 in)	680 mN·m (6 in-lbf)

	A, Displacement 1/		**Separation**	
	--	2/	One-hand random	Two-handed operation
Minimum	15° (262 mrad)	30° (525 mrad)	25 mm (1 in)	75 mm (3 in)
Maximum	40° (700 mrad)	90° (1,570 mrad)	--	--
Preferred	--	--	50 mm (2 in)	125 mm (5 in)

NOTES:

1/ For facilitating performance.

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

FIGURE 6. Discrete rotary selector switch.

5.1.4.1.1.1.2 Moving pointer. Rotary selector switches shall be designed with a moving pointer and a fixed scale.

5.1.4.1.1.1.3 Shape. Moving pointer knobs should be bar-shaped with parallel sides and their index end tapered to a point.

5.1.4.1.1.1.3.1 Exception. Exceptions may be made when pointer knobs are shape coded or when space is restricted and torque is light.

5.1.4.1.1.1.3.2 Shape coding. 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.

5.1.4.1.1.1.4 Positions. A rotary selector switch that is not visible to the user during normal system operation shall have no more than 12 positions.

5.1.4.1.1.1.4.1 Rotary switch always visible to user. A rotary switch that is constantly visible to the user shall have not more than 24 positions.

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

5.1.4.1.1.1.4.3 Switch resistance. Switch resistance shall be elastic, build up, then decrease as each position is approached so that the control snaps into position without stopping between adjacent positions.

5.1.4.1.1.1.5 Contrast ratio. A reference line shall be provided on rotary switch controls. The luminance contrast ratio of this line shall be not less than 3:1 under all lighting conditions.

5.1.4.1.1.1.6 Parallax. The knob pointer shall be mounted sufficiently close to its scale to minimize parallax between the pointer and the scale markings.

5.1.4.1.1.1.7 Parallax error. When viewed from the normal user's position, the parallax errors shall not exceed 25 percent of the distance between scale markings.

5.1.4.1.1.1.8 Attachment. Rotary selector switch shafts and knobs shall be designed only for intended installation orientation.

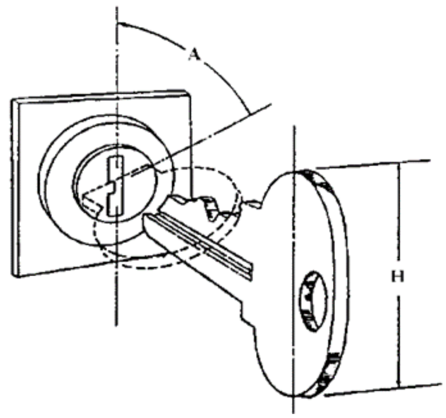
5.1.4.1.1.1.9 Knob mounting. The rotary selector knob attachment shall preclude the possibility of the knob slipping on the shaft and the knob being replaced with the pointing end opposite from its correct position.

5.1.4.1.1.1.10 Dimensions, resistance, displacement, and separation. Rotary selector switch dimensions, resistance, displacement, and separation between adjacent edges of areas swept by rotary selector switches shall conform to the criteria on figure 6.

5.1.4.1.1.2 Key-operated switches (KOS).

5.1.4.1.1.2.1 Use. Where security is a higher priority than speed of control actuation, a KOS may be used to prevent unauthorized operation. Ordinarily, a KOS control system operates by go/no-go.

5.1.4.1.1.2.2 Dimensions, displacement, and resistance. Dimensions, displacement, and resistance of KOS shall conform to the criteria on figure 7.



	A, Displacement	H, Height	Resistance
Minimum	30° (525 mrad)	13 mm (0.5 in)	115 mN·m (1 in-lbf)
Maximum	90° (1,570 mrad)	75 mm (3 in)	680 mN·m (6 in-lbf)

FIGURE 7. Key-operated switches (KOS) (single function).

5.1.4.1.1.2.3 Color, shape, and size coding. Color, shape, and size coding shall meet the criteria in 5.1.4.1.1.2.3.1 through 5.1.4.1.1.2.3.4.

5.1.4.1.1.2.3.1 Color coding. Color may be used to aid in identifying various keys by function or use location and, when illumination is bright enough, to differentiate the colors.

5.1.4.1.1.2.3.2 Color coding of emergency functions. Red (SAE AMS-STD-595/11105 or 21105) shall be reserved for emergency functions.

5.1.4.1.1.2.3.3 Shape coding. 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.

5.1.4.1.1.2.3.4 Size coding. Within the height limits of figure 7, size coding may also be used if no more than two sizes are employed.

5.1.4.1.1.2.4 Marking and labeling. Keylock switch applications shall include appropriate position markings and labels (see 5.4).

5.1.4.1.1.2.5 Multifunction, key-operated switches. The OFF position of multifunction KOSs shall be located at 300 degrees.

5.1.4.1.1.2.6 Total angular displacement. Total angular displacement of multifunction KOSs shall be not greater than 120 degrees.

5.1.4.1.1.2.7 Keys with teeth on both sides. Keys with teeth on both edges that fit the lock with either side up or forward are preferred.

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

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

5.1.4.1.1.2.10 Removal of key. Users shall not be able to remove the key from the lock unless the switch is turned OFF.

5.1.4.1.1.2.11 Actuation. Actuation of an item by a KOS shall be accomplished by turning the key clockwise from the vertical OFF position.

5.1.4.1.1.2.12 Vehicle lock systems. Lock systems used for vehicle exterior doors shall prevent users from inadvertently locking themselves out of the vehicle.

5.1.4.1.1.2.13 Waterproof. Keylocks exposed to external weather conditions shall be weatherproof.

5.1.4.1.1.2.14 Multiple keylock systems. When several keylock systems are required on the same vehicle or equipment and all locks must be accessible to the user, a single key and identical locks shall be used.

5.1.4.1.1.2.15 Limited access. When access to certain closures must be limited to people other than the user, different keylock assemblies shall be used so that the user's key will not unlock these special locks.

5.1.4.1.1.2.16 Auditory signal. An auditory signal shall be provided for vehicle ignition keylock systems to advise the user that the key has been left in the ignition lock after the engine has been shut off.

5.1.4.1.1.3 Discrete thumbwheel controls. Discrete thumbwheel controls shall meet the criteria in 5.1.4.1.1.3.1 through 5.1.4.1.1.3.11.2.

5.1.4.1.1.3.1 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.

5.1.4.1.1.3.2 Indexing. Detent indexing units shall provide 10 positions (0 to 9).

5.1.4.1.1.3.3 Shape. Each position around the circumference of a discrete thumbwheel shall have a segmented or scalloped concave surface or shall be separated by a high-friction area that is raised from the periphery of the thumbwheel.

5.1.4.1.1.3.4 Visibility of digits. The thumbwheels shall not preclude viewing the digits within a 30-degree viewing angle to the left and right of a line perpendicular to the thumbwheel digits.

5.1.4.1.1.3.5 Coding. Thumbwheel controls may be coded by location, labeling, or 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 shall be color coded to permit a visual check that the digits have been reset to their OFF or normal positions.

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

5.1.4.1.1.3.7 Internal illumination. Where ambient illumination provides display brightness below 3.5 candelas per meter squared (cd/m²) (1 footlamberts [fL]), the thumbwheel characters shall be internally illuminated, appear against a black background, and have dimensions approximating the following criteria:

a. Height = 4.8 mm (0.1875 in)

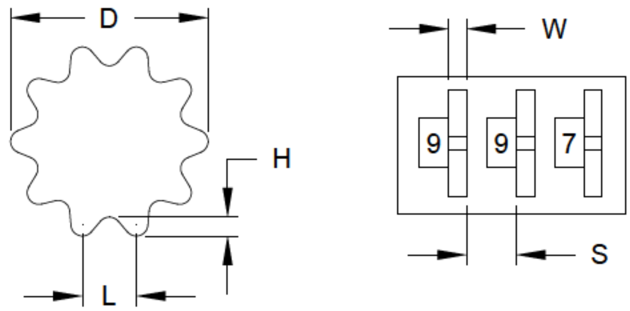
b. Height-to-width ratio = 3:2

c. Height-to-stroke width ratio = 10:1

5.1.4.1.1.3.8 External illumination. Characters that are externally illuminated shall be bold and black engraved on a light (or white) thumbwheel background with dimensions in accordance with 5.1.4.1.1.3.7, except that the height-to-stroke-width ratio shall be approximately 5:1.

5.1.4.1.1.3.9 Visibility. Thumbwheel design shall permit viewing of inline digital readout from all user positions.

5.1.4.1.1.3.10 Dimensions. Discrete thumbwheel control dimensions shall conform to the criteria on figure 8.



	D, Diameter	L, Trough Distance	W, Width	H, Depth	S, Separation	Resistance
Minimum	29 mm (1.125 in)	11 mm (0.43 in)	3 mm (0.125 in)	3 mm (0.125 in)	10 mm (0.4 in)	1.7 N (6 oz)
Maximum	75 mm (3 in)	19 mm (0.75 in)	--	6 mm (0.25 in)	--	5.6 N (20 oz)

FIGURE 8. Discrete thumbwheel control.

5.1.4.1.1.3.11 Resistance. Detents shall be provided for discrete position thumbwheels.

5.1.4.1.1.3.11.1 Elastic. Resistance shall be elastic, build up, and then decrease as each detent is approached so that the control snaps into position without stopping between adjacent detents.

5.1.4.1.1.3.11.2 Separation. The separation between adjacent edges of thumbwheel controls shall conform to the criteria on figure 8. Separation shall be sufficient to preclude accidental actuation of adjacent controls during normal control operation.

5.1.4.1.2 Continuous adjustment rotary controls.

5.1.4.1.2.1 Knobs. Knob design shall meet the criteria in 5.1.4.1.2.1.1 through 5.1.4.1.2.1.7.3.

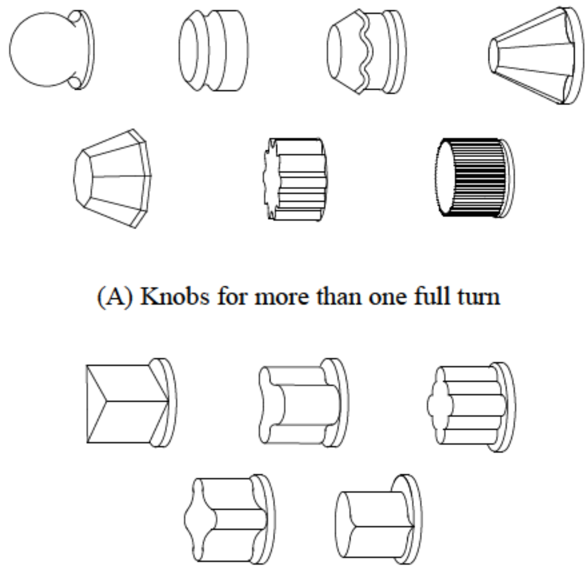
5.1.4.1.2.1.1 Use. Knobs should be used when low forces or precise adjustments of a continuous variable are required. For most tasks, a moving knob with fixed scale should be used instead of a moving scale with fixed index. Special knob designs consisting of a bar-type knob and open-window skirt may be used for applications in which visual confusion may be reduced by exposing only one number of a scale at a time. Handle-like rotary controls may be used for special applications (i.e., a motorcycle accelerator control).

5.1.4.1.2.1.2 Single revolution controls. If positions of single revolution controls must be distinguished, a pointer or marker shall be available on the knob.

5.1.4.1.2.1.3 Shapes. Knobs that perform the same function shall have the same shape.

5.1.4.1.2.1.3.1 Knob function. Knob shape shall be determined by the knob's function and use.

5.1.4.1.2.1.3.2 Representative knob shapes. Representative knob shapes are shown on figure 9.



(A) Knobs for more than one full turn

(B) Knobs for less than one full turn

FIGURE 9. Recommended knob shapes.

5.1.4.1.2.1.4 Rims. All rotary adjustment knobs shall have rims with surfaces capable of obtaining a secure grasp.

5.1.4.1.2.1.4.1 Knurled surfaces. Very small knobs shall have knurled surfaces to provide maximum torqueing capability.

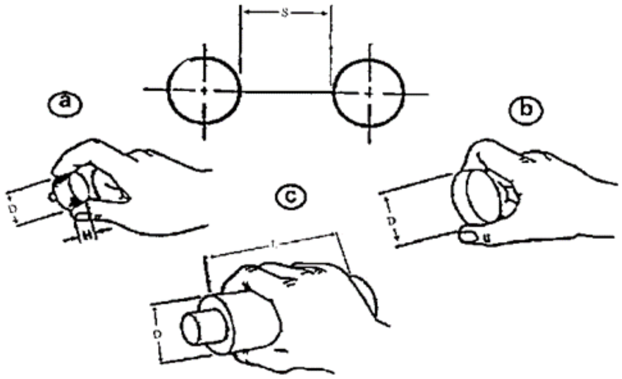
5.1.4.1.2.1.4.2 Serrated rims. Intermediate and larger size knobs shall have serrated rims for low torque applications.

5.1.4.1.2.1.4.3 Rim identification. Intermediate and larger size knobs shall have rim indentation rather than serration for a firmer grasp for high torque applications.

5.1.4.1.2.1.5 Contact hazard. When knobs are used in vehicles and are located where they could be contacted during the sudden deceleration of a crash, frontal surface area shall be large.

5.1.4.1.2.1.6 Rounded edges. All edges shall be rounded in order to minimize the potential injuries associated with small, sharp knob designs.

5.1.4.1.2.1.7 Dimensions, torque, and separation. The dimensions of knobs shall be within the limits specified on figure 10. Within these ranges, knob size is relatively unimportant, provided the resistance is low and the knob can be easily grasped and manipulated.



	Dimensions					
	A, Fingertip Grasp		B, Thumb and Finger Encircled		C, Palm Grasps	
	H, Height	D, Diameter	H, Height	D, Diameter	D, Diameter	L, Length
Minimum	13 mm (0.5 in)	10 mm (0.4 in)	13 mm (0.5 in)	25 mm (1 in)	38 mm (1.5 in)	75 mm (3 in)
Maximum	25 mm (1 in)	100 mm (4in)	25 mm (1 in)	75 mm (3 in)	75 mm (3 in)	--

	Torque		Separation	
	≤25 mm (1 in) Diameter Knobs	>25 mm (1 in) Diameter Knobs	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 (4.5 in-ozf)	42 mN·m (6 in–ozf)	--	--

FIGURE 10. Knobs.

5.1.4.1.2.1.7.1 Limited panel space. When panel space is extremely limited, knobs shall approximate the minimum values on figure 10.

5.1.4.1.2.1.7.2 Low resistance. Knobs shall have resistance as low as possible without permitting the setting to be changed by vibration or merely touching the control.

5.1.4.1.2.1.7.3 Resistance and separation. Resistance and separation between adjacent edges of knobs shall conform to figure 10.

5.1.4.1.2.2 Ganged control knobs. Ganged control knobs shall meet the criteria in 5.1.4.1.2.2.1 through 5.1.4.1.2.2.8.2.

5.1.4.1.2.2.1 Application. Ganged knob assemblies may be used in limited applications when panel space is at a premium. Two-knob assemblies should be used in preference over three-knob or four-knob assemblies. Three-knob configurations should be avoided. Ganged knob configurations should not be used under the following conditions:

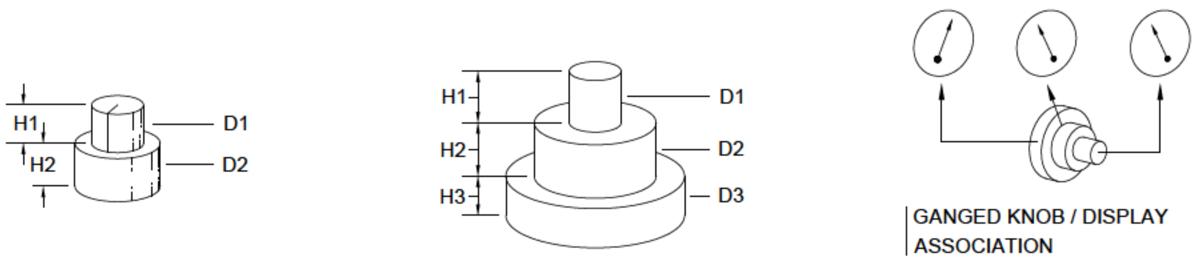
a. Extremely accurate or rapid operations are required.

b. Frequent changes are necessary.

c. Heavy gloves must be worn by the user.

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

5.1.4.1.2.2.2 Dimensions and separation. Dimensions and separation shall conform to figure 11.



	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 (0.63 in)	13 mm (0.5 in)	13 mm (0.5 in)	22 mm (0.88 in)	19 mm (0.75 in)	19 mm (0.75 in)	6.0 mm (0.25 in)	13 mm (0.5 in)	44 mm (1.76 in)	75 mm (3 in)
Maximum				100 mm (4.0 in)						100 mm (4.0 in)

	Torque		Separation			
	≤25 mm (1 in) Diameter Knobs	>25 mm (1 in) Diameter Knobs	One Hand Individually		Two Hands Simultaneously	
			Bare	Gloved	Bare	Gloved
Minimum	--	--	25 mm (1 in)	63 mm (2.5 in)	50 mm (2 in)	90 mm (3.5 in)
Optimum	--	--	50 mm (2 in)	90 mm (3.5 in)	75 mm (3 in)	100 mm (4 in)
Maximum	32 mN·m (4.5 in-ozf)	42 mN·m (6 in-ozf)	--	--	--	--

FIGURE 11. Ganged knobs.

5.1.4.1.2.2.3 Resistance. Resistance shall conform to the requirements on figure 11.

5.1.4.1.2.2.4 Serration. Knobs shall be serrated. Fine serrations shall be used on precise adjustment knobs. Coarse serrations shall be used on gross adjustment knobs.

5.1.4.1.2.2.5 Marking. An indexing mark or pointer shall be provided on each knob.

5.1.4.1.2.2.6 Indexing marks. Marks or pointers shall differ sufficiently to make it apparent which knob indexing mark is being observed.

5.1.4.1.2.2.7 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 11).

5.1.4.1.2.2.8 Inadvertent operation. When it is critical to prevent inadvertent operation of one knob as the other is being adjusted, a secondary knob control action shall be required (e.g., pressing the top knob before it can be engaged with its control shaft).

5.1.4.1.2.2.8.1 Inadvertent movement not critical. Where inadvertent movement is undesirable but not critical, knob diameter/depth relationships shall be optimized as shown on figure 11.

5.1.4.1.2.2.8.2 Contrasting colors. Contrasting colors between knobs may be used to improve knob identification.

5.1.4.1.2.3 Continuous adjustment thumbwheel controls. 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.

5.1.4.1.2.3.1 Orientation and movement. Thumbwheels shall be oriented and move in the directions specified on figure 12. If a thumbwheel is used to affect vehicle motion, movement of the thumbwheel forward or up shall cause the vehicle to move down or forward.

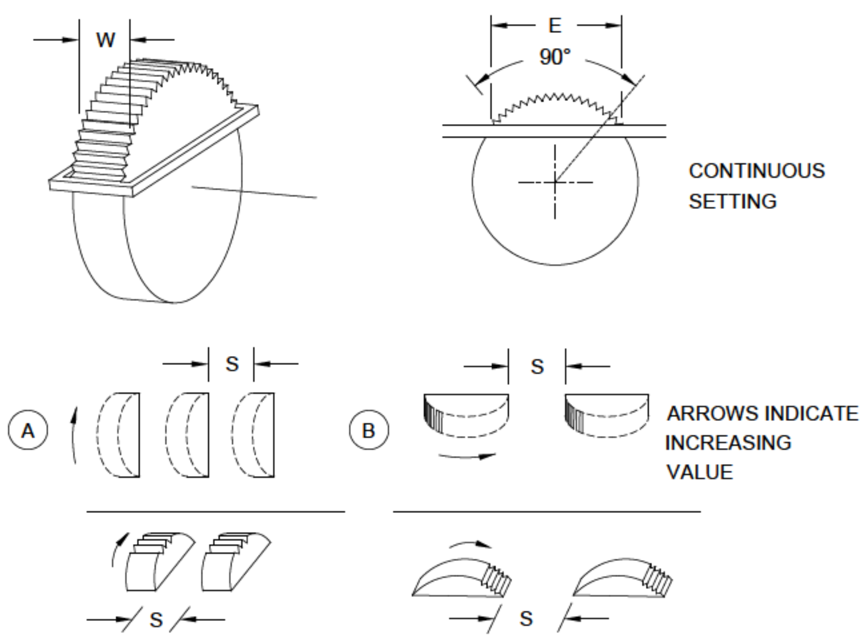


FIGURE 12. Continuous adjustment thumbwheel.

	E, Rim Exposure	W, Width	S		Resistance
			A	B	
Minimum	25 mm [1/] (1 in)	3 mm [1/] (0.125 in)	25 mm (1 in), add 13 mm (0.5 in) for gloves	50 mm (2 in), add 25 mm (1 in) for gloves	To minimize effects of inadvertent input if user subject to motion
Maximum	100 mm (4 in)	23 mm (0.875 in)	N/A	N/A	3.3 N (12 oz)

NOTE:
[1/] Preferred; some miniature applications may require less.

FIGURE 12. Continuous adjustment thumbwheel – Continued.

5.1.4.1.2.3.2 Turning aids. The rim of a thumbwheel shall be serrated or provided with a high friction surface to aid the user in manipulating the control.

5.1.4.1.2.3.3 Dimensions, separation, and resistance. Dimensions, separation, and resistance shall conform to criteria on figure 12.

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

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

5.1.4.1.2.4 Cranks. Cranks shall meet the criteria in 5.1.4.1.2.4.1 through 5.1.4.1.2.4.10.

5.1.4.1.2.4.1 Use. Cranks should be used in the scenarios of 5.1.4.1.2.4.1.1 and 5.1.4.1.2.4.1.2.

5.1.4.1.2.4.1.1 Tasks requiring many rotations. Cranks should be used for tasks that require many rotations of a control, particularly where high rates or large forces are involved.

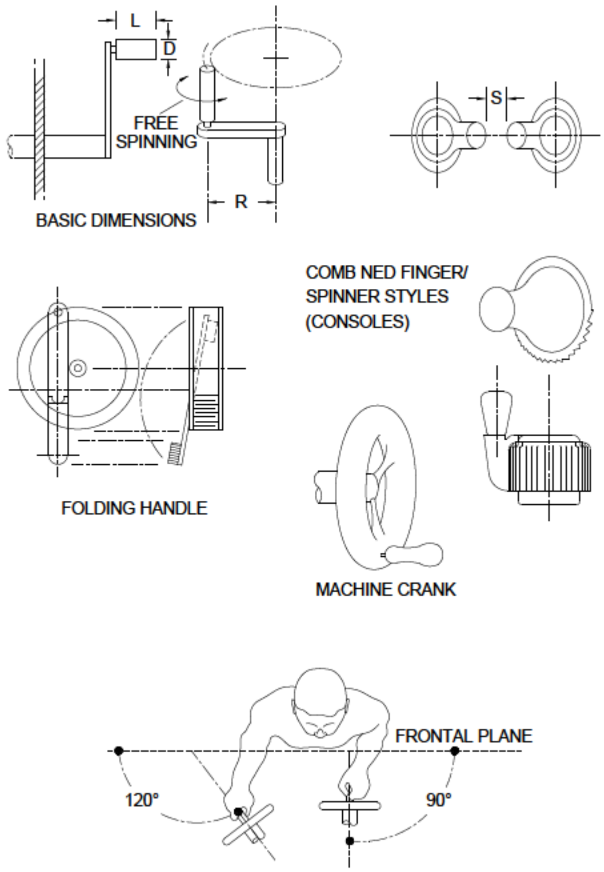
5.1.4.1.2.4.1.2 Large slewing movements. For tasks that involve large slewing movements plus small fine adjustments, a crank handle may be mounted on a knob or handwheel; the crank should be used for slewing and the knob or handwheel for fine adjustments.

5.1.4.1.2.4.2 Cranks used for tuning. Where cranks are used for tuning or other processes involving numerical selection, each rotation shall correspond to a multiple of 1, 10, 100, and so forth.

5.1.4.1.2.4.3 Simultaneously operated hand cranks. Simultaneously operated hand cranks shall be used in preference to other two-axis controllers where extreme precision is required in setting crosshairs or reticles, as in map readouts or optical sighting mechanisms (as opposed to tracking). This type of control may also be used in other applications requiring x-y control provided there is no requirement for rapid or frequent operation.

5.1.4.1.2.4.4 Gear ratio. The gear ratio and dynamic characteristics of such cranks shall allow precise placement of the cursor (e.g., crosshairs) without overshooting, undershooting, or requiring successive corrective movements.

5.1.4.1.2.4.5 Positioning. Cranks that must be turned rapidly shall be mounted so their turning axes are between 60 and 90 degrees from the body's frontal plane (see figure 13).



		Handle		R, Turning Radius	
Loads	**Dimensions**	**L, Length**	**D, Diameter**	**Rate Below 100 RPM**	**Rate Above 100 RPM**
Light Loads <22 N (5 lb); Wrist & Finger Movement	Minimum	25 mm (1 in)	10 mm (0.4 in)	38 mm (1.5 in)	13 mm (0.5 in)
	Preferred	38 mm (1.5 in)	13 mm (0.5 in)	75 mm (3 in)	65 mm (2.5 in)
	Maximum	75 mm (3 in)	16 mm (0.625 in)	125 mm (5 in)	115 mm (4.5 in)
Heavy Loads ≥22 N (5 lb); Arm Movement	Minimum	75 mm (3 in)	25 mm (1 in)	190 mm (7.5 in)	125 mm (5 in)
	Preferred	95 mm (3.75 in)	25 mm (1 in)	--	--
	Maximum	--	38 mm (1.5 in)	510 mm (20 in)	230 mm (9 in)
NOTE: S, Separation between adjacent controls: 75 mm (3 in), minimum.					

FIGURE 13. Cranks.

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

5.1.4.1.2.4.7 Dimensions, resistance, and separation. Dimensions, resistance, and separation between adjacent swept circular areas of cranks shall conform to the criteria on figure 13.

5.1.4.1.2.4.8 Location. Cranks that are to be operated from a standing position shall be mounted between 900 and 1,200 mm (35 to 47 in) above the floor.

5.1.4.1.2.4.9 Folding handle. If a crank handle could become a hazard to persons passing by or if it is critical that the handle not be inadvertently displaced by being accidentally bumped, a folding handle-type control shall be used.

5.1.4.1.2.4.10 Spring-loaded handle. A folding handle shall be spring-loaded to keep it extended in the cranking position when in use and folded when not in use.

5.1.4.1.2.5 Handwheels (two-hand operated). Handwheels shall meet the criteria in 5.1.4.1.2.5.1 through 5.1.4.1.2.5.9.

5.1.4.1.2.5.1 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 and closing, and direct linkage adjustment.

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

5.1.4.1.2.5.3 Spinner handles. For applications where the wheel may be rotated rapidly through several revolutions, a spinner handle may be added, except where it is vulnerable to inadvertent displacement of a critical wheel setting or if it creates a safety hazard.

5.1.4.1.2.5.4 Direction of movement. Except for valves (see 5.1.1.2.5), handwheels shall rotate clockwise for ON or INCREASE and counterclockwise for OFF or DECREASE.

5.1.4.1.2.5.5 Direction of motion indication. The direction of motion shall be indicated on the handwheel or immediately adjacent thereto by means of arrow and appropriate legends.

5.1.4.1.2.5.6 Dimensions, resistance, displacement, and separation. Handwheel dimensions, resistance, displacement, and separation between edges of adjacent handwheels shall conform to the criteria in table IX.

TABLE IX. Handwheels.

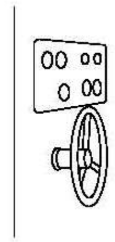
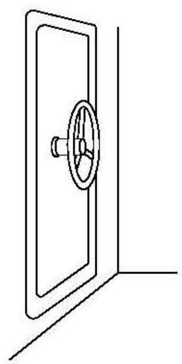
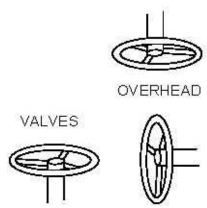
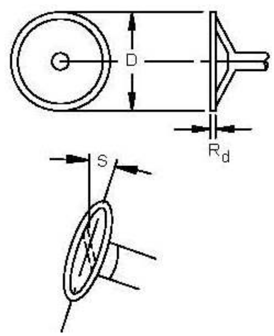
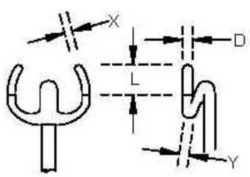
Configuration Example	Application Criteria	Design Criteria				
		Dimensions			Displacement	Separation
		Diameter	Rim Diameter	Minimum Hand Clearance		
	Continuous adjustment for alternate slewing/precise positioning using display reference. Resistance low (e.g., below 110 N [25 lb])	200 to 510 mm (8 to 20 in)	19 to 32 mm (0.75 to 1.125 in)	75 mm (3 in) around rim	See control/display ratios (5.1.2.4)	710 mm (28 in) elbow-elbow clearance
	Continuous lock-unlock operation	200 mm (8 in) for 22 N (5 lb) to 510 mm (20 in) for 155 N (35 lb)	19 to 32 mm (0.75 to 1.125 in)	75 mm (3 in) around rim	N/A	710 mm (28 in) elbow-elbow clearance
	High torque valves	200 to 400 mm (8 to 16 in) for overhead; 200 to 510 mm (8 to 20 in) for other positions; 300 to 1,520 mm (12 to 60 in) above standing surface	19 to 32 mm (0.75 to 1.125 in)	75 mm (3 in) around rim	See 5.14 when applicable	710 mm (28 in) elbow clearance, 100 to 150 mm (4 to 6 in) overhead valve rim-to-rim clearance

TABLE IX. Handwheels – Continued.

Configuration Example	**Application Criteria**	**Design Criteria**				
		Dimensions			**Displacement**	**Separation**
		Diameter	**Rim Diameter**	**Minimum Hand Clearance**		
	Vehicles steering (automotive) maximum resistance power steering Maximum non-power = 220 N (50 lb)	355 to 400 mm (14 to 16 in) for power steering 400 to 510 mm (16 to 20 in) for non-power steering	19 to 32 mm (0.75 to 1.125 in)	30° (525 mrad) for light vehicle (preferred) 45° (785 mrad) for heavy vehicle (preferred)	Max ±120° (2.1 radians) when both hands must remain on wheel	N/A
		D, grip diameter	L, grip length	X-Y, grip tilt		
	Aircraft steering (combine with lever for pitch, rudder pedals for roll/steer)	32 mm (1.125 in) preferred	100 mm (4 in) minimum	X = 15° (262 mrad) Y = 0 to 15° (0 to 262 mrad) preferred	±30° (525 mrad) max preferred	N/A

5.1.4.1.2.5.7 Steering wheel shape. All steering wheels shall be round, except for established uses in submarines, armored combat vehicles, aircraft, and other applications where maximum wheel deflection does not exceed 120 degrees.

5.1.4.1.2.5.8 Power steering failure. Steering systems shall provide sufficient mechanical advantage to meet the force requirements in table IX, even when the primary operating mode is power assisted (i.e., the user shall be able to steer the vehicle to a safe stop if power fails).

5.1.4.1.2.5.9 Steering ratio. Maximum turning limits of vehicles shall be achieved with not more than three and one half turns of the steering wheel if consistent with force limits of table IX.

5.1.4.2 Linear controls.

5.1.4.2.1 Discrete adjustment linear controls.

5.1.4.2.1.1 Push buttons (finger- or hand-operated). Push buttons shall meet the criteria in 5.1.4.2.1.1.1 through 5.1.4.2.1.1.7.

5.1.4.2.1.1.1 Use. Push buttons should be used when a control or an array of controls is needed for momentary contact or for actuating a locking circuit, particularly in high frequency-of-use situations. Push buttons should not be used for discrete control where the function's status is determined exclusively by a position of the switch (e.g., an on-off push button that is pressed in and retained to turn a circuit on and pressed again to release the push button and turn the circuit off).

5.1.4.2.1.1.2 Shape. The push button surface shall be concave (indented) to fit the finger.

5.1.4.2.1.1.2.1 Concave shape impractical. When a concave surface is impractical, the surface shall provide a high degree of frictional resistance.

5.1.4.2.1.1.2.2 Emergency stop. Large hand- or fist-operated, mushroom-shaped buttons shall be used only as EMERGENCY STOP controls.

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

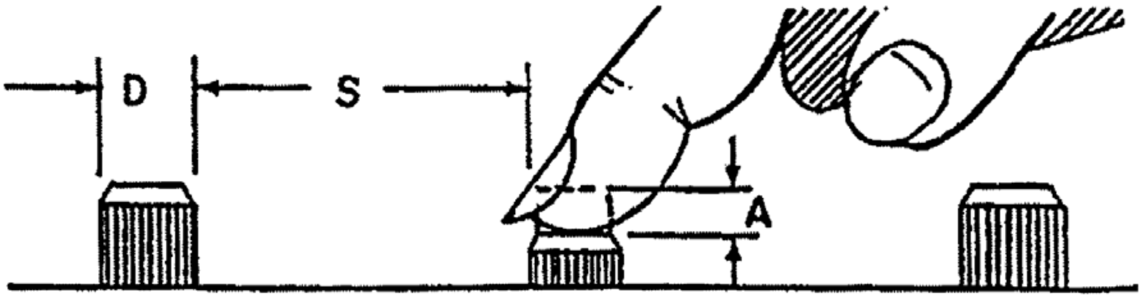
5.1.4.2.1.1.3.1 Tactile feedback. Tactile feedback shall be the primary form of positive indication.

5.1.4.2.1.1.3.2 Other means. Other means for positive indication (e.g., audible click, light) shall be used in addition to tactile feedback and in cases where tactile feedback is not possible.

5.1.4.2.1.1.4 Channel or cover guard. A channel or cover guard shall be provided when accidental actuation of the control must be prevented.

5.1.4.2.1.1.5 Interference. When a cover guard is in the open position, it shall not interfere with operation of the protected device or adjacent controls.

5.1.4.2.1.1.6 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 push buttons shall conform to the criteria on figure 14.



	Dimensions (D, Diameter)						Resistance		
	Fingertip		Thumb		Palm				
	Bare Hand	Gloved Hand 1/	Bare Hand	Gloved Hand 1/	Bare Hand	Gloved Hand 1/	Single Finger	Different Fingers 2/	Thumb or Palm
Minimum	10 mm (0.4 in)	19 mm (0.75 in)	19 mm (0.75 in)	25 mm (1 in)	40 mm (1.6 in)	50 mm (2 in)	2.8 N (10 oz)	1.4 N (5 oz)	2.8 N (10 oz)
Maximum	25 mm (1 in)	--	25 mm (1 in)	--	70 mm (2.8 in)	--	11 N (40 oz)	5.6 N (20 oz)	23 N (80 oz)

	A, Displacement	
	Fingertip	Thumb or Palm
Minimum	2 mm (0.08 in)	3 mm (0.12 in)
Maximum	6 mm (0.25 in)	38 mm (1.5 in)

	S, Separation				
	Single finger		Single Finger Sequential 3/	Different Finger 3/	Thumb or Palm 3/
	Bare	Gloved			
Minimum	13 mm (0.5 in)	25 mm (1 in)	6 mm (0.25 in)	6 mm (0.25 in)	25 mm (1 in)
Preferred	50 mm (2 in)	--	13 mm (0.5 in)	13 mm (0.5 in)	150 mm (6 in)

FOOTNOTES:

1/ For standard cotton flame-resistant anti-flash gloves (i.e., Navy flash gloves [as defined in MIL-G-2874]), add 5 mm (0.2 in) to Diameter (D) of bare hand dimension.

2/ Actuated at same time.

3/ Where gloved hand criteria are not provided, minimum shall be suitably adjusted.

NOTE: Figure 14 does not apply to keyboards (see 5.1.3.2).

FIGURE 14. Push button (finger- or hand-operated).

5.1.4.2.1.1.7 Interlocks or barriers. Mechanical interlocks or barriers may be used instead of the spacing required by figure 14.

5.1.4.2.1.2 Foot-operated controls.

5.1.4.2.1.2.1 Use. Foot-operated controls may be used under any of the following conditions (this list is not comprehensive):

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

b. The user'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 user expects such operating functions to be performed using foot controls (e.g., aircraft rudder/brake pedals, automotive clutch, brake, aircraft floor mike switches, and accelerator pedals).

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

5.1.4.2.1.2.2 Avoidance. Foot-operated controls shall not be used in any of the following conditions:

a. A standing user 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 many separate controls is required.

5.1.4.2.1.2.3 Operation. Foot controls shall be located and designed so they can be operated with natural user movements.

5.1.4.2.1.2.4 Foot control actions to avoid. Foot controls shall not require the user to do any of the following:

a. Perform frequent maximum reaching.

b. 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 user's principal operating orientation).

c. Search for a particular foot control in order to select the proper one.

d. Use a foot control located where it might be stepped on and inadvertently actuated.

e. Shift the foot from one control to another when the foot or clothing might be entrapped by an intervening control.

5.1.4.2.1.2.5 Configuration and placement. Configuration and placement of foot-operated controls shall accommodate the footwear for the user population.

5.1.4.2.1.2.6 Interference. Each foot-operated control shall be located so that actuating it by one foot does not interfere with actuating a control by the other foot.

5.1.4.2.1.2.7 Natural movements. Each foot-operated control shall be located so foot and leg movements are natural and easily accomplished within the workstation where the foot controls are located.

5.1.4.2.1.3 Foot-operated switches.

5.1.4.2.1.3.1 Use. Foot-operated switches should be used only where the user is likely to have both hands occupied when switch actuation may be required or when load sharing among limbs is desirable. Because foot-operated switches are susceptible to accidental actuation, their uses should be limited to non-critical or infrequent operations such as press-to-talk communication.

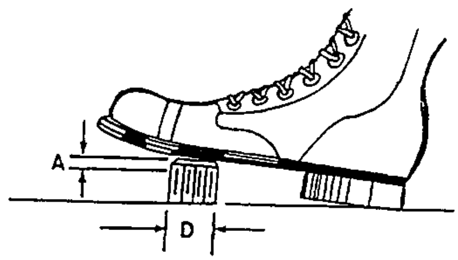
5.1.4.2.1.3.2 Operation. Foot-operated switches shall be positioned for actuation by the toe and the ball of the foot rather than by the heel.

5.1.4.2.1.3.2.1 Location. Foot-operated switches shall not be located so near an obstruction that the user cannot center the ball of the foot on the switch button.

5.1.4.2.1.3.2.2 Pedal. A pedal may be used over the button to aid in locating and operating the switch.

5.1.4.2.1.3.2.3 Frictional resistance. If the switch may become wet and slippery, the switch cap surface shall provide a high degree of frictional resistance.

5.1.4.2.1.3.3 Dimensions, resistance, and displacement. Dimensions, resistance, and displacement of foot-operated switches shall conform to the criteria on figure 15.



	D, Diameter	**Resistance**		**A, Displacement**			
		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 (0.5 in)	18 N (4 lb)	45 N (10 lb)	13 mm (0.5 in)	25 mm (1 in)	25 mm (1 in)	25 mm (1 in)
Maximum	--	90 N (20 lb)	90 N (20 lb)	65 mm (2.5 in)	65 mm (2.5 in)	65 mm (2.5 in)	100 mm (4 in)

FIGURE 15. Foot-operated switches.

5.1.4.2.1.3.4 More than one switch. While only one switch per foot is preferred, when one foot must be used to operate more than one switch, such switches shall be at least 75 mm (3 in) apart horizontally and 200 mm (8 in) apart vertically.

5.1.4.2.1.3.5 Feedback. A positive indication of control actuation shall be provided (e.g., snap feel, audible click, or associated visual or audio display).

5.1.4.2.1.4 Toggle switch controls. Toggle switches are discrete position controls. For small controls that are the same size and shape as toggle switches but used for making continuous adjustments, see 5.1.4.2.2.

5.1.4.2.1.4.1 Use. Toggle switches should be used where two discrete control positions are required or where space limitations are severe.

5.1.4.2.1.4.1.1 Three-position toggle switches. Toggle switches with three positions shall be used only where the use of a rotary control or legend switch control is not feasible or when the toggle switch is spring-loaded to a center-off position.

5.1.4.2.1.4.1.2 Spring-loaded from only one position. Three-position toggle switches 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.

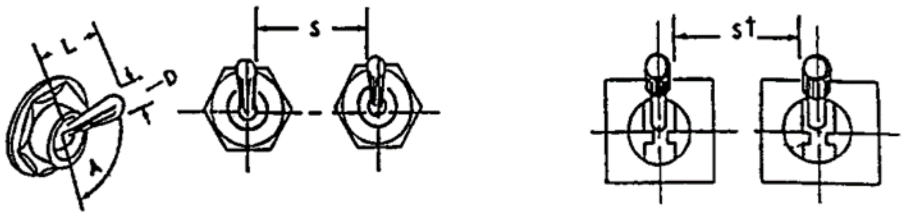
5.1.4.2.1.4.2 Accidental actuation. When preventing accidental actuation is important (i.e., critical or hazardous conditions would result), channel guards, lift-to-unlock switches, or other equivalent prevention mechanisms shall be provided.

5.1.4.2.1.4.2.1 Safety wire. Safety or lock wire shall not be used.

5.1.4.2.1.4.2.2 Resistance. Resistance of lift-to-unlock mechanisms shall not exceed 13 newtons (3 pounds-force).

5.1.4.2.1.4.2.3 Open cover guard. An open cover guard shall not interfere with the operation of the protected device or adjacent controls.

5.1.4.2.1.4.3 Dimensions, resistance, displacement, and separation. Dimensions, resistance, displacement, and separation between adjacent edges of toggle switches shall conform to figure 16. Resistance shall gradually increase then drop when the switch snaps into position.



	Dimensions			Resistance	
	Arm Length (L)		Control Tip (D)	Small Switch	Large Switch
	Use by Bare Finger	Use with Heavy Handwear			
Minimum	13 mm (0.5 in)	38 mm (1.5 in)	3 mm (0.125 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)

	A, Displacement Between Positions	
	Two Positions	Three Positions
Minimum	30° (525 mrad)	17° (300 mrad)
Maximum	80° (1,400 mrad)	40° (700 mrad)
Preferred	--	25° (435 mrad)

	Separation (S)			
	Single Finger Operation		Single Finger Sequential Operation	Simultaneous Operation by Different Fingers
	Normal	Lever Lock Switch		
Minimum	19 mm (0.75 in)	25 mm (1 in)	13 mm (0.5 in)	16 mm (0.625 in)
Optimum	50 mm (2.0 in)	50 mm (2 in)	25 mm (1 in)	19 mm (0.75 in)

FIGURE 16. Toggle switches.

5.1.4.2.1.4.4 Stop between positions. The switch shall not be capable of being stopped between positions.

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

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

5.1.4.2.1.5 Legend switches. Legend switches shall meet the criteria in 5.1.4.2.1.5.1 through 5.1.4.2.1.5.8.

5.1.4.2.1.5.1 Use. Legend switches are particularly well-suited to the conditions listed below:

a. To display qualitative information on an important system status that requires the user's attention.

b. To reduce demands for the user to interpret information.

c. When functional grouping or a matrix of control switches and indicators is required but space is very limited.

5.1.4.2.1.5.2 Characteristics. Characteristics of legend switches shall meet the criteria in 5.1.4.2.1.5.2.1 through 5.1.4.2.1.5.2.6.

5.1.4.2.1.5.2.1 Location. Legend switches should be located within a 30-degree cone (total included angle) along the user's normal line of sight. If the legend switch is placed outside this cone, it shall be oriented and positioned in such a manner that the legend can be read by the user without excessive or unnatural head movement.

5.1.4.2.1.5.2.2 Positive feedback. For positive feedback that the switch has operated, legend switches shall have a detent or a click.

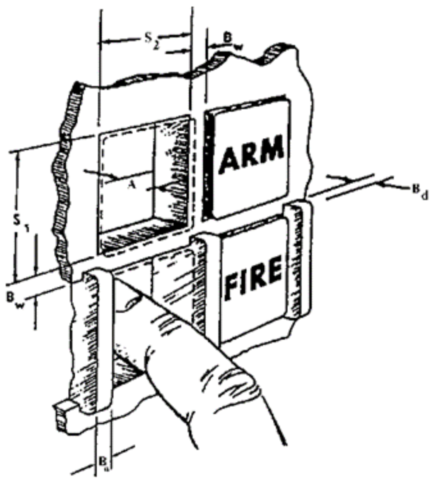
5.1.4.2.1.5.2.3 Lamp/light emitting diodes (LED) replacement. Legend switch lamps/LEDs shall be replaceable from the front of the panel.

5.1.4.2.1.5.2.4 Legibility. Legends shall be legible with or without internal illumination.

5.1.4.2.1.5.2.5 Lamp/LED test. If legend switches do not have duplicate bulbs, dual filament, or equivalent reliability, the legend switch circuit shall permit a positive test of the lamp or LED.

5.1.4.2.1.5.2.6 Lamp/LED reliability. A lamp or LED test or dual lamp/filament reliability shall be provided for switches if the mean time between failure is less than 100,000 hours.

5.1.4.2.1.5.3 Dimensions, resistance, displacement, and separation. Dimensions, resistance, displacement, and separation between adjacent edges of legend switches shall conform to the criteria on figure 17, except that maximum switch separation does not apply to non-matrix applications.



	Size (S_1 and S_2)		Barriers	
	Bare Hand	**Gloved Hand** 1/	**Width (Bw)** 2/	**Depth (Bd)**
Minimum	19 mm (0.75 in) 3/	25 mm (1 in)	3 mm (0.125 in)	5 mm (0.2 in)
Maximum	--	38 mm (1.5 in)	--	--

	Displacement		
	Standard Legend Switch	**Membrane/Tactile Legend Switch**	
		Dome Snap-Action Contact	**Conductive Membrane Contact**
Minimum	3 mm (0.125 in)	7 mm (0.3 in)	5 mm (0.02 in)
Maximum	6 mm (0.25 in)	1 mm (0.04 in)	1 mm (0.04 in)

	Resistance		
	Standard Legend Switch	**Membrane/Tactile Legend Switch**	
		Dome Snap-Action Contact	**Conductive Membrane Contact**
Minimum	2.8 N (10 oz) 4/	1.5 N (5 oz)	2 N (7 oz)
Maximum	11 N (40 oz)	2.5 N (9 oz)	3 N (11 oz)

NOTES:

1/ For standard cotton flame-resistant anti-flash gloves (i.e., Navy flash gloves [as defined in MIL-G-2874]), add 5 mm (0.2 in) to bare hand dimension for S1 and S2.

2/ Bw also refers to switch separation.

3/ 15 mm (0.65 in) where switch is not depressed below the panel.

4/ 5.6 N (20 oz) for use in moving vehicles.

FIGURE 17. Legend switches.

5.1.4.2.1.5.4 Barriers. Barriers shall meet the criteria in 5.1.4.2.1.5.4.1 through 5.1.4.2.1.5.4.4.

5.1.4.2.1.5.4.1 Barrier height. Barrier height from panel surface shall conform to figure 17.

5.1.4.2.1.5.4.2 Critical switches. Unless otherwise specified (see 6.2), barriers shall be provided on critical switches and on switches likely to be inadvertently actuated.

5.1.4.2.1.5.4.3 Visual access. When used, barriers shall not obscure visual access to controls, labels, or displays.

5.1.4.2.1.5.4.4 Rounded edges. Barriers shall have rounded edges.

5.1.4.2.1.5.5 Touch-sensitive switches. 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).

5.1.4.2.1.5.6 Keying covers. The legends or covers shall be keyed to prevent the possibility of interchanging the legend covers.

5.1.4.2.1.5.7 Legend plate. A legend plate shall not contain more than three lines of lettering.

5.1.4.2.1.5.8 Distinguishable from legend lights. Legend switches shall be distinguishable from legend lights.

5.1.4.2.1.6 Rocker switches. Rocker switches shall meet the criteria in 5.1.4.2.1.6.1 through 5.1.4.2.1.6.7.

5.1.4.2.1.6.1 Use. Rocker switches may be used in lieu of toggle switches for functions requiring two discrete positions. They may be used for applications where toggle switch handle protrusions might snag the user's sleeve or phone cord or where there is insufficient panel space for separate labeling of switch positions. Rocker switches with three positions should be used only where the use of a rotary control or legend switch control is not feasible or when the rocker switch is of the spring-loaded center-off type.

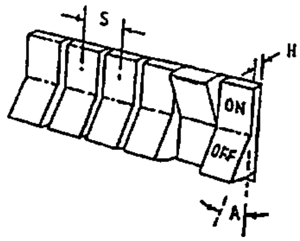
5.1.4.2.1.6.2 Accidental actuation. When accidental actuation must be prevented to avoid critical or hazardous conditions, channel guards or equivalent protection shall be provided.

5.1.4.2.1.6.3 Positive indication. Positive indication of control actuation and position shall be provided.

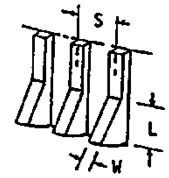
5.1.4.2.1.6.3.1 Physical indication. An indication of control actuation shall be provided (e.g., snap feel, audible click, associated, or integral light).

5.1.4.2.1.6.3.2 Label indication. A label indicating current switch position shall be provided (e.g., ON/OFF).

5.1.4.2.1.6.4 Dimensions, resistance, displacement, and separation. Dimensions, resistance, displacement, and separation between centers of rocker switches shall conform to figure 18.

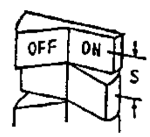


Standard rocker switch: use as alternate two-position toggle switch to provide labeling surface, ease of color coding, switch illumination.



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 (0.25 in)	13 mm (0.5 in)	2.8 N (10 oz)
Maximum	--	--	11 N (40 oz)

	Displacement		**Separation (Center-to-Center)**	
	H, Depressed	**A, Angle**	**S (Bare Hand)**	**S (Gloved Hand)**
Minimum	3 mm (0.125 in)	30° (530 mrad)	19 mm (0.75 in)	32 mm (1.125 in)

FIGURE 18. Rocker switches.

5.1.4.2.1.6.4.1 Resistance. Resistance shall gradually increase then drop when the switch snaps into position.

5.1.4.2.1.6.4.2 Stop between positions. The switch shall not be capable of being stopped between positions.

5.1.4.2.1.6.5 Orientation. Where practicable, rocker switches shall be vertically oriented.

5.1.4.2.1.6.5.1 Actuation. Actuation of the upper wing 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.

5.1.4.2.1.6.5.2 Horizontal orientation. Horizontal orientation of rocker switches shall be employed only for compatibility with the controlled function or equipment location.

5.1.4.2.1.6.6 Color and illumination. Alternate colors may be used to denote the ON and OFF portions of a rocker switch.

5.1.4.2.1.6.6.1 Alternate illumination. Alternate illumination of either the ON or OFF switch position may be used to facilitate positive recognition of current switch position.

5.1.4.2.1.6.6.2 Color coding. For other color coding requirements and guidelines, see 5.17.25.

5.1.4.2.1.6.6.3 Internal illumination. Where ambient illumination will provide display luminance below 3.5 cd/m² (1 fL), the rocker switch shall be internally illuminated.

5.1.4.2.1.6.6.4 Illuminated characters. Digits and letters shall appear as illuminated characters on an opaque background.

5.1.4.2.1.6.7 Character dimensions. The character dimensions shall approximate the following criteria:

a. Height: 4.8 mm (0.1875 in)

b. Height-to-width ratio: 3:2

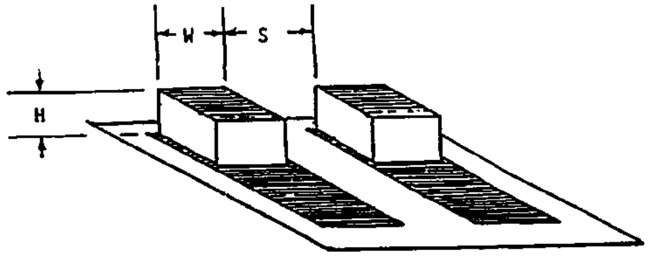
c. Height-to-stroke-width ratio: 10:1

5.1.4.2.1.7 Slide switch controls. Slide switch controls shall meet the criteria of 5.1.4.2.1.7.1 through 5.1.4.2.1.7.6.

5.1.4.2.1.7.1 Use. Slide switch controls may be used for functions that require two discrete positions. Slide switch controls may also be used for functions that require a higher number of discrete positions in which the switches are arranged in a matrix to permit easy recognition of relative switch settings (e.g., audio settings across frequencies). Slide switch controls with more than two discrete positions should not be used where inadvertently selecting the wrong position has serious consequences.

5.1.4.2.1.7.2 Accidental actuation. When accidental actuation must be prevented to avoid critical or hazardous conditions, perimeter guards or equivalent protection (see 5.1.1.7) shall be provided.

5.1.4.2.1.7.3 Dimensions, resistance, and separation. Dimensions, resistance, and separation of slide switch handles shall conform to criteria on figure 19.



	Dimensions			Resistance	
	H, Actuator Height		W, Actuator Width	Small Switch	Large Switch
	Use by Bare Finger	Use with Heavy Handwear			
Minimum	6 mm (0.25 in)	13 mm (0.5 in)	6 mm (0.25 in)	2.8 N (10 oz)	2.8 N (10 oz)
Maximum	--	--	25 mm (1 in)	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 (0.75 in)	13 mm (0.5 in)	16 mm (0.625 in)
Optimum	50 mm (2 in)	25 mm (1 in)	19 mm (0.75 in)

FIGURE 19. Slide switches.

5.1.4.2.1.7.3.1 Detents. Detents shall be provided for each control setting.

5.1.4.2.1.7.3.2 Resistance. Resistance shall gradually increase then drop when the switch snaps into position.

5.1.4.2.1.7.3.3 Stop between positions. The switch shall not be capable of stopping between positions.

5.1.4.2.1.7.4 Orientation. Slide switches shall be vertically oriented with movement of the slide up or away from the user 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.

5.1.4.2.1.7.5 Horizontal orientation. Horizontally oriented or actuated slide switches shall be used only for compatibility with the controlled function or equipment location.

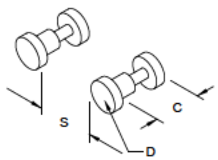
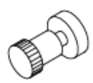
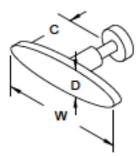
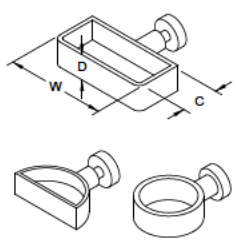
5.1.4.2.1.7.6 Positive indication. Slide switches with more than two positions shall provide positive indication of control setting, preferably a pointer located on the left side of the slide handle.

5.1.4.2.1.8 Discrete push-pull controls. Discrete push-pull controls shall meet the criteria in 5.1.4.2.1.8.1 through 5.1.4.2.1.8.8.

5.1.4.2.1.8.1 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. Push-pull controls may 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 television monitor). A three-position push-pull control should be used only where inadvertently selecting the wrong position has no serious consequences (e.g., vehicle headlight controls – OFF/PARK/HEADLIGHT – with integrated rotary panel light and dome light switches).

5.1.4.2.1.8.2 Handle dimensions, displacement, and clearances. Push-pull control handles shall conform to the criteria in table X.

TABLE X. Push-pull controls.

Configuration Example	Application Criteria	Design Criteria				
		Dimensions			Displacement	Separation
	Push-pull control, low resistance, for two-position, mechanical or electrical systems. Alternate three-position plus rotary function acceptance for application such as vehicle headlight plus parking lights, panel, and dome lights provide serrated rim.	D, minimum diameter: 19 mm (0.75 in).	C, minimum clearance: 25 mm (1 in). Add 13 mm (0.5 in) for gloved hand.	--	25±13 mm (1±0.5 in). Minimum between pull positions: 13 mm (0.5 in).	S, minimum space between: 35 mm (1.5 in). Add 13 mm (0.5 in) for gloved hand.
	Alternate handle; miniature electrical panel switch only. Avoid glove use application.	D, minimum diameter: 6 mm (0.25 in).	--	L, minimum length: 19 mm (0.75 in).	Minimum: 13 mm (0.5 in).	S, minimum space between: 25 mm (1 in).
	High-force push-pull for two-position mechanical system only.	W, minimum width: 100 mm (4 in).	D, depth: 16-38 mm (0.625-1.5 in).	C, minimum clearance: 38 mm (1.5 in). Add 6 mm (0.25 in) for gloved hand.	Minimum: 25 mm (1 in). Preferred: 50 mm (2 in).	--
	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, minimum width: 100 mm (4 in). Add 25 mm (1 in) for gloves.	D, depth: 16-32 mm (0.625-1.25 in).	C, minimum clearance: 32 mm (1.25 in).	Minimum: 25 mm (1 in). Preferred: 50 mm (2 in).	S, minimum space between: 13 mm (0.5 in).

5.1.4.2.1.8.3 Rotation. Except for combination push-pull/rotate switch configurations (e.g., the handle is rotated to disengage the brake setting), push-pull control handles shall be keyed to a non-rotating shaft.

5.1.4.2.1.8.4 Combination push-pull operation. 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.

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

5.1.4.2.1.8.6 Snagging and inadvertent contact. Use, location, and operating axis of push-pull type controls shall preclude the possibility of the user accidentally doing any of the following:

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

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

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

5.1.4.2.1.8.7 Direction of control motion. A pull towards the user shall produce ON or activate. A push away from the user shall correspond to OFF or deactivate. A rotation clockwise shall activate or increase the function of combination push-pull/rotary switches.

5.1.4.2.1.8.8 Resistance. Force for pulling a panel control with fingers shall be not more than 18 newtons (4 pounds-force). Force for pulling a T-bar with four fingers shall be not more than 45 newtons (10 pounds-force).

5.1.4.2.1.9 Printed circuit (PC) switch controls. PC switch controls shall meet the criteria in 5.1.4.2.1.9.1 through 5.1.4.2.1.9.7.

5.1.4.2.1.9.1 Use. PC “dual in-line package”-type switches or hand-selected jumpers should be installed only for settings that require infrequent changes.

5.1.4.2.1.9.2 Dimensions, resistance, displacement, and separation. PC switch controls shall meet the criteria in 5.1.4.2.1.9.2.1 through 5.1.4.2.1.9.2.6.

5.1.4.2.1.9.2.1 Inadvertent actuation. Resistance shall be sufficiently high to avoid inadvertent actuation under expected use conditions.

5.1.4.2.1.9.2.2 Resistance. Resistance shall gradually increase then drop when the actuator snaps into position.

5.1.4.2.1.9.2.3 Stop between positions. The actuator shall not be capable of stopping between positions.

5.1.4.2.1.9.2.4 Recognition of switch setting. Slide-type actuators shall have sufficient travel (displacement) to permit immediate recognition of the switch setting.

5.1.4.2.1.9.2.5 Switch travel. The travel shall be not less than twice the actuator length.

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

5.1.4.2.1.9.3 Rocker-type actuators. When actuators are rocker-type, the actuated wing shall be flush with the surface of the module.

5.1.4.2.1.9.4 Error-free manipulation. Actuators shall be large enough to permit error-free manipulation by the user when using commonly available styluses (e.g., pencil or pen).

5.1.4.2.1.9.5 Special tools. The actuators shall not require the use of a special tool for manipulation.

5.1.4.2.1.9.6 Actuator surface. The surface of the actuator shall be indented to accept the point of the stylus.

5.1.4.2.1.9.7 Indentation depth. The indentation shall be deep enough to avoid slippage of the stylus during manipulation.

5.1.4.2.2 Continuous adjustment linear controls.

5.1.4.2.2.1 Levers.

5.1.4.2.2.1.1 Use. Levers may be used when high forces or large displacements are involved or when multidimensional movements of controls are required.

5.1.4.2.2.1.2 Coding. When several levers are grouped near each other, the lever handles shall be coded.

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

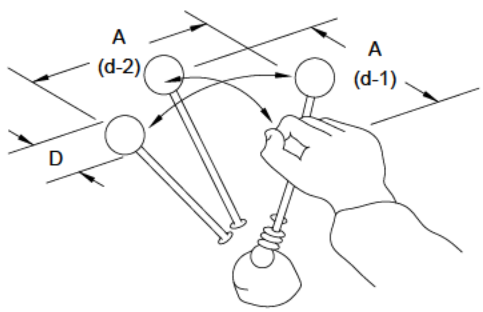
5.1.4.2.2.1.4 Limb support. When levers are used to make fine or continuous adjustments, support shall be provided for the appropriate limb segment as follows:

a. For large hand movements – elbow.

b. For small hand movements – forearm.

c. For finger movements – wrist.

5.1.4.2.2.1.5 Dimensions. The length of levers shall be determined by the mechanical advantage needed. The diameter of spherical lever or grip handles shall conform to the criteria on figure 20 and table XI.



	Diameter		Resistance			
	D		(d-1)		(d-2)	
	Finger Grasp	**Hand Grasp**	**One Hand**	**Two Hands**	**One Hand**	**Two Hands**
Minimum	13 mm (0.5 in)	38 mm (1.5 in)	9.0 N (2 lb)	9.0 N (2 lb)	9.0 N (2 lb)	9.0 N (2 lb)
Maximum	38 mm (1.5 in)	75 mm (3 in)	135 N (30 lb)	220 N (50 lb)	90 N (20 lb)	135 N (30 lb)

	A, Displacement		Separation	
	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 20. Levers.

TABLE XI. Levers.

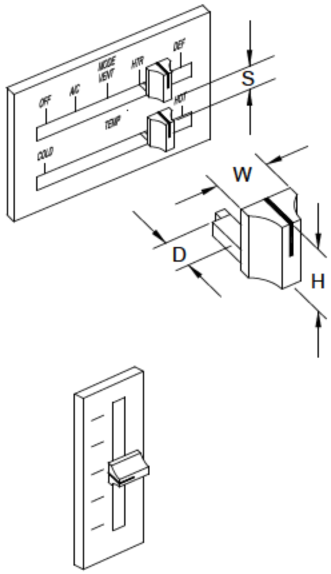
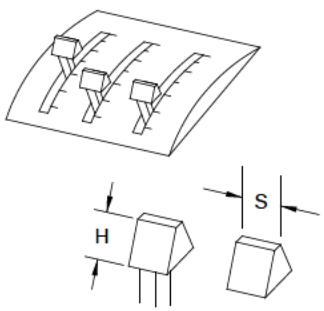
Configuration Example	Application Guidelines	Dimensions			Separation	Displacement
	Slide-levers may be used for low-force, continuous-adjustment, or gross-mode selection (do not use for precise setting).	--	--	--	S, minimum: 19 mm (0.75 in) (25 mm [1.0 in] with gloves)	--
	Handles shall be “tab-shaped” with long dimension perpendicular to motion axis (to serve as a pointer).	D, minimum: 13 mm (0.5 in) (19 mm [0.75 in] with gloves)	W, minimum: 6.5 mm (0.25 in)	H, minimum: 16 mm (0.63 in)		
	Movement axis may be up-down, lateral, or fore-aft. Functional increase shall be: -Up -Right -Forward	--	--	--		
	Banked, slide-lever assemblies may be used for electrically- or mechanically-connected selector or adjustment functions to provide rapid visual check of related settings. NOTE: Resistance for above control types shall be: Min: 2.8 N (10 oz) Max: 110 N (25 lb)	D, minimum: 13 mm (0.5 in) (19 mm [0.75 in] with gloves)	W, minimum: 6.5 mm (0.25 in)	H, minimum: 16 mm (0.63 in)	S, minimum: 19 mm (0.75 in) (25 mm [1.0 in] with gloves)	--

TABLE XI. Levers – Continued.

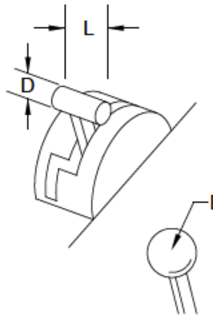
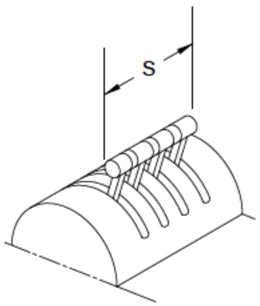
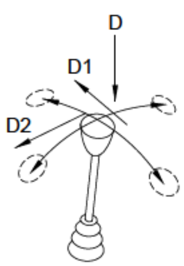
Configuration Example	**Application Guidelines**	**Dimensions**			**Separation**	**Displacement**
	Throttle levers: Handgrip may be either cylindrical or spherical.	D, minimum: 19 mm (0.75 in); maximum: 28 mm (1.1 in). D1: 38±6 mm (1.5±0.25 in)	L, minimum: 65 mm (2.5 in)	--	Finger clearance all sides, minimum 50 mm (2 in)	--
	Multi-engine throttle assembly: NOTE: When thrust reverse is incorporated, the design shall include a separate manipulative motion (lift + aft lever movement).	--	--	--	S, typical 100 mm (4 in), not to exceed 125 mm (5.0 in)	--
	Gear-shift lever: Manual transmission: Locate for right-hand operation. Resistance: approximately 9.0 to 13 N (32 to 47 oz)	D, knob diameter: 32 mm (1.25 in)	--	--	--	D1 and D2 between discrete positions: minimum 125 mm (5 in), maximum 200 mm (8 in)

TABLE XI. Levers – Continued.

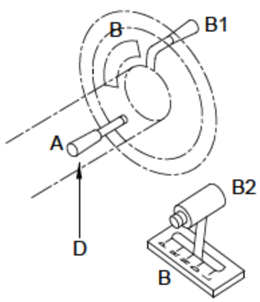
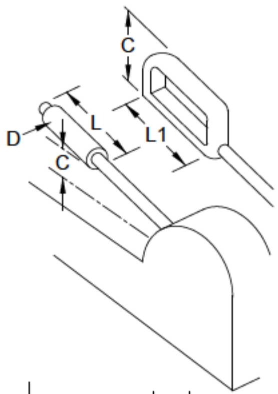
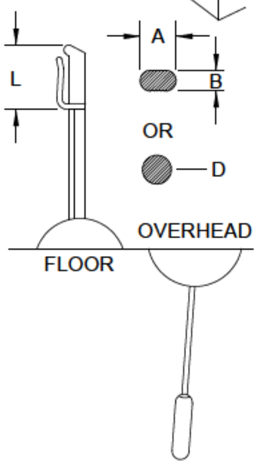
Configuration Example	**Application Guidelines**	**Dimensions**			**Separation**	**Displacement**
	Automatic transmission: (B1 preferred; B2 acceptable). Detented positions required* A. Other functions: 1. Turn signal: rotate about column; CW: right turn, CCW: left turn. 2. Headlight dimming; lever moves toward bottom of column for "dim". B. Letters shall illuminate to indicate position of lever. Resistance: approximately 4.5 to 45 N (16 oz to 10 lb). *It shall be impossible to leave gear lever between positions. Separate motion required to position lever in reverse (lift or press thumb button).	D, handle diameter 19 to 32 mm (0.75 to 1.25 in) if cylindrical. 25 to 32 mm (1.0 to 1.25 in) if spherical.	--	--	Finger clearance between levers and wheel rim: minimum 50 mm (2 in)	Gear shift minimum between positions: B1: 25 mm (1.0 in) B2: 38 mm (1.5 in)
						25 to 50 mm (1.09 to 2.0 in) between detents recommended.

TABLE XI. Levers – Continued.

Configuration Example	Application Guidelines	Dimensions			Separation	Displacement
 	Hand brake, with thumb-button release L1-Loop handle acceptable	D, diameter: 25 to 32 mm (1.0 to 1.25 in)	L, length, minimum: 100 mm (4 in) L, length, minimum: 115 mm (4.5 in)	C, clearance, minimum: 50 mm (2 in)	Minimum: 65 mm (2.5 in) all sides of handle	Nominal: 100 to 125 mm (4 to 5 in)
 	High-force levers: Center of handle shall be approximately 230 to 255 mm (9 to 10 in) laterally from user centerline at elbow level. Provide clip-type release where applicable. Round or oval-shaped handle shall be used. Maximum resistance approximately 187 N (42 lb).	Max A × B = 38 × 25 mm (1.5 by 1.0 in) D: 38 to 45 mm (1.5 to 1.75 in) with clip lever. Maximum fore-aft span shall not exceed 75 mm (3 in).	L, length, minimum: 100 mm (4 in)	--	Minimum clearance: 50 mm (2 in) in front, 75 mm (3 in) either side	Maximum for seated user: 355 mm (14 in)

5.1.4.2.2.1.6 Resistance. Lever resistance shall be within the limits indicated on figure 20 measured as linear force applied to a point on the handle. While it is recognized that in most people the right hand can supply slightly more force than the left, the difference is not significant.

a. The same amount of push-pull force can be applied when the control is along the median plane of the body; when it is directly in front of the arm, 180 mm (7 in) from the median plane.

b. When the control is in front of the opposite (unused) arm, only 75 percent as much force can be applied.

c. 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.

d. Beyond 480 mm (19 in), two-hand operation becomes less effective.

5.1.4.2.2.1.7 Displacement and separation. Control displacement (for the seated user) and separation shall conform to figure 20.

5.1.4.2.2.1.8 Location, position, direction, and range of movement. The location, position relative to the user, direction, and range of lever movement shall be compatible with user reach, mobility, natural movements, and strength capabilities.

5.1.4.2.2.1.9 High forces. When high forces are required of the user, the lever handle shall be located between waist and shoulder levels. For high-force applications, the force will typically be applied in a pulling direction.

5.1.4.2.2.1.10 Detents. When levers are used as "selector" controllers, mechanical detents shall be provided (in addition to panel labels or markings) to deliver tactile feedback that indicates the lever is positively positioned at designated settings.

5.1.4.2.2.1.11 Detents and panel markings. Detents and panel markings shall coincide precisely.

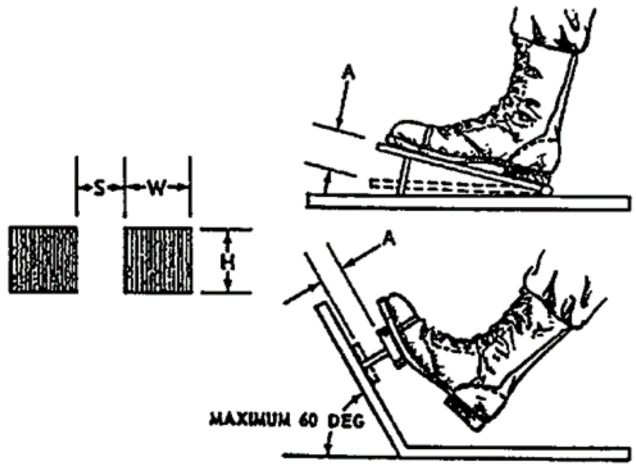
5.1.4.2.2.1.12 Non-slip handles. Surfaces of lever handles shall provide sufficient friction (by means of the specific material used or addition of serrations or knurling) to reduce the probability of the user's hand or fingers slipping while operating the lever.

5.1.4.2.2.2 Pedals.

5.1.4.2.2.2.1 Use. Pedal controls should be used only where the user is likely to have both hands occupied when control operation is required, control system force is too high for manual force capability of the user, or standardized use of pedals has created a stereotype expectancy (e.g., vehicle pedal controls such as clutches, brakes, accelerators, and rudders).

5.1.4.2.2.2.2 Location.

5.1.4.2.2.2.2.1 Pedal control location. Pedal controls shall be located so that the user can easily reach them without extreme stretching or torso twisting and can also reach the maximally-displaced pedals (see figure 21).



	Dimensions					
	H, Height	W, Width	Normal Operation	Heavy Boots	Ankle Flexion	Total Leg Movement
Minimum	25 mm (1 in)	75 mm (3 in)	13 mm (0.5 in)	25 mm (1 in)	25 mm (1 in)	25 mm (1 in)
Maximum	--	--	65 mm (2.5 in)	65 mm (2.5 in)	65 mm (2.5 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)
Maximum	150 mm (6 in)	100 mm (4 in)

FIGURE 21. Pedals.

5.1.4.2.2.2.2.2 Accommodation. Pedal location shall accommodate the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped males of the target user population and the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped females of the target user population.

5.1.4.2.2.2.2.3 Foot and heel placement. Pedals that may be held or must be adjusted (e.g., accelerator or clutch) shall be located so the user can "rest" and "steady" the foot (i.e., the pedal shall be an appropriate critical distance above the floor so the user's heel can rest on the floor while articulating the ankle/foot).

5.1.4.2.2.2.2.4 Heel rest. If the user cannot rest his or her heel on the floor and the pedal angle is more than 20 degrees from the horizontal floor, a heel rest shall be provided.

5.1.4.2.2.2.3 Control return. Except for controls that generate a continuous output (e.g., rudder controls), pedals shall return to the original null position without requiring assistance from the user (e.g., brake pedal).

5.1.4.2.2.2.4 Inadvertent actuation. Where the user's foot may normally rest on the pedal between operations, sufficient resistance shall be provided to prevent the weight of the foot from inadvertently actuating the control (e.g., accelerator pedal).

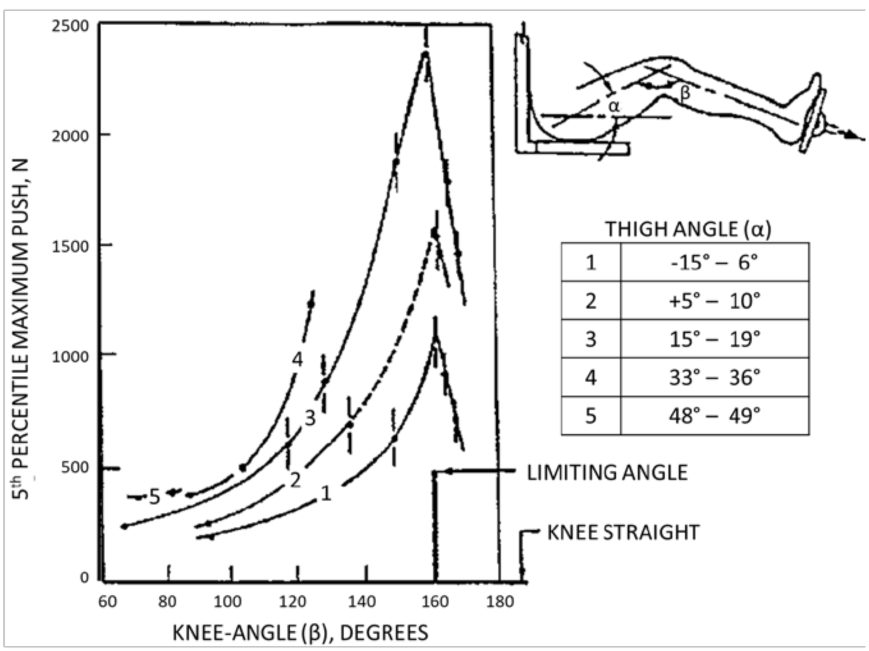
5.1.4.2.2.2.5 Pedal travel path. The travel path shall be compatible with the natural articulation path of the user's limbs (i.e., thigh, knee, ankle).

5.1.4.2.2.2.6 High-force application aids. When high forces are required to fully actuate a pedal, appropriate aids shall be provided to assist the user in applying maximum force. Examples include the following:

a. Seat backrest

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

c. Optimized seat height-to-pedal and normal reach distance for maximum force where the seat reference point and pedal are at the same height and reach distance is configured so the angle between the upper thigh and lower leg is approximately 160 degrees (see figure 22)



NOTE: According to the National Institute of Health, women are approximately 52 percent and 66 percent as strong as the men in the upper and lower body respectively.

FIGURE 22. Leg strength at various knee and thigh angles (5th percentile male data).

5.1.4.2.2.2.7 Strength. High-force application aids shall be operable with two-thirds of male strength (shown on figure 22) in order to accommodate the female population.

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

5.1.4.2.2.2.9 Dimensions, resistance, displacement, and separation. Dimensions, resistance, displacement, and separation of pedals shall conform to the criteria on figure 21.

5.1.4.3 High-force controls.

5.1.4.3.1 Use. Controls requiring user forces exceeding the strength limits of the lowest segment of the expected user population shall not be used.

5.1.4.3.1.1 Proper body support. High-force controls shall not be used except when the user's nominal working position provides proper body support, limb support, or both (e.g., seat backrest or foot support).

5.1.4.3.1.2 Sustained force. Sustained (i.e., durations longer than 3 seconds) high-force requirements shall be avoided.

5.1.4.3.2 Foot controls. Where foot controls require high control forces, the push force 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 shall be corrected, where applicable, for females. Two-thirds of each value is considered to be a reasonable adjustment.

5.1.4.3.3 Arm, hand, and thumb-finger controls. Where arm, hand, and thumb-finger controls requiring high control forces are to be used, the maximum force requirements shall not exceed those specified on figure 23, and shall be corrected, where applicable, for females. Two thirds of each value shown is considered to be a reasonable adjustment.

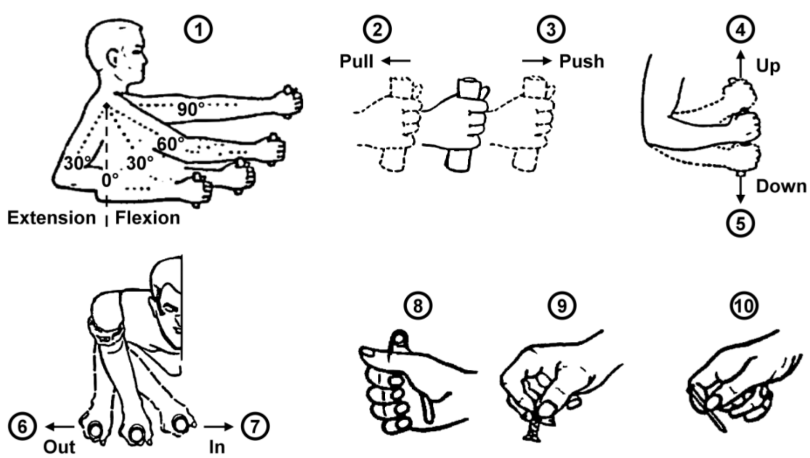


FIGURE 23. Arm, hand, and thumb-finger strength (5th percentile male data).

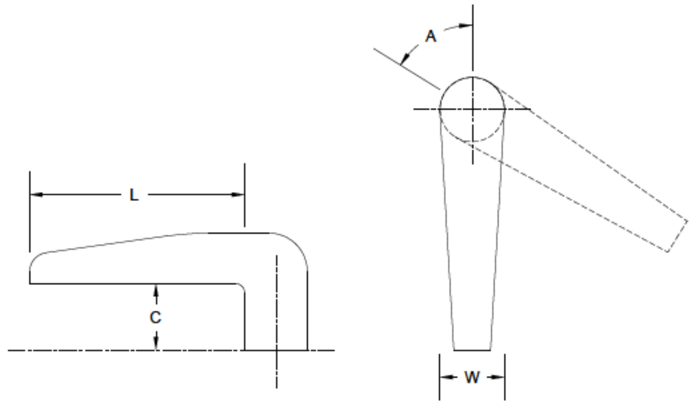
Arm Strength in Newtons (pounds of force)												
(1)	**(2)**		**(3)**		**(4)**		**(5)**		**(6)**		**(7)**	
Degree of Shoulder Flexion/ Extension	**Pull**		**Push**		**Up**		**Down**		**Out**		**In**	
	L	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**
90° (flexion)	222 (50)	231 (52)	187 (42)	222 (50)	40 (9)	62 (14)	58 (13)	76 (17)	36 (8)	62 (14)	58 (13)	89 (20)
60° (flexion)	187 (42)	249 (56)	133 (30)	187 (42)	67 (15)	80 (18)	80 (18)	89 (20)	36 (8)	67 (15)	67 (15)	89 (20)
30° (flexion)	151 (34)	187 (42)	116 (26)	160 (36)	76 (17)	107 (24)	93 (21)	116 (26)	45 (10)	67 (15)	89 (20)	98 (22)
0° (neutral)	142 (32)	165 (37)	98 (22)	160 (36)	76 (17)	89 (20)	93 (21)	116 (26)	45 (10)	71 (16)	71 (16)	80 (18)
30° (extension)	116 (26)	107 (24)	98 (22)	151 (34)	67 (15)	89 (20)	80 (18)	89 (20)	53 (12)	76 (17)	76 (17)	89 (20)

Hand and Pinch Strength Newtons (pounds of force)				
	(8)		**(9)**	**(10)**
	Hand Grip		**Palmer Pinch Grip**	**Tip Pinch Grip**
	L	**R**	**(Thumb Pad to Index & Middle Finger Pads)**	**(Thumb Tip to Index Finger)**
Momentary Hold	250 (56)	260 (59)	60 (13)	60 (13)
Sustained Hold	145 (33)	155 (35)	35 (8)	35 (8)

FIGURE 23. Arm, hand, and thumb-finger strength (5th percentile male data) – Continued.

5.1.4.4 J-handles.

5.1.4.4.1 Dimensions, resistance, displacement, and clearance. Dimensions, resistance, displacement, and clearance of high-torque J-handles shall conform to the criteria on figure 24.



	L, Length	C, Clearance	W, Width	A, Displacement	Resistance
Minimum	95 mm (3.75 in)	32 mm (1.25 in)	16 mm (0.65 in)	±24°	0.7 N·m (6 in-lbf)
Maximum	150 mm (6 in)	50 mm (2 in)	25 mm (1 in)	±60°	0.14 N·m (12 in-lbf)

FIGURE 24. High-torque J-handles.

5.1.4.4.2 Low-torque J-handles. When using small-scale low-torque (less than 0.7 newton•meters [N•m] [6 in pound-foot force]) J-handles, the handle portion shall have a flattened or flared tip for finger placement and the clearance between handle and panel surface can be less than that shown on figure 24.

5.1.4.4.3 J-handles placement. Where more than one J-handle is needed in a workspace and each serve different critical functions, they shall not be placed next to each other or in mirrored (left/right) locations of one another.

5.1.4.4.4 Inadvertent actuation. The use of shape, size, texture, and color differences for each J-handle shall be used to avoid inadvertent activation.

5.1.5 Miniature controls.

5.1.5.1 Use. Miniature controls (smaller versions of standard-sized controls) should be used only when severe space limitations exist. Miniature controls shall not be used when available space is large enough for standard-sized controls or when heavy gloves or mittens will be worn.

5.1.5.2 Dimensions 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 specified herein for standard-sized controls.

5.1.5.3 Resistance and displacement. Resistance and displacement of miniature controls shall conform to the criteria specified herein for the standard size of that type of control.

5.1.5.4 Other design considerations. Other design considerations (e.g., labeling and orientation) shall conform to the requirements specified herein for the standard size of that type of control.

5.1.6 Eye- and head-based controls.

5.1.6.1 Use. Eye- and head-based controls may be used for a variety of tasks including teleoperations, instrument selection on a panel, and visual search tasks.

5.1.6.2 Vibration. Eye- and head-based controls shall not be used in vibrating environments.

5.1.6.3 Precision. Head-based controls shall not be used if the task requires frequent precise head movements.

5.1.6.4 Dwell times. Line-of-sight dwell times shall be not greater than 300 milliseconds (less dwell time preferred).

5.1.6.5 Response time. System response time shall be not greater than 100 milliseconds (faster response time preferred).

5.2 Visual displays. This section is divided into the parts listed below. For requirements pertaining to the visual part of a computer application or operating system through which a user interacts with an information system or software, see 5.17. For graphical and representational displays, see 5.17.21.

a. General visual display requirements (see 5.2.1).

b. Electronic display requirements (see 5.2.2).

c. Non-electronic display requirements (see 5.2.3).

d. Scale requirements (see 5.2.4).

5.2.1 General visual display requirements.

5.2.1.1 Use. Visual displays should be used to provide the user with a clear indication of equipment, system, or environmental conditions for operation under any eventuality commensurate with the operational and maintenance philosophy of the system under design.

5.2.1.1.1 Display face flush with panel. The face of a display should be flush with the surface of the panel in which it is installed.

5.2.1.1.2 Vibration. Visual display vibration or user vibration shall not degrade performance below that required for mission accomplishment (see 5.5.5).

5.2.1.1.3 Motion. Graphic display items shall not move faster than 60 degrees (1.05 radians [rad]) (20 degrees [0.35 rad] preferred) of visual angle per second.

5.2.1.1.4 Orientation of objects. Orientation of displayed objects relative to the user shall be in accordance with the following criteria:

a. Displays shall include reference to the vertical or horizontal direction (e.g., “North” or “straight ahead”).

b. Orientation of objects relative to each other shall provide cues concerning the objects depicted (e.g., front and back, top and bottom).

c. Orientation of objects relative to each other shall provide cues concerning object dynamics (e.g., direction and speed of motion and rotation).

5.2.1.1.5 Flash coding. Flash coding shall be in accordance with 5.17.27.

5.2.1.1.6 International conventions and standards. Display design, location, and luminance characteristics in all military systems utilizing public roadways, airways, and navigable streams, rivers, and sea lanes shall follow international conventions and standards for aircraft, highway vehicles, and marine craft.

5.2.1.1.7 Location. Displays shall be located and arranged so that display content is legible from the user’s operating or servicing position. Also see 5.10.3 for general workstation requirements; see 5.10.3.14 for requirements on primary and secondary displays in sit-stand workstations and consoles.

5.2.1.1.8 Access. Visual displays shall be visually accessible without resorting to use of ladders, flashlights, or other special equipment to read the display. For display mounting requirements for seated workstations, see 5.10.3.9.1.5; for display mounting requirements for standing workstations, see 5.10.3.8.2.5.

5.2.1.1.9 Orientation. Display faces shall be not less than 45 degrees (0.79 radians) from the normal line of sight (see figure 2). Display faces should be perpendicular to the user’s normal line of sight.

5.2.1.1.9.1 Orientation adjustability. Where mission and environmental conditions permit it, display faces may be designed to be adjustable by the user within the constraints of 45 to 90 degrees from the normal line of sight (see figure 2).

5.2.1.2 Luminance considerations.

5.2.1.2.1 Luminance range minimum ratio. The display luminance adjustability (highest to lowest) range shall be not less than 50:1.

5.2.1.2.2 Minimum acceptable luminance level. The display shall be capable of luminance levels of at least 35 cd/m² (10 fL).

5.2.1.2.3 Luminance control. Luminance shall be adjustable so that display content is visible and useable over the expected range of ambient illumination.

5.2.1.2.4 Adjustable to zero. If required by the mission, display luminance shall be adjustable to zero.

5.2.1.2.5 Automatic luminance adjustment. Automatic adjustment of luminance based on ambient illumination may be used if the luminance is bright enough for the full range of ambient illumination.

5.2.1.2.6 Detection of faint signals. Hoods, shields, or other methods shall be used to prevent ambient illumination from degrading the visibility of a display.

5.2.1.3 Display contrast. Display contrast shall be such that the display content is visible over the entire range of the expected ambient illumination.

5.2.1.4 Reflections.

5.2.1.4.1 Reflections from displays. All reflections of the display that may disrupt operations, such as reflections onto windshields, shall be prevented. Viable techniques to prevent or reduce reflections include the following:

a. Construction of the display.
b. Arrangement of the display.
c. Mounting of the display.
d. Use of shields.
e. Use of filters.
f. Use of anti-reflective films or coatings.
g. Adjust display luminance or contrast.
h. Use reverse video.

5.2.1.4.2 Specular reflections. Light from an external source creating a specular reflection on a display shall not exceed 1.0 percent of the display luminance for a viewing angle of 30 degrees or less from the display normal.

5.2.1.4.3 Diffuse reflections. Light from an external source creating a diffuse reflection on a display shall not exceed 0.2 percent for a viewing angle of 30 degrees or less from the display normal or across the expected range of operator viewing angles, whichever is larger.

5.2.1.4.4 Reflected glare. One or more of the following techniques can be used to reduce reflected glare:

a. Proper placement of the display screen relative to the light source.
b. Use of a hood or shield.
c. Providing adjustable height, viewing angle, or contrast.
d. Using a first surface treatment to minimize specular reflections.
e. Providing a filter control over the light source.

5.2.1.4.5 Polarized/tinted surfaces. Neither polarized nor tinted display surfaces shall be used to reduce glare or reflection.

5.2.1.5 Daylight use. Displays intended for use in daylight (up to about 25,000 lux) shall have sufficient luminance to meet the contrast requirements in 5.2.2.7.

5.2.1.6 Variable ambient illumination. When a display is used in a variable ambient illumination environment, controls (dimmers) shall be installed on all displays (e.g., illuminated panels, indicators, or switches) in the immediate area.

5.2.1.7 Illumination for a group of displays. External illumination of a group of displays shall not vary more than 3:1 between the brightest and the darkest area.

5.2.1.8 PPE equipment. Display illumination shall be designed so that display content is visible when CBRNE or other mission-required PPE equipment is used.

5.2.1.8.1 Laser eye protection (LEP). Under applications where the user may be required to wear LEP, specific assessment shall be made to ensure that the color palette is operationally compatible with the LEP.

5.2.1.9 Night operations.

5.2.1.9.1 Night vision device compatibility. Where night vision device compatibility is required, displays shall be in accordance with MIL-STD-3009.

5.2.1.9.2 Blackout discipline. Where operational security or survivability requires blackout discipline, the use of permanently illuminated outdoor displays shall be avoided and illumination of displays within personnel enclosures shall automatically switch off when doors to the enclosure are opened.

5.2.1.9.2.1 Blackout lighting compliance. Where blackout lighting is required, systems shall be in accordance with MIL-STD-1179.

5.2.1.9.3 Display height. When dark adaptation is required, the top of the highest display shall be lower than the window.

5.2.1.9.4 Field use panel dimming. When visual displays are to be viewed out of doors at night, maximum display illumination shall be provided in accordance with the full ON position listed in table XII. When visual displays are to be viewed out of doors at night, no panel lighting current shall flow when the dimming control is in the full OFF position listed in table XII. When visual displays are to be viewed out of doors at night, panel light levels shall be continuously variable from 0.1 cd/m² (0.03 fL) near OFF to 3.5 cd/m² (1 fL) at 50 percent position of control.

TABLE XII. Control positions for full OFF and full ON illumination.

Type	**OFF Position**	**ON Position**
Rotary knob/selector	Full counterclockwise	Full clockwise
Horizontal slider/thumbwheel/lever	Full left	Full right
Vertical slider/thumbwheel/lever	Full down	Full up

5.2.1.9.5 Display hood. To help preserve dark adaptation or to shield the display from high ambient illumination, a one-third hood with rounded corners over the display shall be used.

5.2.1.9.6 Display face away from windows. When dark adaptation is required, all displays shall face away from windows to prevent all specular reflections.

5.2.1.9.7 Ambient light levels for dark adaption. At night, with all overhead lighting off, the ambient illumination from all internal lighting sources (displays or otherwise) within the field of regard (including head rotation) shall not exceed 0.001 lux (lx) (0.00009 footcandles [fc]). The ambient level should be 0.0001 lx (0.000009 fc) to maintain dark adaptation.

5.2.1.9.8 Low-level blue-filtered lighting for visual displays. Low-level blue-filtered white color light shall be used for panel, display, task, and backlit keyboard lighting in accordance with SAE AS25050 (also see 5.5.3).

5.2.2 Electronic display requirements. An electronic visual display is a device that presents images, video, graphics, or text generally employing raster graphics (bitmap) technology without producing a permanent record. The following applies to direct view electronic displays, such as liquid crystal displays, plasma displays, light emitting diode displays, cathode ray tube displays, and electroluminescent displays.

5.2.2.1 Geometric distortion. The combined effects of all geometric distortion shall not displace any point on the display from its correct position by more than 5 percent of the picture height.

5.2.2.2 Geometric stability (jitter). Over a period of 1 second, the movement of a picture element shall be not greater than 0.2 milliradians (41 seconds) of visual angle.

5.2.2.3 Flicker. Electronic visual displays shall include controls for refresh rate and other parameters (e.g., luminance, contrast, or color) to prevent flicker.

5.2.2.4 Luminance uniformity. Luminance across the display (blank screen) shall not vary by more than 2:1 (ratio of maximum to minimum luminance); 1.5:1 is preferred.

5.2.2.5 Color uniformity. The display shall provide color uniformity of r less than 0.030 over the display's viewing envelope, where r is the radius of the allowable circular area on the 1976 UCS chromaticity diagram for the specified color.

5.2.2.6 Image polarity. To maintain dark adaptation, displays shall use light characters on a dark background when ambient light levels are less than approximately 0.1 lx (0.009 fc); otherwise, dark characters on a light background shall be used.

5.2.2.7 Contrast ratio. The contrast ratio between characters and a background shall be 6:1 or greater (10:1 or greater is preferred).

a. For applications related to ship bridge displays, see 5.18.

b. For applications related to cockpit displays, refer to guidance in MIL-HDBK-87213 (tables in MIL-HDBK-87213 may require adjustment to account for the assumption of 70 percent transmissivity of an aircraft bubble canopy).

c. A control shall be provided to vary the contrast between the characters and the background.

d. For large-screen displays, see 5.2.2.12.

5.2.2.8 Display choice. The display choice should reflect the intended context of use, display resolution, and other viewing considerations.

a. Displays with diagonals less than or equal to 16 centimeters (cm) (6.3 in) (handheld and wearable PEDs) should be in accordance with 5.2.2.9.

b. Displays with diagonals greater than 12.7 cm (5 in) and less than or equal to 33 cm (13 in) (small-screen displays) should be in accordance with 5.2.2.10.

c. Displays with diagonals greater than 33 cm (13 in) and less than or equal to 81.28 cm (32 in) (individual displays) should be in accordance with 5.2.2.11.

d. Displays intended for direct viewing with diagonals greater than 81.28 cm (32 in) (multiple viewer displays – direct view) should be in accordance with 5.2.2.12.

e. Displays intended for viewing on an optical projection should be in accordance with 5.2.2.13.

5.2.2.9 Handheld displays and wearable PEDs. Handheld displays and wearable PEDs should be used in the following contexts. For detailed requirements, see 5.19.

a. A single user that needs to access information, typically away from their primary workspace.

b. A single user or a group of users that must move about yet must frequently refer to information required to make decisions.

c. Workspaces where space or other constraints preclude the use of individual displays for each team member to retrieve commonly used information.

5.2.2.10 Small-screen displays.

5.2.2.10.1 Use. Small-screen displays should be used in the following contexts:

a. A single user or a group of users that need to access information, typically away from their primary workspace.

b. A single user or a group of users that must move about yet must frequently refer to information required to make decisions.

c. Workspaces where space or other constraints preclude the use of individual displays for each team member to retrieve commonly used information.

5.2.2.10.2 Adapt formatting. When converting a display from traditional size to small-screen, the design should adapt (not copy) the current system design.

5.2.2.10.3 Font characteristics. Font size should be large enough to discriminate between similar characters (e.g., letter I to number 1 and letter Z to number 2) and shall conform to the requirements of 5.17.18.2.

5.2.2.10.3.1 Standard font. A common standard font should be used (e.g., Arial, Times New Roman, Courier, or Verdana).

5.2.2.10.3.2 Sans serif. Where users must read displays quickly under adverse conditions (e.g., poor lighting), a sans serif style shall be used (e.g., Arial, Verdana, or Helvetica).

5.2.2.10.4 Text organization. To increase ability to skim text, subtitles and hypertext shall be used in text passages that are longer than a single screen.

5.2.2.10.4.1 Variable length lines. Variable length lines shall be avoided by use of hyphenation of words at line breaks to improve readability on small screens.

5.2.2.10.4.2 Scrolling markers. When content cannot be displayed in one screen, scrolling markers shall be provided to enable users to identify where they are on the page.

5.2.2.11 Individual displays.

5.2.2.11.1 Use. Individual displays should be used in the following contexts:

a. A single user accessing information at their primary workspace.

b. A primary user that accesses the display with multiple users that intermittently reference the display.

5.2.2.11.2 Maximum viewing distance of individual displays. The viewing distance from the eye reference point of the seated user to displays located close to their associated controls shall not exceed 70 cm (28 in). At this maximum viewing distance, the maximum diagonal size of individual displays should be no greater than 81.28 cm (32 in). This display size boundary ensures that user's line of sight is no more than 30 degrees off from the perpendicular of the display surface at the corners of the display.

5.2.2.11.3 Viewing distance when seated in ejection seat. Viewing distance of up to 76 cm (30 in) may be used with ejection seats.

5.2.2.11.4 Minimum viewing distance for visual displays. The effective viewing distance to displays shall be not less than 33 cm (13 in) and preferably not less than 50 cm (20 in).

5.2.2.11.5 Viewing dim signals. When periods of display observation will be short or when dim signals must be detected, the viewing distance may be reduced to 25 cm (10 in).

5.2.2.11.6 Long viewing distance. Displays that must be viewed from greater than 50 cm (20 in) should be modified in characteristics such as display size, symbol size, luminance, and resolution to be visible at longer distances. Alphanumeric characters shall conform to the requirements of 5.17.18.2.

5.2.2.12 Multiple viewer displays for direct view.

5.2.2.12.1 Use. Multiple viewer displays for direct viewing are large-screen displays that should be used in the following contexts. See 5.10.3.1 for requirements related to installing electronic displays in combination with visual displays.

a. A group of users frequently refers to the same information and is required to interact as a team, based on the same information.

b. One or more members of a team of users must move about yet must frequently refer to information required to make decisions. They cannot carry information with them or do not have it displayed at their assigned position(s).

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

d. When it is desirable to have general information available to persons who shall not interrupt ongoing group operations by looking over the shoulder(s) of individual user(s) to see individual displays.

e. When a multiple-viewer display consists of multiple individual displays (e.g., a 2-by-2 array of displays) (see 5.2.2.11).

5.2.2.12.2 Avoidance of large-screen displays. Large-screen displays should be used only when the spatial and environmental conditions allow satisfactory observational geometry to ensure that all critical users have visual access in terms of viewing distance, viewing angle; and lack of interference from intervening objects, personnel or ambient lighting. If the display is optically projected, see 5.2.2.13.

5.2.2.12.3 Viewing distance to screen diagonal ratio. The ratio of viewing distance to screen diagonal shall be between 2:10 (3:6 preferred).

5.2.2.12.4 Maximum viewing distance for large-screen displays. The distance between the display and the observer shall conform to the character requirements of 5.17.18.2. Appropriate resolution of other critical details or display elements presented on the display should be assessed for the most distant viewer.

5.2.2.12.5 Minimum viewing distance for large-screen displays. The display shall not be closer to any observer than one-half the display width or height, whichever is greater.

5.2.2.12.6 Physical interruption of view of large-screen displays. A large-screen display shall be located with respect to critical observers so that the view of the display is not obscured regularly by persons moving in normal traffic patterns.

5.2.2.12.7 Control of displayed information of large-screen displays. Control of large-screen group display systems shall ensure that critical information cannot be modified or deleted inadvertently or arbitrarily.

5.2.2.12.7.1 Group display changes. Changes in the group display shall be controlled by designated users.

5.2.2.12.7.2 Individual changes. When individuals must make changes that are of interest only to themselves, a separate display shall be provided.

5.2.2.12.8 Direct view large-screen displays (liquid crystal displays, plasma displays, and other non-projection displays). The luminance contrast for direct-view large-screen displays shall be not less than 1.5:1.

5.2.2.12.8.1 Dark characteristics. Where feasible, dark characters shall be displayed on a light background unless the background appears to flicker.

5.2.2.12.8.2 Color-coded objects. If the display includes color-coded objects, the background shall be a neutral color such as gray.

5.2.2.13 Multi-viewer projection displays.

5.2.2.13.1 Large-screen projection displays. Displays intended for optical projection large-screen displays should be used in the following contexts:

a. Applications requiring group presentation.

b. Pictorial and spatial information.

c. History versus real-time presentation.

d. Synthetically-generated pictures.

e. Simulation of the external world.

f. Superposition of data from more than one source.

5.2.2.13.2 Ambient light. Controls for ambient light shall be provided for the optical projection displays.

5.2.2.13.3 Avoidance of front projection. Front projection shall not be used where physical obstructions will impair viewing or where work areas require high ambient illumination for other activities.

5.2.2.13.4 Viewing distance. The viewing distance/image width relationship of optical projection displays for group viewing should conform to the preferred limits of table XIII and shall not exceed the acceptable limits indicated.

TABLE XIII. Group viewing of optical projection displays.

Factor	Optimum	Preferred Limits	Acceptable Limits
Ratio of viewing distance to screen diagonal	4.0	3.0 to 6.0	2.0 to 10
Angle off centerline	0°	0 to 20°	0 to 30°
Image luminance (no film in operating projector)	35 cd/m^2 1/	27 to 48 cd/m^2 1/	17 to 70 cd/m^2 1/
Luminance variation across screen (ratio of maximum to minimum luminance)	1.0	1.5	3.0
Luminance variation as a function of viewing location (ratio of maximum to minimum luminance)	1.0	2.0	4.0
Ratio of ambient light to the brightest part of the image	0	0.002 to 0.01	0.1 maximum 2/

NOTES:

1/ For still projections, higher values may be used.

2/ For presentations not involving gray scale or color (e.g., line drawings, tables) 0.2 may be used.

5.2.2.13.5 Off-center viewing. Off-center viewing of optical projection displays for group viewing should conform to the preferred limits of table XIII and shall not exceed the acceptable limits indicated.

5.2.2.13.6 Image luminance. Image luminance and light distribution of optical projection displays for group viewing shall conform to the preferred limits and shall not exceed the acceptable limits of table XIII.

5.2.2.13.7 Screen luminance. The screen center luminance at the maximum viewing angle shall be at least half its maximum luminance.

5.2.2.13.8 Luminance ratio. The luminance ratio of optical displays shall conform to table XIV.

TABLE XIV. Luminance ratio of optical projection displays.

Condition	Luminance Ratio
Optimal ambient lighting conditions	500:1
Viewing charts, printed text, and other line work	Not less than 5:1
Animation and photographs with limited luminance range	Not less than 25:1
For images that show a full range of colors (or grays in black-and-white photographs)	Not less than 100:1

5.2.2.13.9 Legibility. To improve legibility, display content shall meet the criteria in 5.2.2.13.9.1 through 5.2.2.13.9.4.6.

5.2.2.13.9.1 Font style. A simple style of numerals and letters shall be used (e.g., Arial or Times New Roman).

5.2.2.13.9.2 Stroke width. Stroke width shall be 0.1667 to 0.125 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.

5.2.2.13.9.3 Letter width, numeral width, character spacing, and word spacing. Letter width, numeral width, character spacing, and word spacing shall be in accordance with 5.4.7.6.1, 5.4.7.6.2, 5.4.7.8, and 5.4.7.9, respectively.

5.2.2.13.9.4 Superposition. When superpositioning is used, the criteria in 5.2.2.13.9.4.1 through 5.2.2.13.9.4.6 shall apply.

5.2.2.13.9.4.1 Contrast. Contrast may be either light on a dark background or vice versa, except where superposition is used.

5.2.2.13.9.4.2 Subtractive superposition. For subtractive superposition (at the source), data shall be presented as dark markings on a transparent background.

5.2.2.13.9.4.3 Additive superposition. For additive superposition (at the screen), data shall be presented as light markings on an opaque background.

5.2.2.13.9.4.4 Colored markings. The use of colored markings against colored backgrounds of comparable brightness shall not be used.

5.2.2.13.9.4.5 Alignment. Mis-registration of superimposed alphanumeric data or other symbols should be minimized.

5.2.2.13.9.4.6 Keystone effects. The projector-screen arrangement should minimize keystone effects (distortion of displayed content proportions due to non-perpendicularity between projector and screen).

5.2.2.14 Stereoscopic, volumetric, and perspective displays.

5.2.2.14.1 General. 3-D displays shall meet the criteria in 5.2.2.14.1.1 through 5.2.2.14.1.8.6.

5.2.2.14.1.1 Use. 3-D displays should be used only if they enhance human performance, the user population will have normal stereoscopic vision, and the field-of-view is large enough for the number of viewers intended. Tasks where 3-D displays have shown to enhance performance over two-dimensional displays are tasks that require knowledge of three dimensions include tracking object(s), spatial judgment, interactive pointing tasks, and visual search.

5.2.2.14.1.2 Egocentric presentation. The primary presentation of data to a user shall be an egocentric perspective.

5.2.2.14.1.3 General use of dynamic displays. If dynamic displays are used, the temporal modulation of stereopsis shall be approximately 1 hertz.

5.2.2.14.1.4 Horizon of dynamic displays. The system shall have a control to manipulate the horizon line.

5.2.2.14.1.5 Depth range of dynamic displays. The depth range of a display shall be limited to ±0.75 diopters in front or behind the display.

5.2.2.14.1.6 Color. Where stereoscopic images are color coded, secondary colors shall be used.

5.2.2.14.1.6.1 Saturated colors. Saturated primary colors shall be avoided.

5.2.2.14.1.6.2 Red and blue. Red and blue shall not be used together as they can cause ambiguity in depth cues.

5.2.2.14.1.7 Information density. Depth-coded objects shall be separated spatially to eliminate disparity averaging, crowding, and repulsion. When using techniques such as wire frame or transparency in 3-D displays, the amount of detail shall be kept to a minimum.

5.2.2.14.1.8 Depth cues. Depth cues shall meet the criteria in 5.2.2.14.1.8.1 through 5.2.2.14.1.8.6.

5.2.2.14.1.8.1 Image size. Image size shall be scaled according to the disparity of the image.

5.2.2.14.1.8.2 Size perception. If accurate size perception is critical to task performance, size scaling shall be done for each user.

5.2.2.14.1.8.3 Occlusions. Inaccurate occlusions shall not occur.

5.2.2.14.1.8.4 Conflicting depth cues. Conflicting depth cues shall not be permitted.

5.2.2.14.1.8.5 Natural depth. Depth cues shall assimilate natural depth; exaggerated depth cues shall be avoided.

5.2.2.14.1.8.6 Grid lines. Grid lines shall be used as a depth cue.

5.2.2.14.2 Stereographic displays. Luminance shall be co-modulated with stereopsis, consistent with the type of image depicted. When stereoscopic effects are created by the presentation of separate images to each eye, the image intended for the left eye shall not be seen by the right eye, and vice versa.

5.2.2.14.3 Tolerance for vertical misalignment. Vertical misalignment or the tilt of one optical axis either up or down shall not exceed 10 minutes of arc.

5.2.2.14.4 Tolerance for rotational difference. Tolerance for rotational differences between stereo pairs shall not exceed a vertical misalignment of 10 minutes of arc.

5.2.2.14.5 Tolerance for magnification difference. Tolerance for either horizontal or vertical differences between stereo pair image size shall not exceed 1.5 percent. The vertical misalignment produced by the image disparity shall not exceed 10 minutes of arc.

5.2.2.14.6 Tolerance for luminance difference. Tolerance for luminance differences between stereo pairs shall not exceed 30 percent.

5.2.2.14.7 Auto-stereographic displays. When the user cannot maintain a direct view (e.g., move frequently, peripheral viewing), auto-stereographic displays shall not be used.

5.2.2.14.8 Volumetric displays. Volumetric displays may be used when displaying complex information in small boundaries, tasks that involve anticipation, and planning in three dimensions (e.g., collision avoidance).

5.2.2.14.8.1 Low ambient light. Volumetric displays shall only be used in low ambient light.

5.2.2.14.8.2 Ray cursors. Ray cursors shall be used in selection tasks.

5.2.2.15 Head-up displays (HUDs).

5.2.2.15.1 General guidance. HUDs shall be compatible with the capabilities and limitations of the human visual system.

5.2.2.15.2 Use. Information presented on HUDs should be limited to critical data, which the user is required to monitor while simultaneously performing the primary visual task.

5.2.2.15.3 Windshield transmission rate. If a vehicle windshield is used as a HUD combiner, the total transmission through the windshield shall be not less than 70 percent as measured along the line of sight.

5.2.2.15.4 Eye-box size. Regardless of the optical display technology, the head motion box or eye-size box shall be not less than 11.5 cm (4.5 in) wide, 6.5 cm (2.5 in) high, and 15 cm (6 in) deep.

5.2.2.15.5 Object angular displacement. The angular displacement of objects viewed through the combining glass assembly shall be not greater than 0.5 milliradian (1.7 minutes) of visual angle.

5.2.2.15.6 Apparent image focus distance. The apparent image focus distance of HUDs for a land-based vehicle application shall be equal to the approximate distance of the driver from the front of the vehicle.

5.2.2.15.7 Field of view. HUDs used on land-based vehicle applications shall have a field of view not less than 6 degrees (105 milliradians) above the horizontal, 5 degrees (87 milliradians) below the horizontal, and 12 degrees (209 milliradians) to the left and right.

5.2.2.15.8 Exit pupil. HUDs shall have a minimum exit pupil (that area within a collimated beam in which the entire image formed by an objective lens is capable of being seen) of 72 mm (2.8 in).

5.2.2.15.9 Characters and symbols. Characters and symbols for HUDs shall meet the criteria in 5.2.2.15.9.1 through 5.2.2.15.9.7.

5.2.2.15.9.1 Alphanumeric character heights. The height for HUD alphanumeric characters shall be not less than 8.1 milliradians (28 minutes) of visual angle.

5.2.2.15.9.2 Non-alphanumeric character heights. The height for HUD non-alphanumeric characters shall be not less than 9.9 milliradians (34 minutes) of visual angle.

5.2.2.15.9.3 Raster lines/symbol height – alphanumeric characters. For head-up raster displays, alphanumeric characters shall not use less than 16 raster lines/symbol height.

5.2.2.15.9.4 Raster lines/symbol height – non-alphanumeric characters. For head-up raster displays, non-alphanumeric characters shall use not less than 20 raster lines/symbol height.

5.2.2.15.9.5 Symbol legibility. Display luminance should allow symbols to be legible under the expected ambient lighting conditions.

5.2.2.15.9.5.1 Direct sunlight. When legibility in direct sunlight or background luminance of 34,000 cd/m² (9,920 fL) or greater is required, symbol luminance shall be not less than 50,000 cd/m² (14,600 fL).

5.2.2.15.9.5.2 High ambient light applications. For most high ambient light applications, symbol luminance shall be 6,900 to 10,300 cd/m² (2,010 to 3,000 fL).

5.2.2.15.9.6 Symbol luminance. Symbol luminance shall be adjustable.

5.2.2.15.9.7 Symbol line width. The line width of symbols used in HUDs shall be not less than 0.5 milliradians (1.7 minutes). For most applications, symbol line width shall be 1±0.2 milliradian (3.4±0.7 minutes).

5.2.2.16 Head and helmet-mounted displays (HMDs).

5.2.2.16.1 Symbol location. Information shall be capable of being displayed within 25 degrees (0.44 radians) of the normal line of sight, which is typically 15 degrees (0.265 rad) below horizontal.

5.2.2.16.2 Gray shades for alphanumeric characters. Monochromatic HMDs shall provide not less than six shades of gray for alphanumeric and simple graphic information.

5.2.2.16.3 Gray shades for complex graphic data. Monochromatic HMDs shall provide not less than six shades of gray for complex graphic or sensor data.

5.2.2.16.4 Field of view. The field of view and field of regard should provide acceptable visual search performance, object recognition, and spatial orientation. Acceptable field of view and field of regard sizes shall be determined by mission requirements.

5.2.2.16.5 Unrestricted view. Users shall have an unobstructed view of all displays, controls, and the real-world environment as necessary.

5.2.2.16.6 Distinctive imagery. Display imagery should be visually distinctive from any anticipated background variation.

5.2.2.16.7 Mode selection. As applicable, a user-selectable optional display mode shall be provided to reduce display clutter.

5.2.2.16.8 Attentional distraction. HMDs should minimize attentional distraction and user cognitive load demand by providing only task-oriented, essential, integrated information with minimum memory requirements.

5.2.2.16.9 Salient cues. HMDs shall provide only salient cueing (e.g., directing attention to critical information).

5.2.2.16.10 Standardized graphics. All information presented graphically (e.g., positional, topographic, and spatial information) shall use standardized symbols in accordance with MIL-STD-1787.

5.2.2.16.11 Helmet characteristics. Helmet characteristics shall meet the criteria in 5.2.2.16.11.1 through 5.2.2.16.11.7.

5.2.2.16.11.1 Head vibration. HMD designs shall attenuate head vibration for frequencies 10 hertz and less.

5.2.2.16.11.2 Weight distribution. Weight distribution of helmet-mounted items shall be balanced to avoid or minimize neck strain, fatigue, and helmet movement relative to the user's head.

5.2.2.16.11.3 External attachments. Any required external attachments shall not restrict user head or shoulder motion.

5.2.2.16.11.4 Cables. HMD cables shall not provide a path to transmit unsafe loads (weight) to the crewmember's helmet, head, or neck.

5.2.2.16.11.4.1 Cable separation device. If a cable separation device/connector is utilized, its position on the cable shall be placed in a location that minimizes the cable length remaining attached to the helmet after cable separation.

5.2.2.16.11.4.2 Cable length. The projection or exposed length of the cable shall be minimized, but the cable shall not restrict normal head movement.

5.2.2.16.11.5 Adjustable. HMDs shall be adjustable for individual eyes to be properly aligned to the system.

5.2.2.16.11.6 Secure. The HMD shall remain secure in relation to the eye during task performance.

5.2.2.16.11.7 Stability. The HMD should not require excessive tightening to achieve the necessary stability.

5.2.2.16.12 Eye dominance. HMDs shall support left or right eye dominance.

5.2.2.16.13 Depth perception. Binocular HMDs shall support depth perception if necessary for the task.

5.2.2.17 Liquid crystal displays (LCDs). Backlighting (if appropriate) and viewing angle shall be adjustable by users.

5.2.2.17.1 Image characteristics. The image shall be light characters on a dark background for reflective LCDs and dark characters on a light background for transmissive (backlighted) LCDs.

5.2.2.17.2 Off-axis viewing. Off-axis viewing of LCDs shall be possible. Display should be clearly readable up to 45 degrees (785 milliradians) off axis.

5.2.2.18 Plasma displays.

5.2.2.18.1 General. Unless specified below, plasma displays shall be in accordance with 5.2.3.1.

5.2.2.18.2 Intensity control. The dimming of plasma displays shall be compatible with the dimming of incandescent lamps.

5.2.2.18.3 Color coding. Plasma display color coding shall be in accordance with 5.2.3.1.9, except for red alphanumeric displays.

5.2.2.18.4 Red plasma displays. Red plasma displays shall not be located near red lights.

5.2.2.18.5 Lamp testing. Plasma indicator lights with 100,000 hours or longer mean time between failure (MTBF) shall not require a lamp test capability.

5.2.2.19 LEDs.

5.2.2.19.1 General. Unless specified below, LEDs shall be in accordance with 5.2.3.1.

5.2.2.19.2 Use. LEDs may be used for following applications:

a. For trans-illuminated displays including legend and simple indicator lights.

b. 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).

c. For graphics applications where display visibility from multiple viewer positions, high MTBF, low display volume, and low power consumption are more important than high resolution, high brightness, high power consumption, or sunlight readability.

5.2.2.19.3 Intensity control. The dimming of LEDs shall be compatible with the dimming of incandescent lamps.

5.2.2.19.4 Color coding. LED color coding shall be in accordance with 5.2.3.1.19; except for red alphanumeric displays.

5.2.2.19.5 Red LEDs. Red LEDs shall not be located near red lights.

5.2.2.19.6 Lamp testing. LED indicator lights with 100,000 hours or longer MTBF shall not require a lamp test capability.

5.2.2.20 Dot-matrix/segmented displays. The following provisions apply to displays only when used to present alphanumeric and symbolic information via dot-matrix or segmentation.

5.2.2.20.1 Use. Dot-matrix, 14-segment, and 16-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.

5.2.2.20.2 Use of seven-segment displays. Seven-segment displays should only be used for applications requiring numeric information.

5.2.2.20.3 Symbol definition. Dot-matrix characters that are not formed by pixels shall contain not less than 5 by 7 dots, with 7 by 9 dots preferred.

5.2.2.20.4 Symbol definition for dot-matrix displays with symbol rotation. If system requirements call for symbol rotation, dot-matrix characters shall contain not less than 8 by 11 dots, with 15 by 21 dots preferred.

5.2.2.20.5 Alphanumeric character and symbol sizes. Alphanumeric characters and symbols shall subtend not less than 4.7 milliradians (16 minutes) of visual angle as measured from the longest anticipated viewing distance.

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

5.2.2.20.7 Viewing angle. Viewing angle of dot-matrix or segmented displays shall be not more than 35 degrees off axis. The optimum viewing angle is perpendicular to the display.

5.2.2.20.8 Emitter color. Monochrome displays shall use the following colors having the following dominant wavelengths in order of preference: green (555 nanometer [nm]), yellow (575 nm), orange (585 nm), and red (660 nm). Blue emitters shall be avoided.

5.2.2.20.9 Emitter color for dot-matrix/segmented displays viewed with protective eyewear. The selected color shall be visible through laser protective (or other) eyewear required to be worn by the user.

5.2.2.20.10 Intensity control. Where applicable, dimming controls shall be provided to maintain appropriate legibility and user dark adaptation levels.

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

5.2.3 Non-electronic display requirements.

5.2.3.1 Transilluminated displays. A transilluminated display is a display in which light passes through the element being viewed. These displays include panels and indicators that use back- or edge-lighting and that use clear, translucent, fluorescent, or sandwich material. Transilluminated displays include the following:

a. Legend lights that present information in the form of words, numbers, symbols, and abbreviations.

b. Simple indicator lights.

c. Panel assemblies that present qualitative status or system readiness information.

5.2.3.1.1 Use. Transilluminated displays should be used to provide qualitative information to the user requiring either an immediate reaction by the user or to draw attention to an important system status.

5.2.3.1.2 Use for maintenance. Transilluminated displays may also be used occasionally for maintenance and adjustment functions.

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

5.2.3.1.4 Limited use of lights and indicators. Lights and illuminated indicators should be used sparingly and reserved for displaying only that information necessary for effective system operation.

5.2.3.1.5 Positive (active) feedback. Changes in display status shall signify changes in functional status, rather than indicate a response to control activation.

5.2.3.1.6 Absence of signal usage. The absence or removal of illumination of a transilluminated display should not be used for the following situations:

a. A malfunction, no-go, or out-of-tolerance condition.

b. A ready or in-tolerance condition unless the status of the caution light and its associated circuitry can be tested by the user. The user should be able to perform this test in an efficient manner that does not interfere with time-critical tasks.

5.2.3.1.7 Powered off signal. For maintenance displays, a “power off” condition shall be accompanied by a signal or visual indication. For operational displays, the absence of a “power on” signal or visual indication may be used to indicate a “power off” condition.

5.2.3.1.8 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 that show the status of the subsystem components, except as required by 5.5.3.3.3.

5.2.3.1.9 Location. When a transilluminated indicator is associated with a control, the indicator light shall be located so that it can be associated with the control without error.

5.2.3.1.10 Visibility. The transilluminated indicator light shall be unobstructed relative to the user's expected viewing position.

5.2.3.1.11 Location of critical functions. For critical functions, indicators shall be located within 15 degrees of the user's normal line of sight (see figure 2).

5.2.3.1.12 Warning lights. Warning lights shall be integrated with their associated controls.

5.2.3.1.13 Luminance levels. The following factors shall be considered in determining luminance levels:

5.2.3.1.13.1 Within-display contrast. Within-display contrast, such as contrast between light ON versus OFF modes, shall use a two-level contrast if the display requires a dormant luminance to read an identifying label plus an active luminance increase to indicate a functioning mode.

5.2.3.1.13.2 Display-surround contrast. Display-surround contrast, such as contrast between the illuminated indicator and its immediate panel surface that effects of ambient reflection on either the display or surround, shall be compensated for by such means as increased display luminance, surround surface modification, or use of filters or shields.

5.2.3.1.13.3 User adaptation. User visual adaptation criteria, such as display luminance, shall be compatible with the user's ability to detect low-level signals or targets in the external visual environment and perceive faint signals on a display or read red-lighted instruments provided for night operation.

5.2.3.1.13.4 Conspicuity. Conspicuity and attention-demand criteria, such as luminance, shall provide the alerting required to ensure that the user will not miss a critical warning, caution, or advisory message.

5.2.3.1.13.5 Distractions. Display luminance shall not distract the user in a manner that is detrimental to safe and efficient system operation.

5.2.3.1.13.6 Glare. Where glare must be reduced, the luminance of transilluminated displays shall be not more than 300 percent of the surrounding luminance.

5.2.3.1.13.7 Luminance control. A multiple step or continuously variable luminance control feature shall be provided when the display is used under variable ambient illumination.

5.2.3.1.13.8 Dimming to full OFF. Dimming to full OFF may be provided in non-critical operations, but shall not be used if inadvertent failure to turn on an indicator could lead to critical user failures (i.e., failure to detect or perform a critical step in an operation).

5.2.3.1.14 False indication or obscuration. Direct or reflected light shall not make indicators appear illuminated when they are not.

5.2.3.1.15 Appearance of being extinguished. Direct or reflected light shall not make indicators appear extinguished when they are illuminated.

5.2.3.1.16 Orientation. Reflection shall be minimized by proper orientation of the display with respect to the observer.

5.2.3.1.17 Contrast within the indicator. The contrast ratio within the indicator shall be not less than 2:1. This requirement does not apply to special displays specifically designed for legibility in sunlight.

5.2.3.1.18 Low ambient illumination applications. For low ambient illumination applications, the contrast ratio shall be not less than 9:1 with the background luminance less than the character luminance.

5.2.3.1.19 Color coding. Transilluminated displays, except for aircrew station and training equipment applications, shall be in accordance with Type I aviation colors of SAE AS25050.

5.2.3.2 Legend lights.

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

5.2.3.2.2 Positive versus negative legend-dark adaption. When the user's dark adaptation must be maintained, illuminated label/opaque background format shall be used and illuminated background/opaque label format shall be used only for critical warning indicators (e.g., master warning lights).

5.2.3.2.3 Positive versus negative legend. Where user dark adaptation is not required, illuminated background/opaque label format shall be used.

5.2.3.2.4 Contrast reversal. Where user dark adaptation is not required, contrast reversal may be employed to designate displays that have a physical appearance similar to legend switches on the same panel.

5.2.3.2.5 Legibility in high illumination. 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 warning indicators (e.g., master warning lights).

5.2.3.2.6 Lettering. The size and other characteristics of lettering shall be in accordance with 5.4.7.

5.2.3.2.7 Visibility and legibility. The lettering on single-legend indicators should be visible and legible whether or not the indicator is illuminated. Exceptions may apply for applications for aircrew stations, warning, and caution indicators (see MIL-STD-411 and MIL-PRF-38039).

5.2.3.2.8 Multifunction 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).

5.2.3.2.9 Stacked legends. Indicators using "stacked" legends shall be in accordance with the criteria in 5.2.3.2.9.1 through 5.2.3.2.9.4.

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

5.2.3.2.9.2 Parallax. Parallax shall be minimized.

5.2.3.2.9.3 Equal brightness. Front and rear legends shall have approximately equal brightness.

5.2.3.2.9.4 Contrast. Front and rear legends shall have approximately equal legend/background contrast.

5.2.3.2.10 Design. The legend face shall be in the plane of the panel that houses it (not recessed).

5.2.3.2.11 Legend face. The legend face area shall accommodate the legend without requiring abbreviation.

5.2.3.2.12 Interchanging legends. The possibility of losing or interchanging legends should be minimized by techniques such as captive legends.

5.2.3.2.13 Legend border. There shall be a border around each legend not less than the width of the letter "H" of the selected font.

5.2.3.2.14 Contrast. The contrast between the legend lettering and the background shall be in accordance with 5.2.2.7.

5.2.3.2.15 Illumination. A legend light shall illuminate immediately upon the occurrence of the event described by its legend.

5.2.3.2.16 Event termination. A legend light shall go out when that event terminates.

5.2.3.2.17 Light leakage. There shall be no light leakage from the illuminated light.

5.2.3.2.18 Redundancy. Lamps shall have double filaments so that when one filament fails, the second filament remains illuminated. The decreased light intensity may indicate the need for lamp replacement.

5.2.3.2.19 Malfunctions. Legend-light indications for isolating malfunctions shall be provided only down to the point dictated by the system maintenance philosophy.

5.2.3.2.19.1 Fail-safe operation. Legend-light indications shall operate in a fail-safe fashion.

5.2.3.2.19.2 Failure. Failure of a legend light or its indicator circuit shall not influence or cause failure of its monitored circuits and equipment.

5.2.3.3 Simple indicator lights.

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

5.2.3.3.2 Spacing. The spacing between adjacent edges of simple round indicator light fixtures shall permit unambiguous labeling and convenient bulb removal.

5.2.3.3.3 Luminance. The luminance of simple indicator lights should be in accordance with the criteria in 5.2.3.3.3.1 through 5.2.3.3.3.4.

5.2.3.3.3.1 Differentiation. Simple light displays used on control panels should be sufficiently bright for the user to easily differentiate between an ON and OFF condition.

5.2.3.3.3.2 Ambient light. The indicator should be positioned or shielded so that bright ambient light will not cause the indicator to appear lighted.

5.2.3.3.3.3 Reflections. The indicator should be positioned or shielded so that the lighted indicator will not reflect on other critical viewing surfaces.

5.2.3.3.3.4 Dark adaptation. Light indicators should not be so bright as to create “dazzle” or destroy user dark adaptation where required.

5.2.3.3.4 Coding. Simple indicator lights shall be coded in accordance with table XV; 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.

TABLE XV. Color coding of simple indicator lights.

Size/Type	**Color**				
	Red	**Yellow**	**Green**	**White**	**Blue**
≥25 mm (1 in), flashing (3 to 5 Hz)	Emergency condition (impending personnel or equipment disaster)	--	--	--	--
≥25 mm (1 in), Steady	Master summation (system or subsystem)	Extreme caution (impending danger)	Master summation (system or subsystem)	--	--
≤13 mm (0.5 in), steady	Malfunction; action stopped; failure; stop action	Delay; check; recheck	Go ahead; in tolerance; acceptable; ready	Functional or physical position; action in progress	Advisory

5.2.3.4 Transilluminated panel assemblies.

5.2.3.4.1 Use. Transilluminated (integrally lighted) panel assemblies may be used for the following functions:

a. To provide illuminated labels for control panels.

b. To serve as a light source for transilluminated control knobs.

c. To provide illuminated association markings on a control panel.

d. To provide a pictorial representation of a system process, communication network, or other information or component organization.

5.2.3.4.2 Luminance. Luminance of transilluminated panel assemblies shall be in accordance with the criteria in 5.2.3.4.2.1 through 5.2.3.4.2.6.

5.2.3.4.2.1 Ambient environment. Markings and controls shall be compatible with the ambient environment and operating conditions.

5.2.3.4.2.2 Luminance control. Luminance control (dimming) by the user shall be provided where applicable to maintain appropriate visibility and user dark adaptation level.

5.2.3.4.2.3 Luminance variation. Luminance variation among separate panels on the same lighting circuit shall not exceed 7:1.

5.2.3.4.2.4 Equal illumination. Panel markings shall be equally illuminated throughout the range of panel light level adjustment.

5.2.3.4.2.5 Replacing lamps. When replaceable lamps are used as the source of illumination for integral lighting of panel assemblies, the lamps shall be accessible without disconnecting the panel.

5.2.3.4.2.6 Lamp redundancy. Enough lamps shall be provided so that failure of one lamp will not cause any part of the display to be unreadable.

5.2.4 Scale requirements.

5.2.4.1 Scale indicators. Scale indicators shall be in accordance with the criteria in 5.2.4.1.1 through 5.2.4.1.5.

5.2.4.1.1 Use. Scale indicators shall be used to display quantitative information combined with qualitative information (e.g., trend or direction-of-motion) and where only quantitative information is to be displayed and there is no requirement (e.g., speed or accuracy of response) that demands the use of numeric digital displays.

5.2.4.1.2 Fixed scales. Moving-pointer fixed scales shall be used in preference to fixed-pointer moving scales.

5.2.4.1.3 Circular scales. Where reading speed is important, circular scales shall be used in preference to horizontal scales or vertical scales, and horizontal scales shall be used in preference to vertical scales.

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

5.2.4.1.5 Numeric values. Numeric values on fixed scales shall increase clockwise, from left to right, or from the bottom up, depending on display design and orientation.

5.2.4.2 Representational displays. Representational displays shall indicate the scale of the object depicted.

5.2.4.3 Adjustable scales. The overall scale used shall be user adjustable as appropriate to the task.

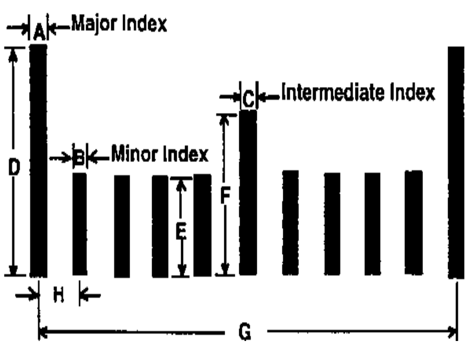
5.2.4.4 Calibration. Provision shall be made for placing calibration information on instruments without degrading dial legibility.

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

5.2.4.6 Scale markings.

5.2.4.6.1 Graduations. Scale graduations shall progress by one, two, or five units or decimal multiples thereof.

5.2.4.6.2 Graduation mark size. No more than three sizes of marks (minor, intermediate, and major) shall be used on any scale (see figure 25 and figure 26).



Dimensions of dark markers on light background, visual angle 1/	
A Width of major scale index	1.16 mrad (4 min) 2/
B Width of minor scale index	0.87 mrad (3 min) 2/
C Width of intermediate scale index	1.16 mrad (4 min) 2/
D Length of major scale index	7.86 mrad (27 min)
E Length of minor scale index	3.49 mrad (12 min)
F Length of intermediate scale index	5.82 mrad (20 min)
G Width of gap between major scale index	25.02 mrad (86 min)
H Width of gap between minor scale index	2.62 mrad (9 min)

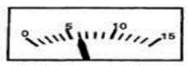
NOTES:

1/ For most applications with a dark graduation mark on a light background, the width of the minor graduation mark can be used for major and intermediate graduation marks as well. Use of this strategy allows the width of the pointer tip to be the same as all the graduation marks. Visual angles are for longest anticipated viewing distance.

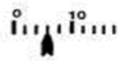
2/ 4.36 mrad (15 min) for light markers on dark background.

FIGURE 25. Scale marker dimensions.

Fixed scale, moving-pointer preferred. Three-level marking numbered at each major mark. Pointer adjacent to graduation marks to preclude obscuration of either marks or numbers.

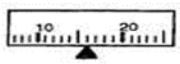


For short, finite scale. Every 5th graduation is marked using only two-level marking.



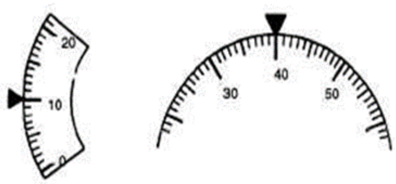
When scale crowding makes pointer-mark association difficult, scale may be graduated in units of two with two-level scale marking and numbering at each major marking.

When dial face is deeply inset within instrument case and visibility of numbers is more important than scale pointer-mark association, pointer may be located inside the graduations along with numbers at major markings. Pointer width shall be narrowed at point in which it passes numbers.



Moving scale against an index mark or pointer may be used when scale length precludes the fixed-scale format (graduation marks would be too close together). Open window configuration helps user focus on significant scale area.

FIGURE 25. Scale marker dimensions – Continued.



When open window configuration is oriented in a vertical position, numbers shall appear upright as each number passes the index mark or pointer. Total scale exposure is desirable when the user needs to refer to other portions of the scale.

FIGURE 26. Scale graduation, pointer position, and scale numbering alternative.

5.2.4.6.3 Minor marks. When no intermediate mark is used (i.e., two-mark sizes), no more than four minor marks shall be used.

5.2.4.6.4 Minor marks with intermediate marks. The number of minor marks between numbered scale markers shall not exceed nine when intermediate marks are used (i.e., three-mark sizes).

5.2.4.6.5 Intermediate marks. Intermediate marks shall only be used when there are more than four minor marks (see figure 25).

5.2.4.6.6 Dimensions. Height, width, and gaps between scale markers shall be in accordance with figure 25.

5.2.4.7 Scale numerals.

5.2.4.7.1 Orientation of numbers on fixed scales. On fixed scales, numerals shall be vertically oriented.

5.2.4.7.2 Orientation of numbers on rotating scales. For hardware rotating scales, numerals shall be radially oriented and positioned to be upright when read against the pointer. For software rotating scales, the numerals should always be oriented upwards.

5.2.4.7.3 Use of whole numbers. Whole numbers shall be used for major graduation marks, except for measurements that are normally expressed in decimals.

5.2.4.7.4 Scale origin. A display scale shall start at zero unless analysis indicates this would be inappropriate for the function involved.

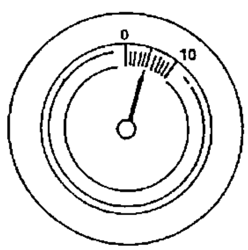
5.2.4.8 Scale pointers.

5.2.4.8.1 Pointer range. Scale pointers shall extend to, but not overlap, the shortest scale graduation marks.

5.2.4.8.2 Relative position of scale marks and numbers. Scale markings and the location of associated numbers shall be arranged to prevent pointers from covering any portion of the scale marks or numerals.

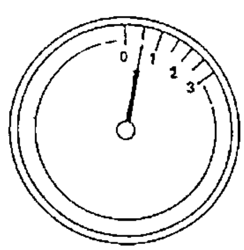
5.2.4.8.2.1 Parallax. Scale marks shall be on or close to the plane of the pointer tip to avoid visual parallax.

5.2.4.8.2.2 Readout accuracy. 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 figure 27).

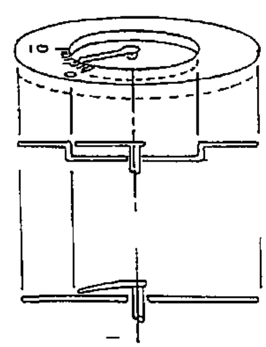


For maximum reading accuracy

(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 27. Relative position of scale marks, numerals, and pointers on circular dials.

5.2.4.8.3 Scale reading and pointer movement. The numeric value of the scale reading shall increase with movement of the pointer up or to the right.

5.2.4.8.4 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.

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

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

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

5.2.4.8.8 Tapers for pointer tips. The pointer tip shall be tapered at a 20-degree angle (40-degree total included angle), terminating in a flat tip equal in width to the minor scale graduations.

5.2.4.8.9 Pointer colors. Pointer colors shall be in accordance with the criteria in 5.2.4.8.9.1 through 5.2.4.8.9.3.

5.2.4.8.9.1 Pointer tip. Pointer color from the tip to the center of the dial shall be the same as the color of the marks.

5.2.4.8.9.2 Pointer tail. The tail of the pointer shall be the same color as the dial face, unless the tail is used as an indicator itself or the pointer is used for horizontal alignment.

5.2.4.8.9.3 Contrast ratio. A contrast ratio not less than 3:1 shall be provided between the scale face and the markings and pointer.

5.2.4.8.10 Pointer mounting. The mounting of pointers shall be in accordance with the criteria in 5.2.4.8.10.1 through 5.2.4.8.10.3.

5.2.4.8.10.1 Coaxial pointers. Not more than two coaxial pointers shall be mounted on one indicator face.

5.2.4.8.10.2 Arrangement. When a common stable value exists for given operating conditions in a group of 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 arranged 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.

5.2.4.8.10.3 Mechanical display. For mechanical displays, the pointer shall be mounted as close as possible to the face of the dial to minimize parallax.

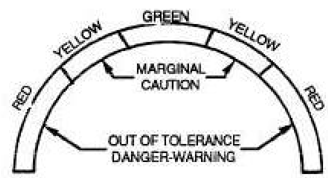
5.2.4.9 Scale coding.

5.2.4.9.1 Use. Coding on the face of scale indicators may be used to convey information such as desirable operating range, inefficient operation, caution, and danger level.

5.2.4.9.2 Operating conditions. Operating conditions that always fall within a given range on the scale shall be made readily identifiable by applying pattern or color coding to that range.

5.2.4.9.3 Distinguishable. Red, yellow, and green may be applied provided they are in accordance with 5.17.25.8 and are distinguishable under all expected lighting conditions.

5.2.4.9.4 Shape coding. Zone scales shall be shape coded when the indicator must be viewed in blackout conditions or where the illuminant color will cause difficulty in color band discrimination (see figure 28).



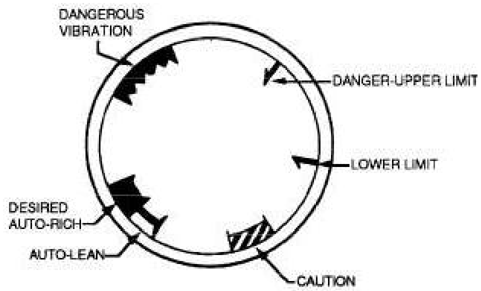


FIGURE 28. Examples of shape and color coding.

5.2.4.10 Circular scales.

5.2.4.10.1 Scale reading and pointer movement. When only positive values are displayed, the magnitude of the scale reading shall increase with clockwise movement of the pointer, starting with 0 degrees equal to 12 o'clock and positive angles measured in a clockwise direction.

5.2.4.10.2 Scale reading and pointer movement with positive and negative values. When positive and negative values are displayed, the magnitude of negative values shall increase with counterclockwise movement and the magnitude of positive values shall increase with clockwise values.

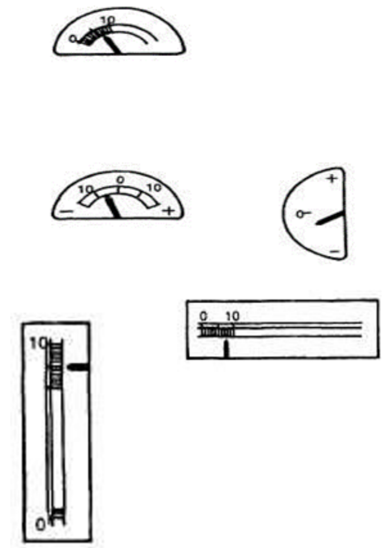
5.2.4.10.3 Positive values less than 360 degrees. Where only positive values are displayed and less than 360 degrees are used, the zero or minimum value shall be in the area between 225 and 300 degrees and the maximum value shall be in the area between 60 and 135 degrees, symmetrically arranged.

5.2.4.10.4 Positive values across 360 degrees or greater. Where only positive values are displayed over the complete 360 degrees or when pointer movement exceeds 360 degrees (in conjunction with a second pointer or indicator), the zero or reference point shall be located at the top (0 degrees).

5.2.4.10.5 Positive and negative values less than 360 degrees. 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 top or at 270 degrees (12 and 9 o'clock).

5.2.4.10.6 Scale break. There shall be an obvious break of at least 10 degrees of arc between the two ends of the scale, except on multi-revolution instruments such as clocks.

5.2.4.10.7 Curved (arc), horizontal straight, and vertical straight scales. See figure 29.



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

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

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

FIGURE 29. Relative position of scale marks, numerals, and pointers on arc and straight-line scales.

5.3 Speech and audio systems.

5.3.1 Audio displays. Speech input is received through microphones for processing and transmission through voice communication systems or for entry to speech recognition systems. Audio displays are used not only to present voice communication from another source but also to present sonically-derived sensor data, synthetic speech, alerting and cueing signals, and other acoustically coded information. Unlike vision, which can be interrupted by eyelid closure, auditory input is continuous. The perception of visual and auditory stimuli is influenced by the ability of the human brain to integrate this input. Vision integrates spatial contrast border, brightness, and color information while audition integrates temporal, spatial, intensity, and frequency information. Visual and auditory integration times vary and depend upon several stimulus parameters but are normally short. These differences and others discussed in this section shall be considered in planning and designing systems utilizing speech or other acoustic signals.

5.3.1.1 Use. Audio displays shall be provided under the following conditions:

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

b. When the common mode of visual display is restricted by over-burdening, ambient light variability or limitation, user mobility, degradation of vision by vibration, high G-forces, hypoxia, other environmental considerations, or anticipated user inattention.

c. When the criticality of the event makes supplementary or redundant notification desirable.

d. When it is desirable to warn, alert, or cue the user to subsequent additional response.

e. When custom or usage has created anticipation of an audio display.

f. When voice communication is necessary or desirable (e.g., hands-busy situations).

5.3.1.2 Signal type. When an audio presentation is required, the optimum type of signal shall be presented in accordance with table XVI and the criteria in 5.3.1.2.1 and 5.3.1.2.2.

TABLE XVI. 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.	Good, information concerning displacement, direction, and rate presented in form compatible with required response.
Status indication	Good, start and stop timing. Continuous information where rate of change of input is low.	Good, especially sounded 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, multi-dimensional information. Meaning intrinsic in signal and context when standardized. Minimum of new learning required.

5.3.1.2.1 Audio signal interference. Audio signals shall not interfere with other sound sources, including verbal communication.

5.3.1.2.2 Auditory presentation. Auditory presentation is preferred over visual presentation under any of the following circumstances:

a. For signals of acoustic origin.
b. For warning signals to call attention to imminent or potential danger.
c. For situations when many displays are visually presented (e.g., piloting an airplane).
d. For presenting information independently of head orientation.
e. For situations when environmental conditions limit vision or make seeing impossible.
f. For conditions of anoxia or high positive G-forces.
g. When signals must be distinguished from noise, especially periodic signals in noise.

5.3.1.3 Signal meaning. Each audio signal shall have only one meaning. The ear acts as an effective detector of periodic signals in noise. Even when it is considerably weaker than the background noise, if the signal is a sinusoid (pure tone) or a combination of sinusoids (complex tone), the ear can detect it. The ear also efficiently detects periodic modulation in the very low frequency range and responds to variations in intensity or frequency.

5.3.1.4 Apparent urgency. The attention-gaining characteristics of the signals in a set (e.g., rapidity of pulse pattern, frequency, intensity) shall match the relative priority of the signal.

5.3.1.5 Use with several visual displays. If immediate discrimination is not critical to personnel safety or system performance, one audio signal may be used in conjunction with several visual displays.

5.3.1.6 Speech supplements. When speech supplements are used, the length of the initial alerting and the actual message shall not interfere with other auditory inputs including interpersonal voice communication unless the message is critical.

5.3.1.7 Silent operations at night. In equipment designed for silent operation at night, the sound level at the ear under an earphone shall be not greater than 50 decibels on the A-weighted scale (dBA). See ANSI/ASA S1.4-Part 1.

5.3.1.8 Manual overrides. Non-critical audio signals shall be capable of being turned off at the discretion of the user.

5.3.1.9 Visual indication. Where the user has the capability to turn off non-critical audio signals, a visual indication that the signal has been turned off shall be provided to the user.

5.3.1.10 Reliability. The design of audio display devices and circuits shall reduce false alarms to the level of reliability stated in the performance specification (see 6.2).

5.3.1.10.1 System or equipment failure. The audio display device and circuit shall be designed to preclude alarm signal failure in the event of system or equipment failure and vice versa.

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

5.3.1.11 Individual speaker recognition. If individual speaker recognition is used for security purposes (e.g., to deny access to classified material by unauthorized personnel), it shall be used in combination with some other control method in order to attain reliability.

5.3.1.12 Sensor applications. Audio displays for sensor systems, such as sonar and electronic countermeasures, shall be made compatible with the criteria stated herein. Deviations shall require approval of the procuring activity.

5.3.1.13 Aircrew stations. Audio displays for aircrew stations shall be designed in accordance with JSSG-2010.

5.3.2 Audio signals.

5.3.2.1 Warning signals. Warning signals shall meet the criteria in 5.3.2.1.1 through 5.3.2.1.6.2.

5.3.2.1.1 Required warning signals. Signals shall be provided to warn personnel of impending danger, to alert the user to a critical change in system or equipment status, and to remind the user of a critical action or actions that must be taken.

5.3.2.1.2 Increasing probability of detection. A warning or caution signal shall provide the user with a greater probability of detecting the triggering condition than normal observation would provide in the absence of the signal. Certain audio signals have been standardized for aircraft use by joint service and international agreements. Audio signals for future aircraft design shall conform to these agreements.

5.3.2.1.3 Nature of warning signals. Warning signals shall consist of distinctive complex sounds of exceptional attention-getting value and be presented at a level of at least 15 dBA above the ambient noise environment, but shall not exceed 140 decibels peak (dBP) for overall signal sound.

5.3.2.1.4 High ambient noise. For any audio signals, if ambient noise levels are too high to accommodate the 15 dBA above ambient without exceeding 140 dBP, other alerting methods (e.g., non-audio signaling or signaling through headset) shall be used.

5.3.2.1.5 Persistence. Audio warning signals shall persist until restoration of normal conditions or warning is acknowledged.

5.3.2.1.5.1 Persistence of visual warning signal. When the audio warning is silenced by acknowledgment, the visual warning signal shall not be hidden from the user.

5.3.2.1.5.2 Timeout. When silenced by acknowledgment, the audio warning signal shall be silenced for a finite period of time appropriate to the nature of the condition. If the condition has not returned to normal within the timeout, the audio signal shall re-initialize.

5.3.2.1.6 Types of signals. Audio warning signals shall be either a two-element or single-element signal as appropriate to the situation in consideration of the total acoustic signal environment.

5.3.2.1.6.1 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. All essential information shall be transmitted in the first 2 seconds of the identifying or action signal.

5.3.2.1.6.2 Single-element signal. A single-element signal is permissible (i.e., when reaction time is critical). All essential information shall be transmitted in the first 0.5 second.

5.3.2.2 Caution signals. Caution signals shall meet the criteria in 5.3.2.2.1 through 5.3.2.2.3.7.

5.3.2.2.1 Distinct from warning signals. Caution signals shall be readily distinguishable from warning signals.

5.3.2.2.2 Awareness signal. Caution signals shall be used to indicate conditions requiring awareness but not necessarily immediate action.

5.3.2.2.3 Nature of caution signals. The nature of caution signals shall be in accordance with the criteria in 5.3.2.2.3.1 through 5.3.2.2.3.7.

5.3.2.2.3.1 Complexity. Caution signals shall consist of distinctive complex sounds at least 15 dBA above the ambient noise environment but shall not exceed 140 dBP for overall signal sound.

5.3.2.2.3.2 High ambient noise. For any audio signals, if ambient noise levels are too high to accommodate the 15 dBA above ambient without exceeding 140 dBP, other alerting methods (e.g., non-audio signaling or signaling through headset) shall be used.

5.3.2.2.3.3 Persistence. Caution signals shall persist intermittently until restoration of normal conditions or manual shut off.

5.3.2.2.3.4 Reset. Upon termination, caution signals shall be automatically reset to respond to the next initiating condition.

5.3.2.2.3.5 Volume control. A volume control may be incorporated provided full volume is automatically restored upon initiation of the next caution signal.

5.3.2.2.3.6 Two-function caution signals. Two-function caution signals, which provide both the alerting and identification functions, shall be used where the total number of caution signals is small.

5.3.2.2.3.7 Single-function caution signals. A single-function caution signal consists of a signal only and shall be accompanied by a visually-presented message identifying the specific nature of the caution situation.

5.3.2.3 Alerting signals. Alerting signals shall meet the criteria in 5.3.2.3.1 through 5.3.2.3.3.

5.3.2.3.1 General. Alerting signals shall be provided whenever there is a requirement for immediate response to a situation outside of the user's normal task sequence, when some system function needs attention on an irregular basis, or when there may be a minor component failure.

5.3.2.3.2 Nature of alerting signals. The nature of alerting signals shall be in accordance with the criteria in 5.3.2.3.2.1 through 5.3.2.3.2.6.

5.3.2.3.2.1 Composition. Alerting signals shall be of a spectral composition and character more demanding of attention than either advisory or cueing signals.

5.3.2.3.2.2 Periodicity. Alerting signals may be momentary or continuous in nature as appropriate, but if momentary, the alerting signal shall be repeated periodically until either proper action is taken or the signal is turned off.

5.3.2.3.2.3 Persistence. Continuously-presented alerting signals shall persist until proper action is taken or signal is turned off.

5.3.2.3.2.4 Reset. After the signal is terminated, it shall be automatically reset to respond to the next initiating condition.

5.3.2.3.2.5 Volume. Alerting signals shall exceed the ambient noise level in the critical band centered on each major component frequency by a least 15 dBA but should not exceed 140 dBP for overall signal sound.

5.3.2.3.2.6 High ambient noise. For any audio signals, if ambient noise levels are too high to accommodate the 15 dBA ambient noise without exceeding 140 dBP, other alerting methods (e.g., non-audio signaling or signaling through headset) should be used.

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

5.3.2.4 Advisory signals. Audio signals may be provided to transmit information of an advisory nature that does not require specific user response or acknowledgment.

5.3.2.4.1 Advisory signal in quiet areas. In quiet areas below 45 dBA, advisory signals shall be presented at a level of 50 to 70 dBA.

5.3.2.4.2 Advisory signal in noise background. Where there is a noise background, advisory signals shall be at least 15 dBA above the ambient noise level in the critical band centered on each major component frequency of the advisory signal.

5.3.2.4.3 Cueing signals. Cueing signals may be used in combination with visually presented messages providing specific task-element instructions.

5.3.2.4.4 Nature of cueing signals. Cueing signals shall be short, tonal, and non-annoying but distinctive in character. As a general rule, cueing signals shall exceed the noise level in the critical band by at least 15 dBA but shall not exceed 140 dBP for overall signal sound.

5.3.2.4.5 High ambient noise. For any audio signals, if ambient noise levels are too high to accommodate the 15 dBA above ambient without exceeding 140 dBP, other alerting methods (e.g., non-audio signaling or signaling through headset) shall be used.

5.3.2.4.6 Appropriate use of cueing signals. Audio cueing signals shall be provided for pacing user actions in situations requiring timely execution of task elements but where user attention may be diverted from the task at hand, or the user depends on the cueing signal to know when to perform the task.

5.3.2.4.7 Cueing signal repetition. The cueing signal system shall be designed to generate a repetition of the signal if the user fails to perform the desired action.

5.3.2.5 Prioritization. When there is a possibility of simultaneous presentation of automatically initiated messages, a message priority system shall be established such that the most critical message overrides for initial presentation any messages of lower priority.

5.3.2.6 Top-priority messages. Following initial presentation of the top-priority message, other messages shall be presented in priority order, except that no caution messages shall be presented until all warning messages are terminated.

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

5.3.3 Characteristics of audio warning signals.

5.3.3.1 Warning recognition time. Warning signals shall be sufficiently distinctive so that they can be unambiguously recognized as warning signals within 0.5 seconds of initiation.

5.3.3.1.1 Single-element signals. Single-element signals shall convey full meaning of the signal within that initial 0.5-second period.

5.3.3.1.2 Two-element signals. Two-element signals shall convey full meaning of the signal within 2.5 seconds of initiation.

5.3.3.2 Control of warning signals. Warning signals may be either manually or automatically initiated, whichever is more appropriate to the circumstances.

5.3.3.2.1 Manually initiated signals. Manually initiated signals shall be manually terminated.

5.3.3.2.2 Automatically initiated signals. Automatically initiated signals shall be in accordance with the criteria in 5.3.3.2.2.1 through 5.3.3.2.2.5.

5.3.3.2.2.1 Persistence. Automatically initiated signals shall persist until either automatically or manually terminated.

5.3.3.2.2.2 Automatic termination. Automatic termination shall not be on a time basis but rather on either initiation of action to restore normal conditions or upon restoration of normal conditions.

5.3.3.2.2.3 Manual termination. Provision for manual termination shall be provided.

5.3.3.2.2.4 Automatic reset. Automatic reset for the next initiating condition shall be provided for all signals that can be automatically initiated.

5.3.3.2.2.5 Volume control. Local area volume control (with volume reduction limited to ensure signal audibility) may be incorporated provided full volume is automatically restored upon initiation of the next warning signal.

5.3.3.3 Frequency. The frequency of warning signals shall meet the criteria in 5.3.3.3.1 through 5.3.3.3.1.3.

5.3.3.3.1 Frequency range. The frequency range shall be between 250 and 8,000 hertz and, if possible, between 500 and 2,000 hertz.

5.3.3.3.1.1 Difference from background. The selected frequency band shall differ from the most intense background frequencies.

5.3.3.3.1.2 Signals traveling long distances. When signals must travel over 300 m (985 ft), sounds with frequencies below 1,000 hertz shall be used.

5.3.3.3.1.3 Signals traveling through obstacles. Frequencies below 500 hertz shall be used when signals must bend around obstacles or pass through partitions.

5.3.3.3.2 Electric power frequency avoidance. The frequency of a warning tone shall be different from that of the electric power used in the system.

5.3.3.4 Intensity. The intensity of warning signals shall meet the criteria in 5.3.3.4.1 through 5.3.3.4.6.

5.3.3.4.1 Compatibility with acoustical environment. The intensity, duration, and source location of audio alarms and signals shall be compatible with the acoustical environment of the intended receiver as well as the requirements of other personnel in the signal area.

5.3.3.4.2 Compatibility with existing signal codes. Warning signal characteristics and meanings selected for a system or facility shall be compatible with signals already established for the particular warning situation.

5.3.3.4.3 Compatibility with other critical signals. No warning signal shall be of such a character as to preclude hearing any other warning signal or reception of vital voice communication.

5.3.3.4.4 Compatibility with clothing and equipment. Audio signals shall be loud enough to be heard and understood through equipment or garments (e.g., parka hood, CBRNE protective hood, PPE, or hearing protective devices) covering the ears of the listener. When hearing protection is required, consider incorporating audio into the hearing protection, such as integrated headsets or custom molded ear plugs, and play warning signals through the headset (see also 5.3.4.2.7).

5.3.3.4.5 Damage risk control. Audio warning signals shall not be of such intensity as to cause discomfort or "ringing" in the ears.

5.3.3.4.6 Maximum level. Sound pressure levels shall not exceed 115 dBA measured at the ear of the listener.

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 10 decibels shall be provided in at least one octave band between 200 and 5,000 hertz at the operating position of the intended receiver. Signal-to-noise ratios can be greater as long as the levels do not exceed 115 dBA at the ear of the listener.

5.3.4.2 Alerting capability. Alerting capabilities shall meet the criteria in 5.3.4.2.1 through 5.3.4.2.7.2.

5.3.4.2.1 Attention and avoidance of startle reaction. Signals with high alerting capacity shall be provided when the system or equipment requires the user to concentrate attention.

5.3.4.2.2 Alerting signals. Alerting signals shall not be so startling as to preclude appropriate responses or interfere with other functions by holding attention away from other critical signals.

5.3.4.2.3 Minimize startle. To minimize startle reactions, the increase in sound level during any 0.5-second period shall be not greater than 30 decibels.

5.3.4.2.4 Intensity. The first 0.2 seconds of a signal shall not be presented at maximum intensity, use square topped waveforms, or present abruptly rising waveforms.

5.3.4.2.5 Onset and sound pressure level. The onset of critical alerting signals shall be sudden.

5.3.4.2.6 Dichotic presentation. When earphones will be worn in the operational situation, a dichotic presentation of alerts shall be used whenever feasible that alternates the signal from one ear to the other by means of a stereo (dual channel) headset.

5.3.4.2.7 Headset. When the user is wearing earphones covering both ears during normal equipment operation, the audio alarm signal shall be directed to the user's headset as well as to the work area.

5.3.4.2.7.1 Outside alarms. Headsets shall not block outside critical alarms.

5.3.4.2.7.2 Binaural headsets. Binaural headsets shall not be required to be used in any operational environment below 85 dBA where sounds that provide the user with useful information cannot be directed to the user's headset.

5.3.4.3 Discriminability. Discriminability shall meet the criteria in 5.3.4.3.1 through 5.3.4.3.7.

5.3.4.3.1 Use of different characteristics. When several different audio signals are to be used to alert a user to different types of conditions, discriminable differences in intensity, pitch, beats and harmonics, or temporal patterns shall be provided.

5.3.4.3.1.1 Absolute discrimination. If absolute discrimination is required, the number of signals to be identified shall not exceed four.

5.3.4.3.1.2 Signal intensity. Signal intensity shall not be used alone as a means of discriminating between signals.

5.3.4.3.1.3 Warnings. Warnings shall differ on two or more parameters.

5.3.4.3.2 Audio signal coding. Where discrimination of warning signals from each other will be critical to personnel safety or system performance, audio signals shall be appropriately coded.

5.3.4.3.3 Perceptibly different alarms. Alarms that are perceptibly different shall correlate with different conditions requiring critically different user responses (e.g., maintenance, emergency conditions, and health hazards).

5.3.4.3.3.1 Search of visual displays. Such signals shall be sufficiently different to minimize the user's search of visual displays.

5.3.4.3.3.2 Harmonically related frequencies. Harmonically related frequencies shall not be used to code different signals; however, they may be used within a single signal.

5.3.4.3.4 Critical signals. Familiar signals with established names or associations shall be selected.

5.3.4.3.4.1 Discriminable from other signals. The first 0.5 seconds of an audio signal requiring fast reaction shall be discriminable from the first 0.5 seconds of any other signal that may occur.

5.3.4.3.4.2 Speech. Speech shall be used whenever feasible.

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

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

5.3.4.3.7 Prohibited types of signals. The following types of signals shall not be used as warnings 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 that 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. Compatibility designs shall meet the criteria in 5.3.4.4.1 through 5.3.4.4.3.

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

5.3.4.4.2 Existing signal compatibility. Established signals shall be used, provided they are compatible with the acoustic environment and the requirements specified herein for the voice communication system.

5.3.4.4.3 Standard signals. Standard signals shall not be used to convey new meanings.

5.3.4.5 Masking. Audio warning signals shall not interfere with any other critical functions or warning signals, or mask any other critical audio signals. 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. When required by operating conditions, this dichotic presentation may also alternate the two signals from ear to ear.

5.3.5 Verbal warning signals.

5.3.5.1 Nature of signals. Verbal warning signals shall have the following two components:

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

b. A brief standardized verbal message to identify the specific condition and to suggest appropriate action.

5.3.5.2 Intensity. Verbal alarms for critical functions shall be not less than 20 dBA above the speech interference level at the operating position of the intended receiver, but should not exceed 140 dBP for overall signal sound.

5.3.5.3 High ambient noise. For any audio signals, if ambient noise levels are too high to accommodate the 15 dBA ambient noise without exceeding 140 dBP, other alerting methods (e.g., non-audio signaling or signaling through headset) should be used.

5.3.5.4 Vocal criteria. The voice shall be distinctive and mature.

5.3.5.5 Message presentation. The message shall be presented in a formal impersonal manner.

5.3.5.6 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 may be used to protect the listener against auditory overload.

5.3.5.7 Message content. Word selection priority shall be intelligibility, descriptiveness, and conciseness, in that order.

5.3.5.8 Comprehension. To provide sufficient context for comprehension, not less than four syllables shall be used unless the resulting message would be inconsistent with standard practice.

5.3.5.9 Verbal critical warnings and priorities. Critical warning signals shall be repeated with not more than a 3-second pause between messages until the condition is corrected or overridden by the crew. Verbal critical warnings shall be in accordance with the criteria in 5.3.5.9.1 through 5.3.5.9.4.

5.3.5.9.1 Priority system. A priority system shall be established to ensure that higher criticality messages override the presentation of lesser priority messages.

5.3.5.9.2 Simultaneous malfunctions. If two or more incidents or malfunctions occur simultaneously, the message having the higher priority shall be given first.

5.3.5.9.3 Remaining messages. The remaining messages shall follow in order of priority.

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

5.3.5.10 Controls for audio warning devices. When an audio signal is designed to persist as long as it contributes useful information, a shutoff switch controllable by the user, the sensing mechanism, or both shall be provided depending on the operational situation and safety factors.

5.3.5.10.1 Manual shutoff. When a manual shutoff is used, a visual indication that the warning has been turned off shall be provided.

5.3.5.10.2 Automatic reset. Whether an audio warning signal is designed to be terminated automatically, manually, or both, an automatic reset function shall be provided.

5.3.5.10.3 Controlled by sensing mechanism. The automatic reset function shall be controlled by the sensing mechanism that recycles the signal system to a specified condition as a function of time or the state of the signaling system so that the warning device can sound again if the condition repeats.

5.3.5.10.4 Redundant visual warning. All nonverbal aural annunciations shall be accompanied by a visual annunciation that 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 provides redundancy.

5.3.5.11 Volume control. Control movements shall be restricted to prevent reducing the volume to an inaudible level, or increasing it to an unacceptably high level. Volume control shall be in accordance with the criteria in 5.3.5.11.1 through 5.3.5.11.5.

5.3.5.11.1 Automatic or manual. The volume (loudness) of an audio warning signal shall be designed to be controlled by the user, the sensing mechanism, or both depending on the operational situation and personnel safety factors.

5.3.5.11.2 Audio signal level. When detection of an audio signal is essential (e.g., hand-held mine detectors), the signal level shall be adjustable by the user.

5.3.5.11.3 Ganging to mode switches. Volume controls may be ganged to mode switches to provide maximum output during mission phases when intense noise may occur and to provide reduced volume at other times.

5.3.5.11.4 Intense noise. Ganging shall not be used if intense noise may occur during an emergency in a mission phase when the volume would be decreased below an audible level.

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

5.3.5.12 Duration. The duration of an audio warning signal shall be at least 0.5 seconds and may continue until the appropriate response is made.

5.3.5.13 Signal termination. The completion of a corrective action by the user or by other means shall automatically terminate the signal.

5.3.5.14 Duration limitations. Signals that persist or increase progressively in level shall not be used for emergency situations if manual shutoff may interfere with the corrective action required.

5.3.5.15 Frequency. The alerting signal shall fall within the range from 250 and 8,000 hertz.

5.3.6 Speech-transmission equipment. Speech-transmission equipment shall be in accordance with the following characteristics.

5.3.6.1 Frequency. Microphones and associated system-input devices shall respond optimally to that part of the speech spectrum most essential to intelligibility (i.e., 200 to 6,300 hertz).

5.3.6.2 Low-bandwidth frequency. Where system engineering necessitates speech-transmission bandwidths narrower than 200 to 6,300 hertz, the minimum acceptable frequency range shall be 250 to 4,000 hertz.

5.3.6.3 Dynamic range. The dynamic range of a microphone used with a selected amplifier shall be wide enough to admit variations in signal input of at least 50 dBA.

5.3.6.4 High-pass filtering. In an environment with predominantly low-frequency noise, 300 hertz cutoff, high-pass filtering shall be used.

5.3.6.5 Loud, low-frequency environments. In very loud, low-frequency noise environments (100 dBA overall), the following shall be applicable.

5.3.6.5.1 Use of noise-canceling microphones. Noise canceling microphones shall be used.

5.3.6.5.2 Characteristics of noise-cancelling microphones. Noise canceling microphones shall be capable of achieving an improvement of not less than 10 dBA peak-speech to root-mean-square noise ratio as compared with non-noise-canceling microphones of equivalent transmission characteristics.

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

5.3.6.7 Peak-clipping of speech signals. Where speech signals are to be transmitted over channels showing less than 15 decibels peak-speech to root-mean-square noise ratios, peak clipping of 12 to 20 decibels may be employed at system input and may be preceded by frequency pre-emphasis as specified in 5.3.6.6.

5.3.6.8 Noise shields. When the talker is in an intense noise field, the microphone shall be put in a noise shield. Noise shields shall meet the following requirements.

5.3.6.8.1 Volume. A volume of at least 250 cubic centimeters (cm^3) (15.25 cubic inches [in^3]) shall be provided to permit a pressure gradient microphone to function normally.

5.3.6.8.2 Seal. A good seal shall be provided against the face with the pressure of the hand or the tension of straps.

5.3.6.8.3 Prevent pressure buildup. A hole or combination of holes covering a total area of 65 square millimeters (mm^2) (0.1 square inch [in^2]) shall be provided in the shield to prevent pressure buildup.

5.3.6.8.4 Resonance. Resonances within the noise shield shall be reduced by shape or by use of sound absorbing material.

5.3.6.8.5 Impediments. The shield shall present no impediment to voice effort, mouth and jaw movement, or breathing.

5.3.6.9 Automatic signal level control. Automatic signal level control may be used in situations with a consistent speech-to-noise differential not greater than 20 dBA.

5.3.6.10 Binaural earphone latency difference. Except for 3-D sound localization applications, critical voice communications systems shall not introduce a discernible binaural asynchronous delay (greater than 1 millisecond). Binaural earphones used for critical voice communication systems shall not have a latency difference between the earphones greater than 20 microseconds.

5.3.6.11 Speaker side tone. The speaker's verbal input shall be in phase with its reproduction as heard on the headset.

5.3.6.11.1 Filtering. This side tone shall not be filtered or modified before it is received in the headset.

5.3.6.11.2 Feedback. Feedback of the speaker's own voice (side tone) shall be provided via the earphones.

5.3.7 Speech reception equipment. Speech reception equipment shall meet the criteria in 5.3.7.1 through 5.3.7.8.2.

5.3.7.1 Frequency range. Headphones and loudspeakers shall be subject to the same frequency response restrictions as microphones and transmission equipment except as described herein.

5.3.7.2 Loudspeakers in multi-speaker installations. Loudspeakers used in multi-speaker installations and headphones receiving feeds from multiple channels (e.g., where several speech channels are to be monitored simultaneously) shall respond uniformly (±5 decibels) from 100 to 4,800 hertz.

5.3.7.3 Loudspeakers for multi-channel monitoring. If several channels are to be monitored simultaneously by means of loudspeakers, the loudspeakers shall be mounted on a horizontal plane around the user's normal forward-facing position such that the angular distance between loudspeakers is maximized within the user's work station. There shall be a minimum spacing of 10 degrees for loudspeakers within 10 degrees of forward facing, 20 degrees from 10 to 45 degrees of forward facing, and 45 degrees for 45 to 90 degrees of forward facing.

5.3.7.4 Active channel indication. If multiple channels are to be monitored simultaneously, a visual signal shall be provided to show which channel is active.

5.3.7.5 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 decibels per octave over the frequency range 140 to 4,800 hertz).

5.3.7.6 Headsets. If listeners will work in high ambient noise (85 dBA or above), binaural rather than monaural headsets shall be provided. Binaural headsets shall be in accordance with the criteria in 5.3.7.6.1 through 5.3.7.6.3.

5.3.7.6.1 Wiring. If dual mono headphones are used, they shall be wired so that the sound reaches the two ears in phase.

5.3.7.6.2 Attenuation. The attenuation qualities of binaural headsets shall be capable of reducing the ambient noise level to less than 85 dBA.

5.3.7.6.3 Provision for eyeglasses wearers. Provisions shall be incorporated to furnish the same protection, regardless of whether or not users wear glasses.

5.3.7.7 Earphone/speaker-to-microphone feedback isolation. Sufficient electrical, mechanical, and acoustical isolation shall be provided to preclude feedback oscillations (squeal problems) or echo effects (non-discernible unwanted voice echo to speaker).

5.3.7.8 Public address systems. The location, number, and loudness of speakers shall provide intelligible signals and messages to all personnel.

5.3.7.8.1 Reverberant spaces. Speaker range in reverberant spaces shall be not greater than 15 m (50 ft) to avoid excessive echoing (see 5.5.4.6.3).

5.3.7.8.2 Audio warnings. Speaker amplitude shall not mask audio warnings.

5.3.8 User comfort and convenience. User comfort and convenience shall meet the criteria in 5.3.8.1 through 5.3.8.8.

5.3.8.1 Comfort. Communication equipment to be worn by a user (e.g., headphones and telephone headsets) shall be designed to prevent metal or any other rigid parts of the headset from contacting the user's skin.

5.3.8.2 Communication equipment. Communication equipment shall preclude user discomfort.

5.3.8.3 Biological organisms. Materials selected shall be impervious to biological organisms such as molds and fungi.

5.3.8.4 Humidity and perspiration. Materials selected shall not deteriorate from humidity or perspiration within thermal environments specified by the procuring activity (see 6.2).

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

5.3.8.6 Accessibility of handsets. Where communication requirements necessitate the use of several telephone handsets, the accessibility of their standby locations shall be determined by operational priority (i.e., the most frequently or urgently needed handset shall be the most accessible). The handsets may also be color coded if they will be visible to operating personnel under the working conditions.

5.3.8.7 Operating controls for voice communication equipment. For situations in which users using microphones or headsets also have both hands occupied most of the time, consideration shall be given to providing hands-free operation of microphone and headset switching through use of foot switches, voice-actuated switches, or remotely controlled switches as appropriate to the circuits in use.

5.3.8.8 Operation from standing position. If there may be any requirement to operate the microphone or headset switching from a standing position, then hand-operated switches shall be provided.

5.3.8.9 Volume controls. Volume controls shall be in accordance with the criteria in 5.3.8.9.1 through 5.3.8.9.5.

5.3.8.9.1 Accessible controls. Accessible volume or gain controls shall be provided for each communication receiving channel (e.g., loudspeakers or headphones).

5.3.8.9.2 Provision of controls power. Volume or gain controls shall be provided with enough electrical power to drive sound pressure level (SPL) to at least 100 dBA overall when using two earphones.

5.3.8.9.2.1 Use of earplugs. When the noise environment requires the use of earplugs, communication earplugs shall be used if operationally feasible. If communication earplugs cannot be used, the power requirements shall be increased by the earplugs' mean attenuation at 1,000 hertz.

5.3.8.9.2.2 Maximum sound pressure level. The SPL of communications earplugs shall not exceed 90 dBA at the eardrum.

5.3.8.9.3 Controls switch compensation for unpressurized compartments. Volume or gain controls shall have pressure operated gain control switches to compensate for altitude in unpressurized compartments.

5.3.8.9.4 Minimum setting of volume controls. 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).

5.3.8.9.5 Power controls. When power (ON/OFF) and volume adjustment are combined into the same control, a noticeable detent position shall be provided between the clearly labeled OFF position and the lower end of the continuous range of volume adjustment.

5.3.8.10 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.

5.3.8.11 Weak signals. A manually operated ON/OFF switch shall be provided to deactivate the squelch when receiving weak signals.

5.3.8.12 Foot-operated controls. Foot-operated controls shall be provided when normal working conditions will permit the user to remain seated at the working position and require access to "talk-listen" or "send-receive" control switches or if console operation requires the use of both hands.

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

5.3.9 Audio displays as part of the user interface. Audio displays may be used as part of the user-computer interface where the common mode of visual display is restricted by overburdening or user mobility needs and it is desirable to cue, alert, or warn the user, or when the user is provided feedback after control actuation, data entry, or completion of timing cycles and sequences. For other interface requirements, see 5.3.1 and 5.3.2. For frequency of audio warning signals, see 5.3.3.3. For audibility of audio displays, see 5.3.4.1.

5.3.9.1 Supportive function. Audio signals used in conjunction with visual displays shall be supplementary to the visual signals.

5.3.9.2 Alert and direct user's attention. Audio signals shall be used to alert and direct the user's attention to the appropriate visual display.

5.3.9.3 Signal characteristics. Signals may be one-time or intermittent.

5.3.9.4 Intermittent signals. Intermittent signals shall be automatically terminated when no longer applicable or by user control.

5.3.9.5 Alarm settings. When alarm signals are established on the basis of user-defined logic, users shall be permitted to obtain status information concerning current alarm settings in terms of dimensions (variables) covered and values (categories) established as critical.

5.3.9.6 Alarm status information. Alarm status information shall be provided in monitoring situations where responsibility may be shifted from one user to another, as in changes of shift.

5.3.9.7 3-D audio displays. 3-D audio displays shall meet the criteria in 5.3.9.7.1 through 5.3.9.7.5.

5.3.9.7.1 Use. 3-D audio displays or multiple voice communications may be used in an environment with numerous and important spatial cues or where a user is likely to be highly tasked visually (e.g., fighter cockpits) to enhance situation awareness, segregate multiple channels, or rapidly redirect the user's vision.

5.3.9.7.2 Presentation format. For most applications, 3-D audio displays shall present data as discrete sound sources located at a constant distance at various azimuths and elevations.

5.3.9.7.3 Angular separation. Angular separation between discrete sounds shall be not less than 15 degrees in the horizontal plane and not less than 30 degrees in the vertical plane unless indicating location of real objects or events.

5.3.9.7.4 Binaural versus monaural. 3-D audio cues shall be presented binaurally.

5.3.9.7.5 Frequency response. The audio system shall be compatible with stereo audio for ⅓ octave bands from 100 hertz to 16 kilohertz.

5.3.10 Speech displays. Speech displays shall meet the criteria in 5.3.10.1 through 5.3.10.8.

5.3.10.1 Use. Voice communication shall be considered for the following situations:

a. The message content or format cannot be predicted in advance.
b. Where mobility is necessary or where the user's eyes are busy.
c. Extensive or rapid interaction between users will be required.
d. The voice signal itself offers assurance of essential psychological support not otherwise available.
e. Users cannot conveniently look at a visual display to obtain information.
f. In a "hands-busy" situation.
g. To announce discrete events.

5.3.10.2 Non-use. Voice communication shall not be used in the following situations:

a. For continuous status information.
b. If display use frequency is high.
c. If simultaneous display of multiple messages is required.
d. If messages are long.
e. If messages include information that must be memorized.
f. If messages include a series of instructions that must be remembered.

5.3.10.3 Output rate. All speech displays shall provide an output rate between 150 and 180 words per minute.

5.3.10.4 Digitized speech. Digitized speech or synthesized speech may be used as long as the intelligibility requirements of MIL-STD-1474 are met.

5.3.10.5 Message priority control. Where simultaneous messages could occur, they shall be prioritized so that the initial presentation of the most critical message receives transmission priority and overrides lower priority messages.

5.3.10.6 Instructional display structure. Instructional prompt messages shall be structured with the desired goal first, followed by the desired action (e.g., "to delete, press enter" rather than "press ENTER to delete").

5.3.10.6.1 Prompts. Prompts shall be repeated following a user command or 10 seconds of inactivity.

5.3.10.6.2 User response. If the user is required to take an action, a revised version of this message prompt shall be displayed that indicates to the user that the system is waiting for a response and gives the user additional instructions on how to respond (if applicable).

5.3.10.7 Message cancel capability. A manual cancellation capability shall be provided for all speech displays after the initial presentation.

5.3.10.8 Say again capability. Message repetition shall be provided on user's command.

5.3.11 Speech intelligibility.

5.3.11.1 Use. When information concerning the speech intelligibility of a system is required, two recommended methods are available, with the appropriate selection being dependent upon the requirements of the test.

5.3.11.1.1 Modified rhyme test (MRT). The MRT described in ANSI/ASA S3.2 shall be used to measure the communication performance of most military communication systems.

5.3.11.1.2 Articulation index (AI). The AI or the speech transmission index (STI) shall be used as predictive estimators of intelligibility.

5.3.11.2 Criteria. The intelligibility criteria shown in table XVII shall be used for voice communication. The efficiency of communications needed and the type of material to be transmitted shall determine which of the communication requirements of table XVII is to be selected.

TABLE XVII. Intelligibility criteria for voice communication systems.

Communication Requirement	**Score**	
	MRT	**AI** [1/]
Exceptionally high intelligibility	97%	0.7
Normal acceptable intelligibility	91%	0.5
Minimally acceptable intelligibility for mechanized equipment user(s)	80%	0.4
Minimally acceptable intelligibility	75%	0.3

NOTE:

[1/] The AI shall not be used to measure intelligibility of synthetic speech because some key acoustic features are not present in non-human "speech". Instead, intelligibility of synthetic speech shall be measured using representative panels of talkers and listeners. See MIL-STD-1474.

5.3.12 Communications. Communications shall meet the criteria in 5.3.12.1 through 5.3.12.7.2.

5.3.12.1 General.

5.3.12.1.1 Frequency range. Communication requirements shall be based on the one-third octave band center frequency range of 160 to 5,000 hertz. Most of the energy required for near-perfect speech intelligibility are in the range of 200 to 6,300 hertz. Consonants contain energy mainly at frequencies above 1,500 hertz, whereas vowels contain lower-frequency energy. Unfortunately, the consonants, which convey most of the information in English speech, contain very little energy.

5.3.12.1.2 Power. The communication system shall be capable of power output at least 15 dBA higher in sound intensity than the anticipated ambient noise.

5.3.12.1.3 Gain control. The user shall have a gain control for adjusting the output level.

5.3.12.1.4 Sound pressure level. Output sound pressure level shall not exceed 115 dBP voice level at the ear, but where appropriate, the average level may be increased by using compression or automatic volume control.

5.3.12.1.5 Audible signals. When two or more items of communication equipment with audible signals (telephone, radio, and intercom) are in the same area, each shall have a distinct signal.

5.3.12.1.6 3-D audio technology. If distinct signals are not possible, 3-D audio technology shall be used.

5.3.12.2 Receiver and headset. The receiver and headset shall have a frequency response of +3.0 decibels between 250 and 6,000 hertz to maximize intelligibility.

5.3.12.2.1 Warning signals. Auditory warning signals shall be presented through the user's headset and to the work area when ambient noise level will exceed 85 dBA or when the user will ordinarily wear earphones covering both ears during normal equipment operation.

5.3.12.2.2 Headsets. If listeners wear headsets while working in high ambient noise (85 dBA or above), headsets shall cover both ears and their attenuation qualities shall be capable of reducing the ambient noise level to less than 85 dBA.

5.3.12.2.2.1 Critical alarms. Headsets shall not block outside critical alarms.

5.3.12.2.2.2 Microphones. Microphones on headsets used in high ambient noise conditions shall support active or passive noise reduction as required to meet speech intelligibility requirements.

5.3.12.2.2.3 Push-to-talk. Push-to-talk shall be used where appropriate to minimize time on air with high ambient noise interference.

5.3.12.2.2.4 Headset jacks. Headset jacks or connectors shall be placed so the headset cord will not obstruct the work area or interfere with the user's normal functions.

5.3.12.3 Radio sets. Radio sets shall be in accordance with the criteria in 5.3.12.3.1 through 5.3.12.3.1.5.

5.3.12.3.1 Location. The radio set shall be located where normal system operations and crew activities are not likely to damage it.

5.3.12.3.1.1 Interference. Such locations shall also minimize interference with the crew's normal range of movement and eliminate hazards to them.

5.3.12.3.1.2 Radio control panels. Radio control panels shall be readily visible and accessible to users.

5.3.12.3.1.3 Reach. The user shall be able to reach control panel(s) to change frequency without having to open doors or remove covers.

5.3.12.3.1.4 Protective devices. When protective devices such as fuses and circuit breakers are located inside the equipment, there shall be a visible status indicator where the user can see it.

5.3.12.3.1.5 Controls. The user shall be able to manipulate and utilize all controls while wearing gloves if required for operational use.

5.3.12.3.2 Safety. All external metal parts that users ordinarily touch shall be at ground potential.

5.3.12.3.2.1 Discharge high-voltage circuits. There shall be a provision for discharging high-voltage circuits and capacitors to 30 volts within 2 seconds before maintenance personnel work on them.

5.3.12.3.2.2 Exposed terminals. If components in a high-voltage circuit have exposed terminals, they shall be protected so that operating and maintenance personnel cannot short circuit, ground, or contact them accidentally.

5.3.12.4 Radio antenna.

5.3.12.4.1 Location. Locations for radio antennas shall be selected to minimize the possibility of radio frequency hazards to personnel.

5.3.12.4.2 Ground potential. Antennas and waveguides shall be at ground potential except for the radio frequency energy meant to be radiated.

5.3.12.5 Control box. Control boxes shall be located in an area that provides users easy access to controls.

5.3.12.5.1 Interference. The control boxes shall not interfere with the user's normal movements or present any hazard to them.

5.3.12.5.2 Footsteps. The control boxes shall not be placed where they are likely to be used as footrests or steps.

5.3.12.5.3 Cables. Any cables connected to headsets or microphones shall be clear of rotating or moving linkages.

5.3.12.5.4 Reach. Boxes shall be within easy reach of standard connecting cables (760 mm [30 in]) from the operator's nominal working area.

5.3.12.5.5 Warning lights. If warning lights are mounted on the control box, they shall be located within the responsible operator's field of vision.

5.3.12.6 Audio accessories.

5.3.12.6.1 Stowage mechanisms. Stowage mechanisms (e.g., hooks or hook-and-loop fastener straps) shall be provided in each crewmember's normal working area for storing audio accessories such as microphones, headsets, handsets, and cords when not in use.

5.3.12.6.2 Obstruction. Stowage mechanisms shall be located where they will neither obstruct the user's normal movements nor be likely to cause injury when equipment is removed from stowed positions.

5.3.12.7 Cable routing.

5.3.12.7.1 Neat routing. All interconnecting cables shall be routed neatly (clamped at approximately 300 mm- (12-in) intervals) to eliminate droop and unnecessary loops so that personnel are not apt to use them as handholds or steps.

5.3.12.7.2 Protective guards. If neat routing is not feasible, cables shall be covered by protective guards.

5.3.13 Speech recognition.

5.3.13.1 Use. Speech recognition systems may be used as controls when the user's hands are occupied, when regular or frequent mobility is required, or when the user's visual attention is fully occupied. Speech recognition systems should be used when:

a. The consequences of recognition errors are low.
b. Identifying and correcting errors is easy.
c. Use is expected to be infrequent.
d. The system can be readily inhibited when speech recognition is not desired.

5.3.13.2 Nonuse. Speech recognition systems shall not be used for tasks that involve describing the position or manipulation of objects. Speech recognition systems shall be used only where satisfactory performance can be obtained. This may preclude environments that produce stress in the user, are noisy, or have high G-loading.

5.3.13.3 Adapt to the user and environment. Speech recognition systems shall adapt to variability in acoustic environments, speaker styles, and user errors.

5.3.13.4 Minimal training. Speech recognition systems shall require minimal training.

5.3.13.5 Feedback. Speech recognition systems shall provide feedback to the user so the user knows the system has understood them.

5.3.13.6 Input vocabulary. Input vocabulary shall be minimized consistent with system needs and selected to provide phonetically distinct elements to eliminate misinterpretation.

5.3.13.7 Interword delays. Speech recognition systems shall not require interword delays or exaggeration in speech.

5.3.13.8 Prompting. Voice prompting from the computer shall be provided where there is an advantage to freeing the user from reading a display.

5.3.13.9 Lack of user response. Lack of user response to the prompt shall result in a repetition of the prompt.

5.3.13.10 Correction capability. A capability shall be provided to reject unintended and involuntary sounds such as sneezes, coughs, throat clearing, or non-command words.

5.3.14 Alternative input devices.

5.3.14.1 Speech recognition devices. Speech recognition devices shall not be used as the sole control device.

5.3.14.2 Alternative control device. An alternative control device shall be provided in case of speech recognition device degradation or failure.

5.4 Labeling and marking. While the focus of this section is labels that appear on controls, instruments, gauges, consoles, panels, equipment, signs, and placards, it is possible that some of the requirements and design criteria herein will also apply to labels on electronic displays. The reader is cautioned to ensure the appropriateness of the requirements and design criteria herein to labels on electronic displays before application. Design rules for labels, markings, and colors for controls are given in this section. In this section, the term “label” is intended to include legends and markings.

5.4.1 General. Label characteristics shall be consistent with requirements for accuracy of identification, time available for recognition or other responses, distance at which the labels must be read, illumination level and color, criticality of the function labeled, and label design within and among controls and systems.

5.4.1.1 Need for labeling. Controls, displays, and other items that must be located, identified, or manipulated should be appropriately and clearly labeled to permit rapid and accurate human performance.

5.4.1.2 Clear labeling. Controls and displays shall be appropriately and clearly labeled with the basic information needed for proper identification, utilization, actuation, or manipulation of the item.

5.4.1.3 Use. Except where it is obvious to observers what an item is and what they are to do with it, labels shall be provided whenever it is necessary for users to locate and identify items, to interpret and follow procedures, or to avoid hazards.

5.4.1.4 Principles of labeling. Labels shall meet the following criteria:

a. Give the user relevant information needed to perform his or her task.

b. Where appropriate, be supplemented with other coding, such as color and shape (as in warning or danger signs).

c. Use only boldface type to emphasize words or phrases.

5.4.1.5 Functional result. The labels for controls shall indicate the functional result of control movement, such as increase, ON, and OFF.

5.4.1.6 Functional relationship. When controls and displays must be used together to make adjustments, appropriate labels shall indicate their functional relationship.

5.4.1.7 Hierarchical labeling. A hierarchical labeling scheme shall be used on panels to reduce confusion and search time based on the following criteria:

a. Use major labels to identify major systems or user workstations.

b. Use subordinate or group labels to identify subsystem or functional groups.

c. Use component labels to identify each panel or console element.

d. Do not repeat information contained in higher-level labels in lower level labels.

5.4.1.7.1 Size graduation. To reduce confusion and operator search time, labels shall be graduated in size.

5.4.1.7.1.1 Character size on group labels. The characters in group labels shall be larger than those used to identify individual controls and displays, unless analysis shows that individual control labels should have primacy.

5.4.1.7.1.2 Character size for controls and displays. The characters identifying controls and displays shall be larger than the characters identifying control positions.

5.4.1.7.1.3 Determination of smallest character size. With the smallest characters determined by viewing conditions, the dimensions (height and width) of each character shall be at least 25 percent larger than those of the next smaller label.

5.4.1.7.1.4 Lines of demarcation. Lines of demarcation shall have enough contrast to be visually distinctive from the panel background.

5.4.1.7.2 Letter size in hierarchical labels. Labels should be graduated in letter size such that system or workstation labels are about 25 percent larger than subsystem or functional group labels, subsystem or functional group labels are about 25 percent larger than component labels, and component labels are about 25 percent larger than control position labels (see figure 30).

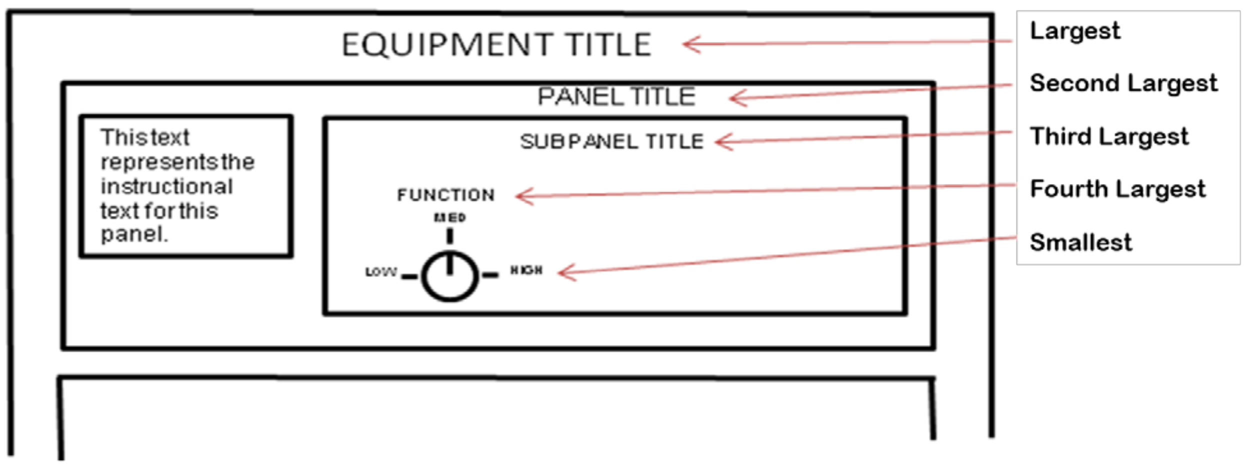


FIGURE 30. Label-size hierarchy.

5.4.1.8 Labels in environmental extremes. Labels subject to exposure in environmental extremes (e.g. exposure to deteriorating chemicals, weather, elevated or cold temperatures, and other environmental and physical elements) for an extended period of time shall be evaluated using an appropriate standard.

5.4.2 Location.

5.4.2.1 Consistent location. Labels shall be consistently located relative to the object being labeled throughout the system.

5.4.2.2 Readability. Control labels shall be located so that they are readable regardless of the position of the control.

5.4.2.2.1 Visible during control actuation. Labels shall be visible to the user during control actuation.

5.4.2.2.2 Discrete functions. All discrete functional control positions shall be identified.

5.4.2.2.3 Direction. Direction of motion (increase, decrease) should be identified for continuous-motion rotary controls.

5.4.2.3 Obscuration. Labels shall not obscure, or be obscured, by other sources of information.

5.4.2.4 Position near control or visual indicator. Labels shall be placed on or very near the items that they identify.

5.4.3 Placement.

5.4.3.1 At or below eye level. When controls are placed at or below eye level, the corresponding label should be placed above the controls or display that they describe.

5.4.3.2 Above eye level. When controls are placed above eye level, the corresponding label may be located below the control if label visibility will be enhanced.

5.4.3.3 Floor level. Labels shall not be placed near the floor or other positions that preclude the observer from easily viewing the label from work posture appropriate to the equipment.

5.4.3.4 Overhead panels. On overhead panels, markings and labeling should be oriented so that they appear upright when viewed from the user's operational position.

5.4.3.5 Overhead items. Items that are located overhead and out of view should be identified with labels on walls with an arrow pointing in the direction of the item.

5.4.3.6 Moveable controls. Labels shall not be placed on movable controls that allow the label to rotate to an upside-down position.

5.4.3.7 Redundant labeling. Redundant labeling shall be used for installations such as pipes that take several runs and can be viewed from several planes or components that can be viewed from two sides.

5.4.3.8 Adjacent labels. Adjacent labels shall be sufficiently separated to not be read as one continuous label.

5.4.3.9 Functional grouping. Labels shall be used to identify functionally grouped controls.

5.4.3.9.1 Line enclosing a grouping. 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.

5.4.3.9.2 Colored areas. When colored areas are used and space is available, the label shall be centered at the top within the area.

5.4.3.9.3 Insufficient space. When there is insufficient room for the label to be centered in the enclosed or colored area, it shall be located in the best available space provided the grouping is demarcated.

5.4.4 Orientation. The orientation of labels shall conform to figure 31.

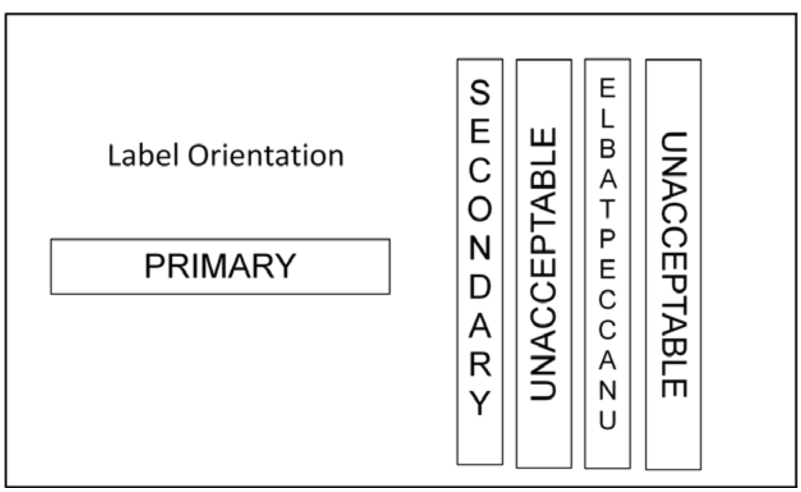


FIGURE 31. Orientation of labels.

5.4.4.1 Horizontal orientation. Labels and information thereon (i.e., words and symbols) shall be oriented so that alphanumeric characters are read horizontally from left to right.

5.4.4.2 Vertical orientation.

5.4.4.2.1 Use of vertical orientation. Vertical orientation should be used only when labels are not critical for personnel safety or performance and where space is limited.

5.4.4.2.2 Reading labels in a vertical orientation. When used, vertical labels shall read from top to bottom.

5.4.4.2.3 Orientation of characters. Where vertical orientation is necessary, the characters shall be readable in an upright orientation.

5.4.5 Visibility and legibility.

5.4.5.1 Accurate reading. Labels shall be easy to read accurately from the operational reading distances and in the anticipated vibration and illumination environments.

5.4.5.2 Considerations. The design of labels shall consider the following factors:

a. Contrast between the lettering and its immediate background.

b. Height, width, stroke width, spacing, style of letters and numerals, and size of detail for other abstract or pictorial symbols.

c. Method of application (etching, engraving, decal, silk screen).

d. Relative legibility of alternate words that might be used to convey the same meaning.

e. Specular reflection.

5.4.5.3 Access. Labels shall be placed on the outside of equipment covers to identify control, display, or other functions located within a covered compartment.

5.4.5.4 Access opening label. Access openings shall be labeled to identify the functions of items accessible through them.

5.4.5.5 Cables. Labels attached to lines or cables for the purpose of identification shall be positioned so the label is visible and properly oriented with respect to the normal viewing position of the maintainer.

5.4.5.5.1 Cable ends. Both ends of a cable or line shall be labeled.

5.4.5.5.2 Cable connections. Cable connection elements shall contain appropriate matching labels.

5.4.5.6 Color and contrast.

5.4.5.6.1 Label color. Label color(s) shall be chosen for maximum contrast against the label background and the surrounding equipment.

5.4.5.6.2 Contrast. When the ambient illumination will be above 10 lx (0.9 fc), dark characters on a light background should be used.

5.4.5.6.3 Color coding. If color coding is used, the number of different colors shall not exceed five.

5.4.5.6.4 Markings for dark adaptation. When dark adaptation is required, markings should be white on a dark background.

5.4.5.6.5 Label background. Labels that include their own independent background shall provide contrast between lettering and the immediate background.

5.4.5.6.6 Metallic backgrounds. Shiny metallic backgrounds shall not be used for labels.

5.4.6 Wording and information.

5.4.6.1 Wording. Labels should be unambiguous and as concise as possible without distorting the intended meaning or information.

5.4.6.2 Short sentences. Short direct sentences in active voice should be used on instructional labels.

5.4.6.3 Equipment functions. Labels shall primarily describe the function(s) of items. If needed for clarity, engineering characteristics or nomenclature may also be described.

5.4.6.3.1 Identify specific function. Where a general function is obvious, only the specific function should be identified (e.g., “rpm” rather than “engine rpm”).

5.4.6.3.2 Instruction labels. Instruction labels should briefly and simply express the intended action.

5.4.6.4 Simplicity. Control and display labels should convey meaning in the most direct manner by using simple words and direct phrases.

5.4.6.5 Commonly used terms and symbols. Terms, abbreviations, and symbols used on panel labels should have commonly accepted meanings for all intended users.

5.4.6.5.1 Technical terms. Unusual technical terms should be avoided.

5.4.6.5.2 Roman numerals. Use of Roman numerals should be avoided.

5.4.6.5.3 Abstract symbols. Abstract symbols should be used only if they have a commonly accepted meaning (e.g., %).

5.4.6.5.4 Distinguishability. Symbols, terms, and characters should be unique and distinguishable from one another.

5.4.6.6 Abbreviations. Abbreviations should be used in labels only if they are familiar to the users (e.g., psi and km).

5.4.6.6.1 New abbreviations. If a new abbreviation is required, its meaning should be obvious to the target user.

5.4.6.6.2 Use of periods. Periods shall be omitted except when needed to preclude misinterpretation.

5.4.6.6.3 Word tense. The same abbreviation shall be used for all tenses.

5.4.6.6.4 Singular and plural forms. The same abbreviation shall be used for singular and plural forms of a word.

5.4.6.6.5 Define abbreviations. All abbreviations should be defined. A list of abbreviation definitions, including acronyms, should be readily accessible to the user.

5.4.6.7 Consistent terms. Designations and terms used on labels shall be consistent with designations and terms in user and technical documentation.

5.4.6.8 Consistent use. Labels shall be consistent within and across panels in their use of words, acronyms, abbreviations, and system or part numbers.

5.4.6.9 Not functionally identical. The same words shall not be used to identify two or more controls or displays when they are not functionally identical.

5.4.6.10 Label similarity. Words and abbreviations of similar appearance should be avoided where an error in interpretation could result.

5.4.6.11 Similar words. When labels containing similar words, abbreviations, or acronyms are located in close proximity to each other, more distinguishable words should be selected or a means of coding should be used to reduce the probability of selecting the wrong control or reading the wrong display.

5.4.6.12 Placards and signs. The design of placards and signs shall meet the following criteria:

a. Omit words that are unnecessary to convey the meaning of the message.

b. Place each procedural step on a separate line and include numbers, dots, or other techniques to emphasize the beginning of each step.

c. Avoid use of instructions that require reference to another resource.

5.4.6.13 Irrelevant information. Trade names and other irrelevant information shall not appear on labels.

5.4.7 Design of label characters.

5.4.7.1 Character height. Character height should subtend a visual angle of 4.4 milliradians (15 minutes) (viewing distance multiplied by 0.004) as a minimum; a visual angle of 5.8 milliradians (20 minutes) (viewing distance multiplied by 0.006) is preferred.

5.4.7.2 Character height for viewing distance. Unless circumstances require otherwise, labels shall be clearly legible at a viewing distance of 710 mm (28 in). The recommended height for letters and numerals at this distance is approximately 5 mm (0.18 in). Table XVIII gives minimum character heights for other viewing distances.

TABLE XVIII. Minimum character height for various viewing distances.

Viewing Distance	Minimum Height
Less than 0.5 m (20 in)	2.3 mm (0.1 in)
0.5 to 1.0 m (20 to 40 in)	4.7 mm (0.2 in)
1.0 to 2.0 m (40 to 80 in)	9.4 mm (0.4 in)
2.0 to 4.0 m (80 to 160 in)	18 mm (0.75 in)
4.0 to 9.0 m (160 to 360 in)	38 mm (1.5 in)

5.4.7.3 Character height versus luminance. Labels shall be clearly visible under all conditions of expected luminance. Table XIX gives minimum character heights for various levels of luminance.

TABLE XIX. Minimum character height for various levels of luminance.

Markings	3.5 cd/m^2 (1 fL) or Below	Above 3.5 cd/m^2 (1 fL)
Critical markings with variable position (e.g., numerals on counters)	5 mm (0.2 in)	3 mm (0.12 in)
Critical markings with fixed position (e.g., numerals on fixed scales, controls, emergency instructions)	4 mm (0.16 in)	2.5 mm (0.1 in)
Non-critical markings (e.g., identification labels, routine instructions)	2.5 mm (0.1 in)	2.5 mm (0.1 in)
NOTE: The above values assume a 710 mm (28 in) viewing distance. For other distances, multiply the above values by D/710 mm (D/28 in).		

5.4.7.4 Stroke width.

5.4.7.4.1 Stroke width in normal illumination. If labels are expected to be read under normal illumination and black characters are specified on a white or light background, the stroke width should be ⅙ to ⅐ of the height.

5.4.7.4.2 Stroke width in dim illumination. Where dark adaptation is required or legibility at night is a critical factor and white characters are specified on a dark background, the stroke width of the characters should be $\frac{1}{7}$ to $\frac{1}{8}$ of the height.

5.4.7.4.3 Stroke width for transilluminated characters. For transilluminated characters, the stroke width should be $\frac{1}{10}$ of the height.

5.4.7.4.4 Consistent stroke width. The stroke width shall be the same for all letters and numerals of equal height.

5.4.7.4.5 Stroke width for distance viewing. The stroke width ratios shall apply regardless of how high characters are made for distance viewing. However, for certain applications, characters with different stroke widths may be used on the same sign for emphasis. In this case, the thinnest character stroke shall be no less than $\frac{1}{8}$ nor the thickest character stroke greater than $\frac{2}{5}$ of the respective character heights.

5.4.7.5 Width-to-height ratios.

5.4.7.5.1 Numerals and letters. The width-to-height ratio for numerals and letters should be 3:5.

5.4.7.5.2 Exceptions. The following items are exceptions to width-to-height ratio requirements:

a. The width-to-height ratio for the letters “M” and “W” should be 4:5.

b. The letter “I” and numeral “1” should be one stroke wide.

c. The numeral “4” should be one stroke wider.

5.4.7.5.3 Wide characters. Where wide characters are required (e.g., labels on curved surfaces, column alignment of numbers), the basic width-to-height ratio may be increased to as much as 1:1.

5.4.7.6 Letter and numeral width.

5.4.7.6.1 Letter width. The width of letters should be $\frac{3}{5}$ to $\frac{4}{5}$ of the height, except for “I”, which should be $\frac{1}{10}$ to $\frac{2}{5}$ of the height.

5.4.7.6.2 Numeral width. The width of numerals should be $\frac{3}{5}$ of the height, except for “4”, which should be $\frac{4}{5}$ of the height, and “1”, which should be $\frac{1}{5}$ of the height.

5.4.7.7 Stroke continuity.

5.4.7.7.1 Continuous stroke characters. Continuous stroke characters should be used where applicable and practical for all equipment labels, legends, placards, and signs.

5.4.7.7.2 Stencil characters. Stencil characters shall not have stroke breaks greater than ½ the character stroke width.

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

5.4.7.9 Word spacing. The minimum space between words shall not be less than $\frac{3}{5}$ of the character height.

5.4.7.10 Line spacing. The minimum space between lines shall be approximately one-half the character height (e.g., line spacing in points equals ½ the font size in points).

5.4.7.11 Capital versus lower case letters.

5.4.7.11.1 Case of letters for unitary labels. When the text on a label is exclusively a single word or referencing a unitary object (e.g., FEED PUMP), the label shall appear as all capital letters.

5.4.7.11.2 Case of letters for multiple-word labels. When the text on a label are phrases or sentences, the text shall appear as mixed case letters.

5.4.7.11.3 Abbreviations. Capital letters should be used for abbreviations.

5.4.7.11.4 Identification labels. Capital letters shall be used for identification labels, headings and subheadings, signal words (e.g., danger, caution, attention, notice), legends, and short message labels.

5.4.7.12 Style or font.

5.4.7.12.1 Plain style. Letters and numerals shall be of a plain style using sans-serif fonts, except as may be necessary to distinguish between characters that might otherwise be confused (e.g., “L”, “I”, “1”, “0”, “O”).

5.4.7.12.2 Confusion between characters. When a label contains pairs of characters that might be confused, the following criteria applies:

a. The lower case letter “l” should have a short extension at the bottom extending to the right.

b. The numeral “1” should have a short extension at the top extending to the left.

c. The numeral “0” should appear narrower than the letter “O” of a given font.

5.4.7.13 Borders.

5.4.7.13.1 Sufficient clear space. There shall be clear space between characters and words used for labeling or signing to facilitate reading at the expected distances.

5.4.7.13.2 Minimum clearance. There shall be a minimum clearance around a character or word of at least ½ the character height.

5.4.8 Label mounting.

5.4.8.1 Attachment. Labels that are not part of the equipment or component shall be securely attached to prevent their loss, damage, slippage, or accidental removal.

5.4.8.2 Attach to structural member. Labels shall be attached to a structural member that is not removed during equipment servicing or routine maintenance.

5.4.8.3 Mechanically mounted. Labels containing critical operational or maintenance information that are susceptible to damage should be mechanically mounted.

5.4.8.4 Corrosion prevention. Metallic labels shall be mounted in a manner that prevents galvanic corrosion.

5.4.8.5 Label removal. Labels shall be removable without damaging the surface upon which it was attached.

5.4.8.6 Mount on flat surfaces. Whenever practicable, labels should be mounted on a flat surface.

5.4.8.7 Curved labels. Curved labels (e.g., a label that is wrapped around a pipe or cable) should be avoided.

5.4.8.8 Maintain visibility. If a label must be placed on a curved surface, lettering or symbols shall be completely visible to the user from the normal viewing position.

5.4.8.9 Label reflectance. Labels shall be constructed of non-reflective materials to avoid illegibility due to a light source being reflected back to the user.

5.4.8.10 Dual labeling. When the curvature of the surface is such that the lettering becomes too small to be read, another mode of labeling, such as an attached tag, shall be used.

5.4.8.11 Tag mounting. When tags are used, the attaching hardware shall be durable and permit secure fastening.

5.4.8.12 Non-interference of tag. The length of the attaching hardware should be minimized so that the tag does not interfere with the operation or maintenance of the equipment.

5.4.8.13 Wear and dirt. Labels shall be mounted to minimize wear or obscuration by grease, grime, or dirt. If grease, grime, or dirt are likely to accumulate, the labels should be mounted on a vertical surface.

5.4.8.14 Overhaul interval. Labels shall remain legible for the overhaul interval of the labeled equipment.

5.4.8.15 Temporary labels. Temporary labels shall not obscure prior permanent labels unless the old label is to be replaced.

5.4.8.16 Tag-outs.

5.4.8.16.1 Identification. Tag-out labels shall clearly identify out-of-service components and equipment.

5.4.8.16.2 Mounting. Tag-outs shall be securely affixed.

5.4.8.16.3 Obscuration. Tag-outs shall not obscure any label associated with the non-operable item.

5.4.8.16.4 Activation. Tag-outs shall be designed to physically prevent actuation of a control.

5.4.8.16.5 Adjacent devices. Tag-outs shall not obscure any adjacent devices or their associated labels.

5.4.9 Pictorial symbols.

5.4.9.1 Faster user response. Pictorial symbols may be used in place of or in addition to word labels when the pictorial provides a faster user response.

5.4.9.2 Avoid ambiguity. Pictorial symbols shall be reflective of the function they are describing in the expected visual operating environment(s).

5.4.9.3 Rotating controls. Pictorial symbols shall not be used on a control that may rotate and position the symbol so that it may be confusing.

5.4.9.4 Arrows. Arrows used in labels or markings shall be clearly recognizable and easily identifiable from typical viewing distances. Simple forms with sharp angles and a tapered overall shape are preferable to wide angles and a relatively uniform overall shape (see figure 32).

Acceptable   Unacceptable

FIGURE 32. Examples of acceptable and unacceptable arrows.

5.4.10 Equipment labeling. Labels and markings on equipment can be used to identify the equipment; provide warnings or cautions; supply useful information, such as instructions, weight, or calibration information; and record and supply historical data, such as the date of servicing or replacement.

5.4.10.1 Units, assemblies, subassemblies, and parts.

5.4.10.1.1 Types of labels.

5.4.10.1.1.1 Equipment identification information labels. Equipment identification labels shall contain information to identify the equipment and its provenance.

5.4.10.1.1.2 Weight labels. Weight and center of gravity placards shall be placed on any unit of equipment that must be moved for maintenance if its weight exceeds 13.6 kg (30 lb).

5.4.10.1.1.3 Number of lifters. If a unit of equipment is designed to be lifted or carried by more than one person, the label shall include the number of people recommended to lift or carry it.

5.4.10.1.1.4 Instruction labels. Critical instructions for the servicing or maintaining a unit of equipment should be provided in a label on the equipment.

5.4.10.1.1.5 Data labels. A label should be provided on a unit of equipment for data that must be available to or recorded by the maintainer.

5.4.10.1.2 Unobstructed label. Each unit, assembly, subassembly, and part shall contain a label placed in a location that provides no visual obstruction from the defined user's viewing area with name, number, code, mark, or symbol, as applicable.

5.4.10.1.3 Location. The gross identifying label on a unit, assembly, or major subassembly shall be located externally in such a position that it is not obscured by adjacent items; on the flattest, most uncluttered surface available; or on a main chassis of the equipment.

5.4.10.1.4 Terms. Equipment shall be labeled with terms descriptive of the test or measurement applicable to their test points.

5.4.10.1.5 Panel identification. If the panel must be identified from others, each panel within a given equipment or console shall be labeled.

5.4.10.1.6 Panel function. When a given panel integrates a specific operating function distinct from another panel, a general system or subsystem identification label shall be provided.

5.4.10.1.7 Subfunction differentiation. When subfunction areas on a single panel must be easily and quickly differentiated from other areas on the panel, the subfunction area shall have a label approximately centered above the subfunction area.

5.4.10.1.8 Subfunction area. When the shape of the components within the subfunction area is not uniform, the surrounding area should have a border to define the limits of the subfunction area.

5.4.10.2 Cabinets.

5.4.10.2.1 Multiple cabinets. When several equipment cabinets are located in a single work area, each cabinet shall be labeled to identify the contents in each equipment cabinet.

5.4.10.2.2 Label location. Cabinet identification labels shall be located in a conspicuous position with respect to the typical observation points from which each piece of equipment must be identifiable.

5.4.10.2.3 Storage cabinets.

5.4.10.2.3.1 Contents. The contents of storage cabinets shall be labeled on the outside of the cabinet door.

5.4.10.2.3.2 Label at eye height. For large storage cabinets, labels should be placed at standing eye height (i.e., between 127 to 165 cm [50 to 65 in] above the standing surface).

5.4.10.2.3.3 Visible when door open. A prominent redundant label that identifies the contents of the cabinet shall be visible when the door is open.

5.4.10.2.4 Label size. The size of the characters on each label shall be consistent with the viewing distance (see table XVIII).

5.4.10.2.5 Label differentiation. Labels for identifying prime equipment cabinets, panels, subfunctions on a panel, and individual panel components shall be capable of being differentiated in terms of the label character height (see 5.4.1.7).

5.4.10.3 Labeling for identification.

5.4.10.3.1 Assembly labels. Assembly labels shall specify the overall system of which the assembly is a part.

5.4.10.3.2 Name and function. Assembly labels shall include the name and function of the assembly.

5.4.10.3.3 Stock number. Assembly labels should include a stock number for requisition purposes.

5.4.10.3.4 Instruction plates. Instruction plates shall be as brief as clarity allows and placed where the user can easily see them.

5.4.10.3.5 Reading order. Instructions shall read from left to right and listed in a step-by-step format rather than in a continuous paragraph.

5.4.10.3.6 Diagrams. Diagrams should contain only the information the user needs.

5.4.10.3.7 Diagram orientation. Diagrams shall be oriented to relate directly to the objects to which they pertain.

5.4.10.3.8 Diagram location. Diagrams shall be located in conspicuous places on or near controls.

5.4.10.4 Lift and hoist points.

5.4.10.4.1 Clearly marked. Lift and hoist points shall be clearly marked indicating weight and stress limitations.

5.4.10.4.2 Point of lift. Lift and hoist points shall be labeled at the point of lift; not on removable parts of the body member that may be separated from the lift point.

5.4.10.5 Warning labels for safety and hazards. Also see 5.7.2.

5.4.10.5.1 Prominent display. If hazards to personnel or equipment may be present, appropriate warning signs or labels shall be displayed prominently.

5.4.10.5.2 Safety standards. All danger, warning, and safety instructions shall be in accordance with appropriate safety standards.

5.5 Environment.

5.5.1 Environmental range. To maximize the effectiveness of the designed system, the system design shall accommodate the full range of environmental conditions in which the system is required to operate and meet the specified performance parameters over that range (see 6.2).

5.5.1.1 Target audience. The design shall accommodate the target audience population that will interact with the system or facility and the clothing and gear the target population will be wearing, carrying, and stowing on the system as specified (see 6.2).

5.5.1.2 Environmental conditions. The system design shall allow operation, maintenance, and support in all environmental conditions and extremes as specified (see 6.2).

5.5.1.3 Impacts from corrosive environments. Corrosion can cause material deterioration that adversely impacts human factors. Military materiel shall be designed to minimize the effect of corrosion conditions that deteriorate materials and could impact operating and maintenance procedures.

5.5.1.4 Corrosion prevention. Corrosion prevention should be sustained for the time between depot level maintenance at a minimum.

5.5.2 General workplace considerations.

5.5.2.1 Heating, ventilating, and air conditioning (HVAC) for manned spaces. Any spaces that will not require HVAC shall be specified (see 6.2).

5.5.2.1.1 General. Indoor climate requirements shall be provided for “manned spaces”. A space is considered “manned” if it is designed for manned entry and routinely occupied continuously for more than a short interval, which typically means 20 minutes.

5.5.2.1.1.1 Ventilation methods. Personnel efficiency, health and health hazard, safety, and energy conservation factors should be considered in selection of ventilation methods (including airflow amounts and efficiency) for manned spaces.

5.5.2.1.1.2 Thermostat. Each manned location (area connected by a common ventilation system) shall have its own thermostat for temperature regulation and dehumidification purposes linked to HVAC systems or equipment. A humidity sensor may be necessary for control of moisture if relative rates of infiltration of moisture and outside air differ.

5.5.2.1.1.3 Monitoring of hazardous contaminants. Provision shall be made for routine and emergency monitoring of hazardous contaminants if their generation and presence may be reasonably anticipated for the environment.

5.5.2.1.2 Heating. Within work environments occupied during extended periods of time including mobile personnel enclosures, heating shall be provided to maintain interior dry bulb temperature above 10 °C (50 °F).

5.5.2.1.2.1 Precise work. If precise work is done for more than 20 minutes in an environment below 16 °C (60 °F), special provisions should be made to keep hands warm.

5.5.2.1.2.2 Heated air discharge. Heating systems shall be designed such that hot air discharge is not directed on personnel.

5.5.2.1.2.3 Ground vehicle heating provisions. For ground vehicle heating requirements, see 5.6.6.

5.5.2.1.2.4 Shipboard heating provisions. For shipboard heating requirements, see Physiological Heat Exposure Limits in NEHC-TM-OEM 6260.6.

5.5.2.1.3 Ventilation. Ventilation design shall meet the following requirements. For design guidance, see the ACGIH publication, "Industrial Ventilation: A Manual of Recommended Practice for Design."

5.5.2.1.3.1 Capture contaminants. Ventilation systems shall be designed to capture and contain contaminants as close to the source of generation as possible.

5.5.2.1.3.1.1 Airflow patterns. Airflow patterns including flow of replacement or make-up air shall be used to provide a flow away from users and into the ventilation system.

5.5.2.1.3.1.2 Process controls. Where appropriate, process controls should be interlocked with operation of the ventilation system to prevent generation without appropriate containment.

5.5.2.1.3.2 Minimum air supply for enclosures less than 4.25 cubic meters (m^3) per person. A minimum of 0.85 m^3 (30 ft^3) of total ventilation air per minute per person shall be introduced into the enclosure. The number of people to be accommodated will be specified by the procuring activity (see 6.2).

5.5.2.1.3.2.1 Fresh air requirement for enclosures less than 4.25 m^3 per person. In addition to the total ventilation air requirement, outside fresh air shall be supplied at a minimum rate of 0.57 cubic meters per minute (m^3/min) (20 cubic feet per minute [ft^3/min]) per person.

5.5.2.1.3.3 Minimum air supply for enclosures larger than 4.25 m^3 per person. Outside fresh air shall be supplied at a rate sufficient to produce at least six complete air exchanges per hour.

5.5.2.1.3.4 Air velocities. Air velocities shall be in accordance with the criteria in 5.5.2.1.3.4.1 through 5.5.2.1.3.4.3.

5.5.2.1.3.4.1 Maximum air velocities. Air velocities shall not exceed 30 meters per minute (m/min) (100 ft/min) (0.5 meters per second [m/s] or 1.7 feet per second [ft/s]) at any measured position in the space.

5.5.2.1.3.4.2 Exception to maximum air velocities. An exception would be in work locations where spot cooling of personnel is provided. In these cases, air shall be moved past personnel at a velocity not more than 60 m/min (200 ft/min).

5.5.2.1.3.4.3 Maximum air velocities in workspaces with paper. Where manuals or loose papers are used, airspeed past these items shall be not more than 20 m/min (65 ft/min) to preclude pages in manuals from being turned by the air or papers from being blown off work surfaces.

5.5.2.1.3.5 PPE ventilation requirements. Under CBRNE or other mission-required PPE conditions, ventilation requirements shall be modified as required. Consultation shall be made with habitability or medical experts to make this determination based upon size of the space, number of personnel, and level of physical exertion. For CBRNE survivability, see 4.11.

5.5.2.1.3.6 Ventilation requirements for harmful substances. Ventilation or other protective measures shall be provided to keep gases, vapors, dust, and fumes within the permissible exposure limits specified by 29 CFR 1910, the limits specified in the ACGIH Documentation of the Threshold Limit Values for Physical Agents (TLVs) (ACGIH TLV), or applicable military-unique exposure limits specified in DoDI 6055.01.

5.5.2.1.3.7 Prevention of fresh air contamination. Intakes for ventilation systems shall be located to minimize the introduction of contaminated air from sources such as exhaust pipes. For vehicle ventilation, see 5.6.6.2.

5.5.2.1.3.8 Engine room ventilation. Engine room ventilation shall be in accordance with ISO 8861 and ISO 8862.

5.5.2.1.3.9 Airborne contaminant exposure. Airborne contaminant exposures should be minimized or eliminated by a prioritized hierarchy of controls focusing upon substitution or elimination where possible; emission controls when substitution is infeasible; containment; and ventilation where other controls are not fully effective. Protective equipment should be used as a last option when other controls are infeasible or not fully effective, or on an interim basis such as during construction or demolition.

5.5.2.1.4 Air conditioning. Air conditioning design shall meet the following requirements.

5.5.2.1.4.1 Cold air discharge. Cold air shall not be directly discharged on personnel unless there is a means to redirect the airflow away from personnel.

5.5.2.1.4.2 HVAC system design. The HVAC system shall be capable of providing and maintaining a relative humidity within a range from 30 percent minimum to 70 percent maximum with 40 percent to 45 percent preferred. The temperature/humidity design goal shall be between 21 °C and 25 °C (70 °F and 77 °F) and 45 percent humidity.

5.5.2.1.4.3 Temperature uniformity. The temperature of the air at floor level and at head level at any personnel position shall not differ by more than 5.5 °C (10 °F). A temperature difference of less than 3.0 °C (5 °F) is preferred. Side walls of the compartment shall be kept at equal temperatures insofar as possible; however, temperature differences of 11 °C (20 °F) or less do not significantly degrade comfort. In berthing areas, the difference between the inside bulkhead/wall surface adjacent to the berthing and the average air temperature within the space shall be less than 10 °C (18 °F).

5.5.2.1.4.4 Personal equipment thermal control. When special protective clothing or personal equipment (such as full and partial pressure suits, fuel handler suits, body armor, arctic clothing, and temperature regulated clothing) are required and worn, a comfort micro-climate between 20 °C (68 °F), 14 millimeters of mercury (mm Hg) (0.55 inches of mercury [in Hg]) ambient water vapor pressure at 35 °C (95 °F), 3 mm Hg (0.12 in Hg) ambient water vapor pressure is desirable and, where possible, shall be maintained by heat transfer systems.

5.5.2.1.4.5 Maximum effective wet bulb globe temperature ($WBGT_{eff}$). The $WBGT_{eff}$ within manned spaces shall be no greater than 30 °C (86 °F) under normal operational internal heat loads and the worst-case design climatic conditions as defined in AR 70-38. If this criterion cannot be met in shipboard spaces, apply the Physiological Heat Exposure Limits (PHELs) provided in NEHC-TM-OEM 6260.6. For aircraft cockpit design, apply the Fighter Index of Thermal Stress (FITS) provided in AFI 48-151. For prolonged work at metabolic rates above 250 watts, use the ACGIH TLV for $WBGT_{eff}$. The ACGIH TLV was developed and should be used for general (non-military) populations who may be older and less fit than military populations.

5.5.2.1.4.6 Acclimatization. Acclimatization is necessary to ensure physiological adaptation to a given level of heat stress. Personnel without prior exposure to physical activity similar to the relevant job tasks and concurrent heat stress exposure have a lower tolerance and may be at greater risk for heat strain or injury.

5.5.2.1.4.7 Calculations.

5.5.2.1.4.7.1 Calculation of unadjusted WBGT.

The WBGT with no direct exposure to sunlight is: WBGTin = 0.7 Tnwb + 0.3 Tg

The WBGT with direct exposure to sunlight is: WBGTout = 0.7 Tnwb + 0.2 Tg + 0.1 Tdb

Where: T_{nwb} is the natural wet bulb temperature

T_g is the globe temperature

T_{db} is the dry bulb temperature

NOTE: $WBGT_{in}$ and $WBGT_{out}$ may be measured using compact data logging devices with sensors for all three of the temperatures that automatically calculate the WBGT.

5.5.2.1.4.7.2 Calculation of $WBGT_{eff}$.

$WBGT_{eff} = WBGT_{in/out}$ + CAF, where CAF is the clothing-adjustment factor from table XX.

5.5.2.2 Climate and other outdoor environmental considerations.

5.5.2.2.1 General usability and maintainability considerations under all anticipated outdoor conditions. Usability and maintainability of the designed system under all anticipated outdoor environments are critical design criteria.

TABLE XX. Clothing-adjustment factors for WBGT.

Clothing Type	Reference	CAF, °C (°F)
Long sleeve shirt & pants	ACGIH	0 (0)
Woven cloth coveralls	NEHC-TM-OEM 6260.6	3.5 (6.3)
Double cloth coveralls	NEHC-TM-OEM 6260.6	5.0 (9.0)
Turnout gear or ground crew ensemble	AFI 48-151	5.6 (10.0)
Body armor, humid conditions – add	TB MED 507/AFPAM 48-152	2.8 (5.0)
Plastic coveralls over underwear	ACGIH	0.5 (0.9)
Hood with plastic coveralls – add	AIHA White Book	1.0 (1.8)
MOPP4, easy work	TB MED 507/AFPAM 48-152	5.6 (10.0)
MOPP4, moderate or hard work	TB MED 507/AFPAM 48-152	11.1 (20.0)
NOTE: MOPP4 represents "mission-oriented protective posture" level 4 (all protection worn).		

5.5.2.2.2 Consideration of environmental effects on human performance. Design shall consider the effect of the maintenance and working environment on human performance. Consideration shall be given to adverse conditions as well as normal environmental factors of temperature, precipitation, humidity, sunlight, illumination, and dust, which could affect the ability of personnel to perform as required.

5.5.2.2.3 Adverse climate effects identification. Where the system will be used in or otherwise be exposed to precipitation, direct sunlight (solar loading), dusty conditions, or other climatic effects during normal operations and maintenance activities, the designer shall identify all adverse effects upon personnel and equipment.

5.5.2.2.4 Adverse climate effects mitigation. The design shall mitigate all identified adverse climate effects identified.

5.5.2.2.5 Specific climatic considerations for system maintenance. The following specific climatic factors shall be taken into consideration for areas used to maintain systems.

5.5.2.2.5.1 Air conditioning for maintenance areas. Air conditioning shall be provided, when feasible, if temperatures exceed 29.5 °C (85 °F).

5.5.2.2.5.2 Ventilation for maintenance areas. Ventilation shall be provided in equipment trailers or other locations where personnel are performing monitoring, servicing, or other maintenance tasks.

5.5.2.2.5.3 Ventilation and air conditioning for maintenance areas with solar loading. When maintenance technicians must work for long periods of time inside equipment exposed to the sun, air conditioning or a large volume of air shall be provided in the enclosure in compliance with established ventilation criteria.

5.5.2.2.5.4 Heat protection for maintenance areas with solar loading. Where feasible, appropriate heat reflector and absorbent surfaces on equipment that must be maintained shall be employed while personnel and equipment are exposed to the sun.

5.5.2.2.5.5 Frequent maintenance. Where frequent maintenance, such as checking or adjusting a component, is impossible or delayed because of excessively high temperatures, the equipment shall be redesigned so the component is in a cooler area. If redesign of equipment to move frequent maintenance components to a cooler area is impossible, provision shall be made to cool the component to permit the required maintenance.

5.5.2.2.5.6 Design for maintenance wearing protective equipment. Under extremely cold conditions or where there is significant wind-chill (below -12 °C [10 °F]), design for operations and maintenance shall accommodate the requirement for special gloves or other protective equipment.

5.5.2.2.5.7 Shelter for above organizational level maintenance under cold conditions. In cold environments, heated working areas for maintenance personnel above the organizational level shall be provided.

5.5.2.2.5.8 Design for organizational level maintenance under cold conditions. Maintenance shall be able to be performed without shelter at the organizational level when the temperature is as low as -29 °C (-20 °F) or an equivalent wind chill factor exists. For organizational maintenance activities, the equipment shall be designed (use quick-disconnect servicing equipment) to require a minimum sustained working time. Procedures for organizational level maintenance under cold conditions shall be clear and specific.

5.5.2.2.5.9 Heating for maintenance activities. When monitoring, servicing, repairing, or other similar maintenance tasks are to be performed in areas in which the temperature will drop below 18 °C (64 °F), air heating shall be provided if maintenance tasks are conducted in a shirt-sleeve environment.

5.5.2.2.5.10 Maintenance accessibility under cold conditions. The following shall be considered in design of maintenance accessibility for winterized equipment:

5.5.2.2.5.10.1 Winterization equipment. Winterization equipment, such as preheaters, shall be positioned where they do not interfere with accessibility to perform maintenance tasks.

5.5.2.2.5.10.2 Location of access doors and panels. The location of access doors and panels shall consider the effects of rain, snow, and ice formation.

5.5.2.2.5.10.3 Workspace openings. Where feasible, workspace access openings shall be provided to accommodate personnel wearing cold-weather clothing.

5.5.2.2.5.10.4 Drains. Drains that can be accessed by personnel wearing cold-weather clothing shall be provided to drain liquids to prevent freeze damage.

5.5.2.2.5.10.5 Freezing of bare hands. In areas where technicians may suffer freezing if bare hands are used when maintaining equipment, such as liquid oxygen lines, access and internal workspace shall be provided to permit them to wear the appropriate protective gloves.

5.5.2.2.5.10.6 Drying of equipment. A means shall be provided for drying of equipment that is to be returned to out-of-door arctic temperatures after shop maintenance has been performed on it.

5.5.3 Workspace lighting.

5.5.3.1 General. General and supplementary lighting should be used as appropriate to ensure that illumination is compatible with each operator and maintainer task situation.

5.5.3.1.1 High efficiency lighting. High efficiency lighting sources (such as LEDs) should be employed in favor of less efficient sources. This has the benefit of not only reduced operating costs, but reduced maintenance workload as well.

5.5.3.1.2 Lighting controls at entrances and exits. Lighting controls for illumination shall be provided at entrances and exits of enclosed workplace areas.

5.5.3.1.3 Self-illuminated lighting controls. Self-illuminated lighting controls shall be used in areas where controls cannot be seen when lights are turned off.

5.5.3.1.4 Illumination levels for tasks. Workspace ambient lighting for applications not subject to special lighting requirements shall be in accordance with table XXI. For applications not addressed in table XXI, The Illuminating Engineering Society Lighting Handbook may be used.

TABLE XXI. Specific task illumination requirements.

Work Area for Type of Task	**Illumination Level** [1/]		**Work Area or Type of Task**	**Illumination Level**	
	Preferred lux (fc)	**Minimum lux (fc)**		**Preferred lux (fc)**	**Minimum lux (fc)**
Assembly, bench, & inspection			Mess room (cafeteria)	540 (50)	300 (28)
Coarse work detail	540 (50)	325 (30)	Muster station	540 (50)	200 (18)
Medium work detail	810 (75)	540 (50)	Medical space		
Fine work detail	1075 (100)	810 (75)	Waiting area	755 (70)	540 (50)
Precise work detail	3230 (300)	2155 (200)	Exam/treatment room	1075 (100)	810 (75)
Assembly (missile component)	1075 (100)	540 (50)	Missile facilities		
Bakery	540 (50)	325 (30)	General inspection	540 (50)	325 (30)
Battery room	300 (28)	200 (18)	Repair and service	1075 (100)	540 (50)
Bomb shelters & mobile shelters	20 (2.0)	10 (1.0)	Storage areas	215 (20)	215 (20)
Bridge	540 (50)	325 30)	Offices		
Business machine operation	1075 (100)	540 (50)	General	755 (70)	540 (50)
Cargo handling (weather decks)	215 (20)	150 (14)	Computer workstation	540 (50)	300 (28)
Chart room			Ordinary visual tasks	540 (50)	325 (30)
General lighting	540 (50)	150 (14)	Paint room		
On chart table	1075 (100)	810 (75)	General	540 (50)	325 (30)
Circuit diagram	1075 (100)	540 (50)	Color matching	2155 (200)	2155 (200)
Control rooms			Passageways (walkways, hallways)	215 (20)	150 (14)
General lighting	540 (50)	325 (30)	Pump room	340 (32)	225 (20)
Computer work	300 (28)	300 (28)	Pump rows, valves	200 (18)	150 (14)
Computer work station	540 (50)	300 (28)	Purifier room (water or oil)	500 (46)	215 (20)
Consoles (front)	540 (50)	325 (30)	Radar room	540 (50)	200 (18)
Consoles (rear)	325 (30)	110 (10)	Radio room	540 (50)	540 (50)
Compressor/pump/generator	300 (28)	200 (18)			

TABLE XXI. Specific task illumination requirements – Continued.

Work Area for Type of Task	Illumination Level [1/]		Work Area or Type of Task	Illumination Level	
	Preferred lux (fc)	Minimum lux (fc)		Preferred lux (fc)	Minimum lux (fc)
Crane cab	540 (50)	400 (37)	Reading		
Dials/gauges	540 (50)	325 (30)	Large print	325 (30)	110 (10)
Electrical equipment testing	540 (50)	325 (30)	Newsprint	540 (50)	325 (30)
Elevators	325 (30)	215 (20)	Small type/prolonged reading	755 (70)	540 (50)
Emergency lighting	55 (5.0)	30 (3.0)	Recording	755 (70)	540 (50)
Emergency generator room	340 (32)	225 (20)	Recreation rooms	540 (50)	300 (28)
Escape trunks	55 (5.0)	30 (3.0)	Repair rooms		
Fan room	200 (18)	150 (14)	General lighting	540 (50)	325 (30)
Fire pump room	300 (28)	200 (18)	Instrument repair	2155 (200)	1075 (100)
Food storage			Sanitary spaces		
Non-refrigerated	540 (50)	200 (18)	General	540 (50)	325 (30)
Refrigerated	215 (20)	100 (9.0)	Sinks and mirrors	540 (50)	540 (50)
Galley	755 (70)	540 (50)	Toilets	540 (50)	150 (14)
Gyro room	300 (28)	200 (18)	Scales	540 (50)	325 (30)
HVAC room	300 (28)	200 (18)	Screw fastening	540 (50)	325 (30)
Instrument shop	540 (50)	325 (30)	Service areas (general)	215 (20)	110 (10)
Laundry			Shaft alley	215 (20)	110 (10)
General	540 (50)	540 (50)	Snack and coffee bar	540 (50)	500 (46)
Hand pressing	1395 (150)	1395 (150)	Stairs and ladders	215 (20)	110 (10)
Lay down areas	540 (50)	200 (18)	Storage areas		
Laboratory	540 (50)	360 (33)	General warehouse	110 (10)	55 (5.0)
Library	755 (70)	540 (50)	Large parts	110 (10)	55 (5.0)
Loading/off-loading area	340 (32)	150 (14)	Small parts	300 (28)	300 (28)
Lounges	540 (50)	300 (28)	Fine parts	540 (50)	540 (50)
Manifold area	215 (20)	100 (9.0)	Steering gear room	540 (50)	300 (28)
Machine operation (automatic)	540 (50)	325 (30)	Switchboards	540 (50)	325 (30)
Machine shop			Tanks	215 (20)	215 (20)
General lighting	540 (50)	325 (30)	Testing (see assembly)		
Fine bench work	1075 (100)	745 (80)	Welding/mechanical shop	500 (46)	500 (46)
Maintenance platform	540 (50)	200 (18)	Windlass room	215 (20)	100 (9.0)
Machinery room	540 (50)	200 (18)	Work and repair areas	700 (65)	540 (50)

FOOTNOTE:

[1/] As measured at the task object or 76 cm (30 in) above the floor.

NOTE: Task lighting inside vehicles shall be designed to accommodate the specific tasks to be performed within the vehicle while still ensuring that the lighting will neither distract or impair the driver's performance nor create an unacceptable visual signature. This may include continuously variable intensity controls.

5.5.3.1.5 Luminance ratio. The luminance ratio between any two different sources of luminance light within an operator's or maintainer's field of view should not exceed 5:1.

5.5.3.1.6 Task area contrast ratios. The contrast ratios between the lightest and darkest areas or between a task area and its surroundings shall be no less than the ratios specified in table XXII.

TABLE XXII. Contrast ratios.

Comparisons	**Environmental Classification**		
	A 1/	**B** 2/	**C** 3/
Between lighter surfaces and darker surfaces within the task	5:1	5:1	5:1
Between tasks and adjacent surroundings	3:1	3:1	5:1
Between tasks and more remote surfaces	10:1	20:1	4/
Between luminaires and adjacent surfaces	20:1	4/	4/
Between the immediate work area and the rest of the environment	40:1	4/	4/

NOTES:

1/ A = Interior areas where reflection off entire space can be controlled for optimum visual conditions.

2/ B = Areas where reflection off immediate work area can be controlled, but there is only limited control over remote surroundings.

3/ C = Areas (indoor and outdoor) where it is impractical to control reflection and difficult to alter environmental conditions.

4/ Contrast ratio control not practical.

5.5.3.1.7 Display adjacent surfaces. Surfaces adjacent to the display screen shall have a matte finish.

5.5.3.1.8 Nearby light sources. Other light sources within the operational space shall not degrade the visibility of the display content.

5.5.3.1.9 Luminance of displays from ambient illumination. Ambient illumination onto a display shall not contribute more than 25 percent to the total display luminance.

5.5.3.1.10 Ambient illumination. Ambient illumination in the display area shall be bright enough to perform visual tasks (e.g., setting controls and reading instruments).

5.5.3.1.11 Display visibility. Ambient illumination shall not degrade the visibility of display content.

5.5.3.1.12 Flicker. Light sources shall not have a perceptible flicker.

5.5.3.1.13 Dimming. For tasks and conditions where control over the ambient illumination is required (e.g., dark adaptation conditions), continuous dimming control shall be provided.

5.5.3.2 Location. Lights shall not be placed where persons climbing or descending stairs or ladders would have to look directly into the light.

5.5.3.3 Ease of maintenance.

5.5.3.3.1 Placement. Luminaires shall not be placed in locations that are difficult to access for bulb replacement or other maintenance.

5.5.3.3.2 Long-life characteristics. In cases were luminaires must be located in difficult-to-reach locations, lights with long-life characteristics should be chosen.

5.5.3.3.3 Visibility of indicator lights for maintenance. Indicator lights used solely for maintenance and adjustment should be covered or made not visible during normal operation but shall be readily accessible when required for maintenance.

5.5.3.4 Mounting. Luminaires mounted on exposed sides of ships or structures shall be located so as not to shine into the eyes of users of ship or structure-mounted cranes or approaching aircraft.

5.5.3.5 Fall protection. Stanchions or poles supporting luminaires that are located at the edge of ships or structures shall have anchor points on each side of the stanchion or pole so a person wearing a safety harness can be secured to at least one of the anchor points on the stanchion or pole at all times when climbing to and from the luminaire (see section 4.9.3).

5.5.3.6 Dark adaptation and night vision conditions. Where dark adaptation is required or night vision devices are used, ambient illumination shall meet the following requirements.

5.5.3.6.1 White light. When dark adaptation is required, ambient white light capable of continuous dimming to zero should be used.

5.5.3.6.2 Red lighting. Red lighting should not be used in areas where color recognition or readability of maps and color symbology is required.

5.5.3.6.3 Night vision device (NVD) compatibility. Illumination for NVD compatibility shall meet the requirements of MIL-STD-3009.

5.5.3.6.4 Continuously controllable. Illumination shall be continuously controllable to zero.

5.5.3.7 Portable lighting. Portable lighting shall be provided for personnel performing visual tasks in areas where fixed illumination is not provided.

5.5.3.8 Colored ambient illumination. Except where required for dark adaptation or night vision device compatibility, colored ambient illumination shall not be used.

5.5.3.9 Emergency lighting. Emergency lighting shall be provided for use when the power supply to the normal lighting is not available or fails.

5.5.3.9.1 Automatic activation. Unless precluded by operational or signature requirements, emergency lighting shall automatically engage in the event that the normal lighting fails.

5.5.3.9.2 Independent source. Emergency lighting shall be powered from a source independent of that supplying the normal lighting.

5.5.3.9.3 Duration. Duration and illuminance of emergency lighting shall be commensurate with mission performance requirements.

5.5.3.9.4 Egress path lighting. Emergency lighting shall provide illumination for emergency egress.

5.5.3.9.5 Location. Emergency lighting shall be located in accordance with NFPA 101 or other relevant life-safety codes.

5.5.3.10 Variations in ambient illumination. Large variations in illuminance across the workspace shall be avoided. The illuminance ratio between the task area and the immediate surround shall be no more than 3:1 and no more than 10:1 between the task area and the general background (see table XXII).

5.5.3.11 Glare.

5.5.3.11.1 Glare avoidance. Luminaires shall be designed and placed in locations to avoid glare and specular reflections.

5.5.3.11.2 Surfaces within field of regard. Placement of smooth, highly polished surfaces within 60 degrees of a person's normal visual field should be avoided.

5.5.3.11.3 Direct glare.

5.5.3.11.3.1 Bright light sources within the field of regard. Direct glare arises from a light source within the visual work field. Direct glare shall be controlled by not placing bright light sources within 60 degrees of the center of the visual field.

5.5.3.11.3.2 Indirect lighting. Since most visual work is at or below the eye's horizontal position, placing luminaries high above the work area minimizes direct glare. The following techniques may also be used to reduce glare:

a. Using indirect lighting.

b. Using a greater number of relatively dim light sources.

c. Using polarized light, shields, hoods, or visors to block the glare in confined areas.

5.5.3.11.3.3 Eyeglasses. Luminaire design and placement should avoid glare caused by eyeglass reflection, both front and back.

5.5.3.11.4 Reflected glare.

5.5.3.11.4.1 Large surface areas. Large surface areas, such as walls, partitions, panels, and work surfaces, shall not be glossy or otherwise be a source of specular reflections. Preferred surface reflectance values for some spaces are shown on figure 33.

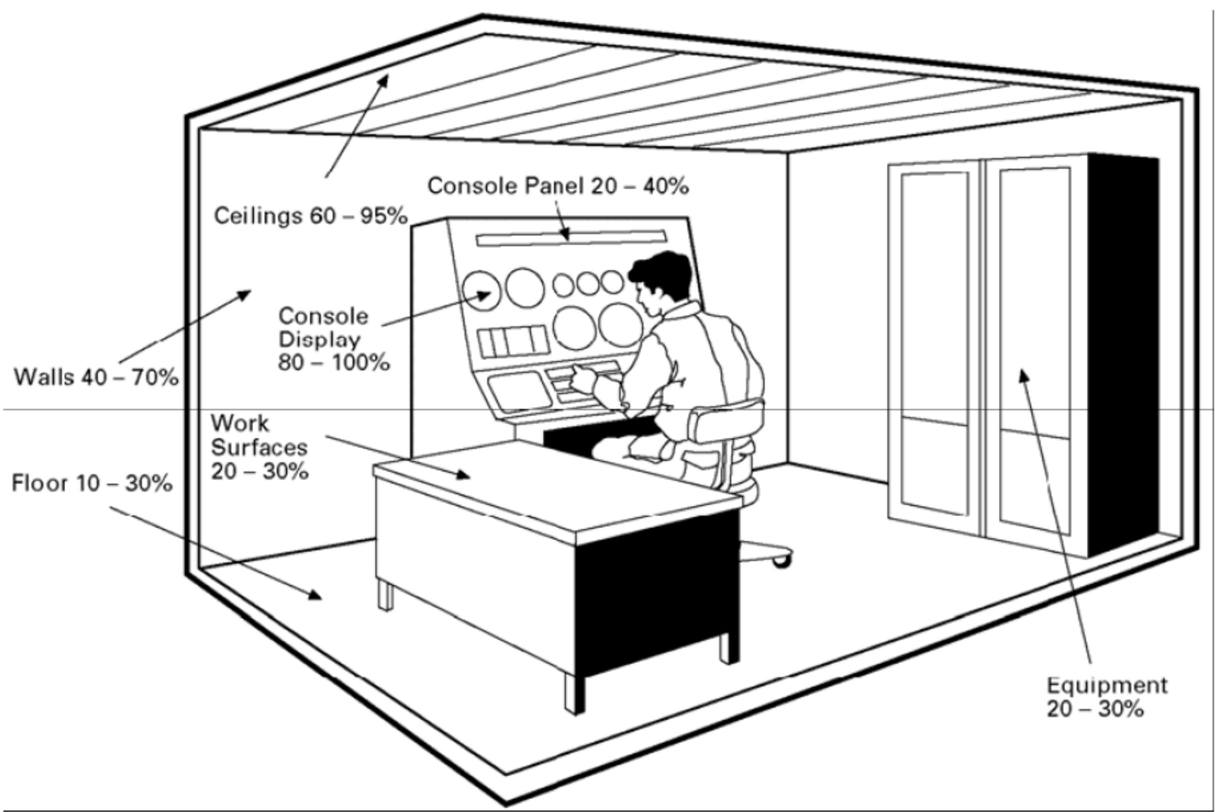


FIGURE 33. Surface reflectance values.

5.5.3.11.4.2 Non-saturated colors. Large surface areas should be covered with non-saturated light colors, such as tints, pastels, whites, and light shades of gray, to increase the reflectance of space lights.

5.5.3.11.4.3 Non-critical areas. Some non-critical areas, such as door frames and molding, may be glossy if ease of cleaning is essential.

5.5.3.12 Reflectance. Reflectance designs shall meet the criteria in 5.5.3.12.1 through 5.5.3.12.3.

5.5.3.12.1 Reflections from task background. The luminance of reflections from the task background shall be not greater than three times the average luminance of the immediate background.

5.5.3.12.2 Reflections from surfaces. Workspaces shall not contain surfaces that result in reflections of more than 20 percent.

5.5.3.12.3 Reflections from surfaces within field of regard. Smooth highly polished surfaces should not be placed within 60 degrees of the user's normal line of sight.

5.5.4 Acoustical energy and noise.

5.5.4.1 General. The acoustical environment shall not cause injury, fatigue, interfere with voice or other audio communications, or degrade system effectiveness. Apart from environmental considerations (such as annoyance to the community at large which lie outside the scope of this document), the most critical effects include noise-induced hearing injury and the impact of signal comprehension on communications, survivability, and mission effectiveness (lethality).

5.5.4.2 Equipment design. Equipment shall not generate noise in excess of maximum allowable levels in accordance with MIL-STD-1474.

5.5.4.3 Total system compliance. Total system noise shall be in accordance with MIL-STD-1474. The fact that a component that contributes to the overall noise may be Government-furnished equipment shall not eliminate the requirement that the total system conform to the criteria herein.

5.5.4.4 Hazardous noise.

5.5.4.4.1 Allowable limits. Environments and conditions in which SPLs equal or exceed 85 dBA and 140 dBP even on an intermittent basis shall be evaluated in accordance with MIL-STD-1474 and the hearing conservation policy of the procuring activity.

5.5.4.4.2 Workstations. To reduce personnel noise exposure, controls, displays, and workstations required to monitor equipment should be located in separate spaces that are acoustically isolated from the noise sources.

5.5.4.4.3 Hearing protection.

5.5.4.4.3.1 Compatibility with hearing protection. The system shall be compatible with personal hearing protection worn within the context of mission performance and as specified by the procuring activity (see 6.2). If personal hearing protection devices are authorized for the design, the system design shall accommodate the wearing of personal hearing protection devices within the context of mission activities.

5.5.4.4.3.2 Hearing protection device performance. Personal hearing protection devices shall reduce noise at the ear reference point to a non-hazardous level in accordance with service policy.

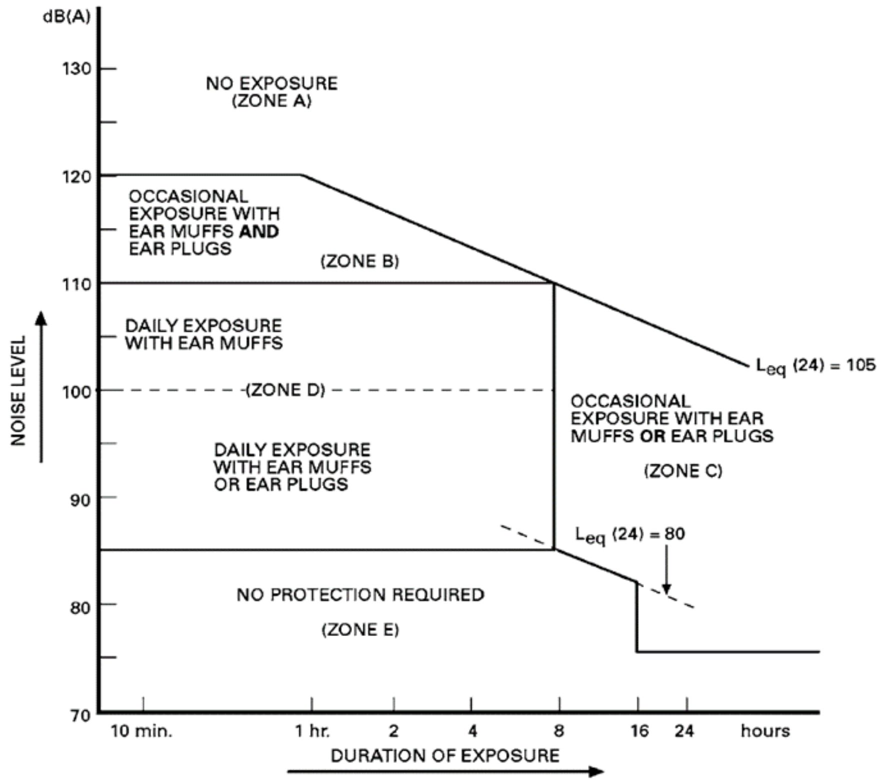
5.5.4.4.3.3 Selection of hearing protector. The selection of hearing protection shall be based on noise level, duration of exposure, and mission requirements (such as communications, sound localization, and comfort).

5.5.4.4.3.4 Communications.

5.5.4.4.3.4.1 Communication headsets. Communication headsets, including those having active noise cancelling, may be used if their noise reduction properties have been characterized in accordance with the same standards used to characterize hearing protectors.

5.5.4.4.3.4.2 Communication through earplugs. Where both earplugs and communications are required, communication signal must be able to pass through earplugs.

5.5.4.4.4 Exposure limits and protection. Unless otherwise specified by DoD or service-specific hearing conservation policies, maximum permissible daily and occasional noise exposure limits shall not exceed those given on figure 34.



NOTES:

1. Figure and description adapted from IMCO Resolution MSC.337.
2. Zone A, Maximum exposure with protection: Even when wearing hearing protection, no personnel shall be exposed to levels exceeding 120 dBA or to a 24-hour equivalent continuous sound level (Leq[24]) exceeding 105 dBA.
3. Zone B, Occasional exposure: Both earmuffs and ear plugs shall be worn. Only occasional exposure should be allowed. If exposure is less than 10 minutes, either earmuffs or plugs are required, not both.
4. Zone C, Occasional exposure: Only occasional exposures shall be allowed, and earmuffs or plugs shall be required.
5. Zone D, Daily exposure: Hearing protection shall be worn for daily exposure within zone D. Choice of earmuffs or ear plugs is at user discretion providing they meet the requirements with zone D.
6. Zone E, Maximum exposure without protection: For exposures of less than 8 hours, personnel without hearing protection shall not be exposed to noise levels exceeding 84 dBA. When personnel remain for more than 8 hours in spaces with a high noise level, an Leq(24) of 80 dBA shall not be exceeded. For at least a third of each 24 hours, personnel shall be subject to an environment with a noise level not exceeding 75 dBA.

FIGURE 34. Permissible noise exposure limits.

5.5.4.4.4.1 High noise area. Any area where continuous noise levels can exceed 84 dBA shall be classified as a "high noise area".

5.5.4.4.4.2 Hazard signage. A DANGER hazard sign shall be posted at every entrance into a “high noise area”.

5.5.4.4.4.3 Level of protection. The sign shall comply with 5.7.2.1 and describe the level of protection required based on figure 34.

5.5.4.4.4.4 Portable equipment. If hand tools or other portable or localized equipment produce hazardous noise, a hazard sign shall be posted at the work site or on the equipment identifying the hazard and requiring the use of hearing protectors at that site or with that equipment.

5.5.4.4.4.5 Label requirements. The hazard sign for hand tools or other portable equipment shall comply with the DANGER label requirements for hazard warnings (see 5.7.2.1).

5.5.4.5 Non-hazardous noise. Environments in which continuous noise levels do not exceed 84 dBA and 140 dBP shall be considered non-hazardous.

5.5.4.5.1 Noise reduction to support verbal communication. Workspace noise shall be reduced to levels that permit necessary direct (person-to-person) and telephone communication. Direct communications should be possible without additional vocal effort. Workspace noise levels should allow for communications to meet speech intelligibility criteria in MIL-STD-1474.

5.5.4.5.2 Permissible distance guidance. Permissible distances between a speaker and listeners for specified voice levels and ambient noise levels depends on vocal effort, speaker-to-listener distance, and ambient noise.

5.5.4.5.3 General workspaces. Areas requiring occasional telephone use or occasional direct communication at distances up to 1.5 m (5 ft) shall not exceed 75 dBA (e.g., maintenance shops and shelters, garages, keypunch areas, and shipboard engineering areas).

5.5.4.5.4 Operational areas. Areas requiring frequent telephone use or occasional direct communication at distances up to 1.5 m (5 ft) shall not exceed 65 dBA (e.g., operation centers, mobile command and communication shelters, combat information centers, word processing centers).

5.5.4.5.5 Large workspaces. Areas requiring no difficulty with telephone use or requiring occasional direct communication at distances up to 4.6 m (15 ft) shall not exceed 55 dBA (e.g., drafting rooms, shop offices, laboratories).

5.5.4.5.6 Small office spaces and special areas. Areas requiring no difficulty with direct communication shall not exceed 45 dBA (e.g., conference rooms, libraries, offices, command and control centers).

5.5.4.5.7 Extreme quiet areas. Areas requiring extreme quiet shall not exceed 35 dBA (e.g., recording studios).

5.5.4.5.8 Shipboard areas. See the shipboard equipment noise requirements and shipboard compartment noise requirements in MIL-STD-1474.

5.5.4.6 Facility design.

5.5.4.6.1 General. The workspace or facility design shall minimize the ambient noise level through sound absorption and attenuation to meet the criteria herein.

5.5.4.6.2 Attenuation by materials and layout.

5.5.4.6.2.1 Use of acoustic materials. Acoustic materials shall be provided as necessary in the construction of floors, walls, and ceilings to provide the required sound control.

5.5.4.6.2.2 Minimization of noise transmission. Transmission of noise may be attenuated by the use of high-density materials, multilayer materials (e.g., concrete, gypsum board), and construction techniques (e.g., staggered seams in walls, use of double-paned windows).

5.5.4.6.2.3 Floor, wall, and ceiling treatments to mitigate reverberation. Reverberation in rooms and workstations may be controlled by applying sound-absorbing materials on floors, ceiling tiles, and wall treatments.

5.5.4.6.3 Reduction of reverberation time. Where speech communication is a consideration, the acoustical treatment shall reduce reverberation time below the applicable limits of figure 35.

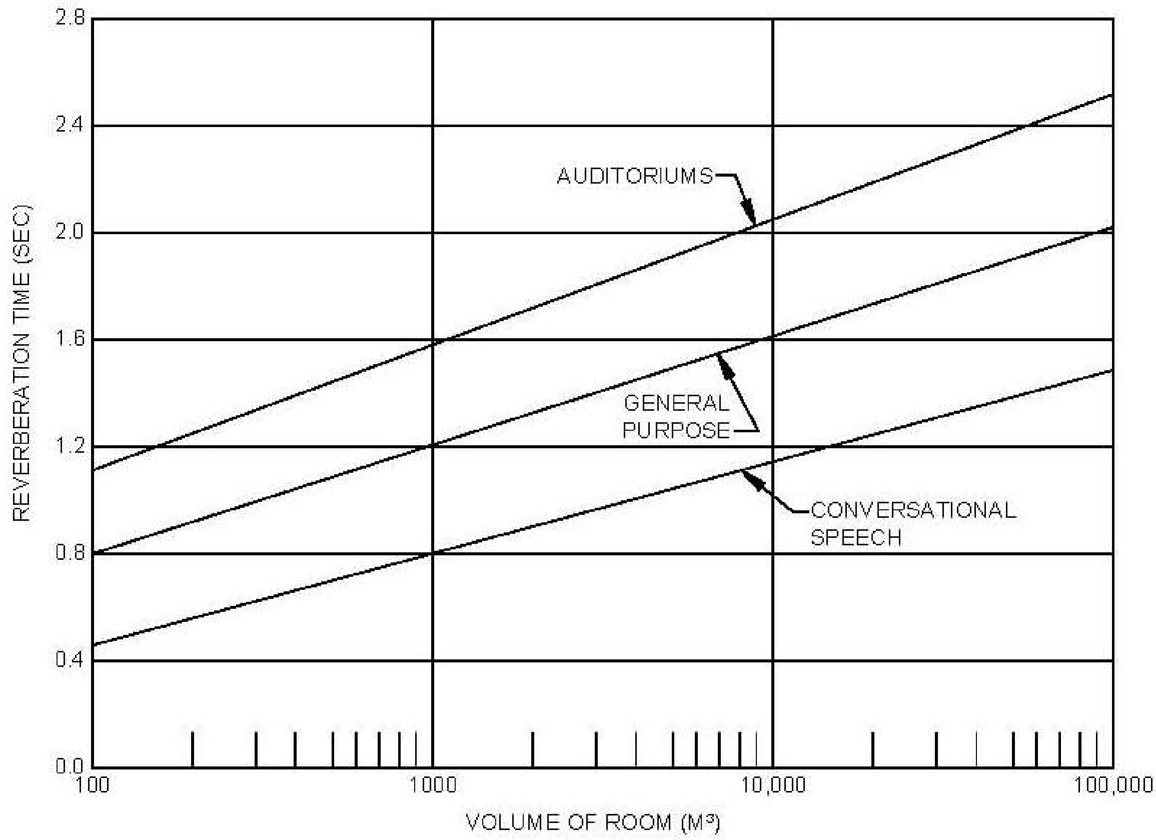


FIGURE 35. Range of acceptable reverberation times.

5.5.5 Vibration and shock.

5.5.5.1 Vehicular whole-body vibration. The following provisions apply to whole-body vibration in accordance with ISO 2041 and ISO 5805 where the vibratory motions are limited to those transmitted to the human body as a whole through supporting surfaces. Vehicles include all land, water or sea, and air vehicles including, but not limited to, heavy ground vehicles, all-terrain vehicles, trucks, aircraft, high speed boats, and ships.

5.5.5.1.1 Mitigation of whole-body vibration by design. Vehicles for use on land, at sea, or in air shall be designed to control the transmission of whole-body vibration to levels that will permit safe and effective operation and maintenance. Vibration and shock control should be considered in the context of operational capabilities for unimpeded operator performance and integrated into design criteria.

5.5.5.1.2 Operational environments. The anticipated operational dynamic environment and exposure duration are required to determine the analysis method and threshold for whole-body vibration or shock. Table XXIII defines environmental categories expected to occur during operation of military vehicles. The vehicle examples provided in table XXIII are not restrictive.

TABLE XXIII. Operational environments.

Category	Description of Environment	Frequency Range and Directions	Exposure Criteria
A	The environment is classified as strictly vibration and can be characterized as oscillatory in nature (periodic). Examples: Ground vehicles on relatively smooth road and aircraft with minimal to moderate turbulence	0.5 to 80 Hz* X, Y, and Z (note: refer to ISO 2631-1 Figure 1, Basicentric axes of the human body)	Health (5.5.5.1.5) Comfort (5.5.5.1.6) Perception (5.5.5.1.7) Performance (5.5.5.1.8)
B	The environment is classified as predominately vibration and can be characterized as oscillatory in nature (periodic) but also contains occasional shocks or transient vibration (aperiodic). Examples: Off-road ground vehicles with severe terrain and aircraft in severe buffeting	0.5 to 80 Hz* X, Y, and Z (note: refer to ISO 2631-1 Figure 1, Basicentric axes of the human body)	Health (5.5.5.1.5) Comfort (5.5.5.1.6) Perception (5.5.5.1.7) Performance (5.5.5.1.8)
C	The environment may contain some underlying vibration, but is dominated by repeated or multiple shocks or transient vibration exceeding 9.81 ms^{-2} or 1 g. Examples: Aircraft in extreme buffeting; vessels at 20+ knots in sea state 5	0.01 to 80 Hz Vertical (Z) Only	Health (5.5.5.1.5)
D	The environment is classified as low frequency oscillatory motion at or below 0.5 Hz that can cause kinetosis or motion sickness and other associated syndromes. Examples: Motion in ships, undersea vehicles, sea rescue vehicles, and other sea vessels; low frequency oscillations during aircraft maneuvering; spacecraft	0.1 to 0.5 Hz Vertical (Z) Only	Motion Sickness (5.5.5.1.9)
NOTE: Some environments may include major frequency components beyond 80 Hz that consistently occur during vehicle operation (i.e., some propeller aircraft). A higher frequency range may be warranted in these cases. ISO 2631-1 provides one-third octave weightings up to 400 Hz.			

5.5.5.1.3 Evaluation of whole-body vibration and shock using ISO 2631-1 and -5. Evaluation of military vehicle vibration and its possible effects on health, comfort, perception, performance, and motion sickness shall be in accordance with ISO 2631-1 and ISO 2631-5. Table XXIII includes the specific effects to be evaluated for each environment category in accordance with the appropriate criteria given in 5.5.5.1.4 through 5.5.5.1.9. For categories A and B, the basic evaluation method for health as described in ISO 2631-1 is always applied first. Additional evaluation methods as described in ISO 2631-1 may be considered for assessing health, particularly with regard to vibration exposures with occasional or substantial shocks or transient vibration (category B). For category C, the evaluation methods in ISO 2631-5 should be used.

5.5.5.1.4 Measurement of whole-body vibration and shock.

5.5.5.1.4.1 Categories A and B. For categories A and B, triaxial accelerations (orthogonal accelerations) shall be measured at the interface between the human and the predominant vibration source. For seated occupants, this is the interface between the buttocks and seat support, usually the seat pan or seat cushion. For the seated occupant, it is highly recommended to measure triaxial accelerations at the interfaces between the occupant and the seat back and foot support, particularly for assessing comfort and perception in accordance with ISO 2631-1. For standing occupants, this is the floor or deck. For the recumbent occupant, this is the interface between the pelvis and supporting surface. The frequency range for categories A and B is 0.5 to 80 hertz. The acceleration time histories need to be sufficiently long so that a minimum of 5 to 10 complete cycles for the minimum frequency are obtained.

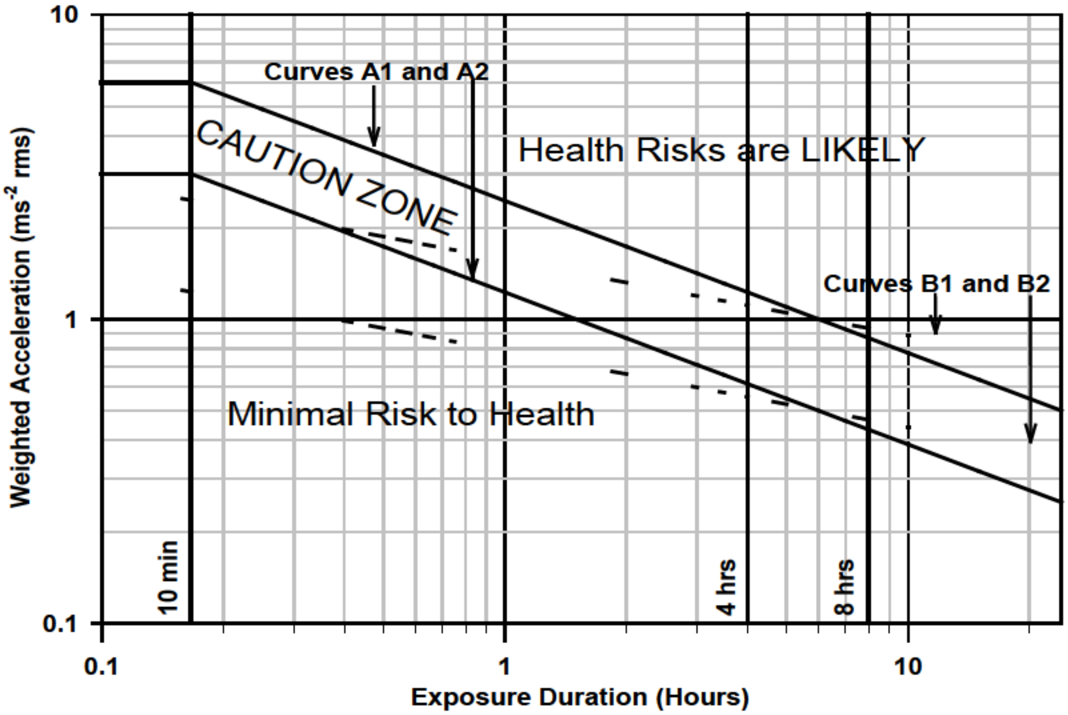
5.5.5.1.4.2 Category C. For category C, Z accelerations shall be measured at the interface between the occupant ischial tuberosities and predominant impact source (seat pan or seat cushion). Category C is limited to impacts that exceed 9.81 m/s^2 (32.2 ft/s^2) or 1 g (1 g in this context is the force per unit mass due to gravity at the Earth's surface and is the standard gravity and should not be confused with "g" in the SI units where it represents grams). The time histories are evaluated between 0.01 and 80 hertz in accordance with ISO 2631-5. The acceleration time histories need to be sufficiently long to include representative impacts. For detail on instrumentation, see ISO 2631-1, ISO 2631-5, and ISO 5348.

5.5.5.1.4.3 Category D. For category D, Z accelerations shall be measured at the interface between the human and the predominant vibration source. For standing occupants, this is the floor or deck. For seated occupants, this is the interface between the buttocks and seat support, usually a seat cushion (seat pan). The acceleration time histories need to be sufficiently long to provide accurate resolution of low frequency oscillations between 0.1 and 0.5 hertz.

5.5.5.1.5 Whole-body vibration exposure health criteria. Triaxial acceleration data shall be processed in accordance with ISO 2631-1 using the basic method, the frequency weightings, and multiplying factors for health. The effects of vibration on occupant health for standing and recumbent exposures are not known. The criteria for seated exposures should be applied to standing and recumbent exposures with caution using measurements obtained between the feet and supporting surface (standing) or the pelvis and the supporting surface (recumbent) per ISO 2631-1. Vehicle design shall be in accordance with the following requirements.

5.5.5.1.5.1 Category A: vibration. Acceleration levels for all three orthogonal axes shall be calculated when assessing health risk. The assessment of the health risk will use the vector sum of the three orthogonal axes of the seat pan frequency weighted root mean square (RMS) accelerations after applying the respective multiplying factors (also known as the seat pan vibration total value, a_v, in accordance with ISO 2631-1).

5.5.5.1.5.1.1 Daily seated exposure. The seat pan vector sum or vibration total value of the daily seated exposure within 24 hours shall not fall within the zone labeled "Health Risks are LIKELY" above curve A1 (solid line) as shown on figure 36 for any occupied space.



Exposure Duration (hrs)	Weighted Acceleration (m/sec^2)			
	Curve A1	Curve A2	Curve B1	Curve B2
0.1667 (10 min)	6.00	3.00	2.453	1.227
1.0	2.449	1.225	1.568	0.784
2.0	1.732	0.866	1.318	0.659
4.0	1.225	0.612	1.108	0.554
6.0	1.0	0.5	1.002	0.501
8.0	0.866	0.433	0.932	0.466
15.0	0.632	0.316	0.797	0.398
24.0	0.5	0.25	0.708	0.354

NOTE: Curves A1 and A2 represent the upper and lower zones, respectively, associated with Equation B.1 in ISO 2631-1, Annex B. Curves B1 and B2 represent the upper and lower zones, respectively, associated with Equation B.2 in ISO 2631-1, Annex B.

FIGURE 36. Health guidance zones for limited exposures.

5.5.5.1.5.1.2 Warning to occupants. If any vector sum or vibration total value falls within the "Caution Zone" bounded by curves A1 and A2, a warning to occupants shall be provided indicating the potential health risk and attempts shall be made to reduce the exposure magnitude or duration to levels within the "Minimal Risk to Health" zone below curve A2.

5.5.5.1.5.1.3 Allowable exposure durations. When the mission duration is unknown or varies for a particular vehicle, the following equations may be applied based on the measured accelerations:

a. The maximum allowable exposure duration associated with the upper boundary (curve A1) on figure 36 prior to entering the "Health Risks are LIKELY" zone can be approximated as:

$$t = 6/a_v^2$$

Where a_v = the seat pan vector sum or vibration total value.

b. Likewise, the maximum allowable exposure duration associated with "Minimal Risk to Health" or the lower boundary (curve A2) on figure 36 can be approximated as:

$$t = 1.5/a_v^2$$

c. The assumption is made that the estimate of the seat pan vector sum or vibration total value is expected to represent the exposure associated with the majority of missions.

5.5.5.1.5.1.4 European Parliament Directive. The European Parliament Directive 2002/44/EC provides a daily exposure limit value standardized to an 8-hour reference period of 1.15 $\mathrm{m/s^2}$ (3.8 $\mathrm{ft/s^2}$) and a daily exposure action value standardized to an 8-hour reference of 0.5 $\mathrm{m/s^2}$ (1.6 $\mathrm{ft/s^2}$) for whole-body vibration. These guidelines use the highest frequency weighted acceleration in any orthogonal direction and not the vector sum.

5.5.5.1.5.2 Category B: vibration with occasional shock or transient vibration.

5.5.5.1.5.2.1 Fourth power vibration dose method. If the ISO 2631-1 guidelines warrant the application of alternative methods, the fourth power vibration dose method can be applied in addition to the basic method described for category A.

5.5.5.1.5.2.2 Exposures less than or equal to 6 hours. For daily seated exposures lasting less than or equal to 6 hours in a 24-hour period, the seat pan vibration dose value in any orthogonal direction shall not exceed an exposure limit value of 17 $\mathrm{m/s^{1.75}}$, which corresponds to curve B1 on figure 36.

5.5.5.1.5.2.3 Warning to occupants. If any vibration dose values for exposures less than or equal to 6 hours fall within the "Caution Zone" bounded by curves B1 and B2 (17 and 8.5 $\mathrm{m/s^{1.75}}$, respectively), a warning to occupants shall be provided indicating the potential health risk and attempts shall be made to reduce the vibration dose value below 8.5 $\mathrm{m/s^{1.75}}$ or within the "Minimal Risk to Health" zone below curve B2 on figure 36.

5.5.5.1.5.2.4 Exposures greater than 6 hours. For daily seated exposures lasting greater than 6 hours in a 24-hour period, the seat pan vibration dose value in any orthogonal direction shall not exceed an exposure limit value of 8.5 $\mathrm{m/s^{1.75}}$, which corresponds to curve B2 on figure 36.

5.5.5.1.5.2.5 European Parliament Directive. The European Parliament Directive 2002/44/EC provides a daily exposure limit value of 21 $\mathrm{m/s^{1.75}}$ and a daily exposure action value of 9.1 $\mathrm{m/s^{1.75}}$.

5.5.5.1.5.3 Category C: repeated/multiple shocks or transient vibration. The primary evaluation methodology and limits for this environment shall be in accordance with ISO 2631-5. The methodology and limits apply to relatively severe exposure conditions dominated by accelerations in the Z direction that may contain periods of free-fall, such as movement that occurs during the operation of military off-road vehicles and high-speed marine craft.

5.5.5.1.5.3.1 Acceleration daily dose. For operational environments where peak accelerations exceed 9.81 $\mathrm{ms^{-2}}$ or 1 g, the acceleration daily dose, D_{zd}, shall be calculated by applying the seat-to-lumbar spine transfer function to the measurement of the vertical acceleration occurring at the interface between the seat pan and occupant in the frequency range 0.01 to 80 hertz in accordance with ISO 2631-5. The D_{zd} is then used to calculate the daily equivalent static compression dose, S_d, which, in turn, is used to calculate the stress variable, R.

5.5.5.1.5.3.2 *R* values. Using the guidelines provided in ISO 2631-5, table C2, *R values for risk of injury*, R for males shall not exceed a value of 1.42, and for females shall not exceed a value of 0.87. These R values correspond to a 50 percent risk of injury or moderate risk.

5.5.5.1.6 Whole-body vibration exposure comfort criteria. Triaxial acceleration data shall be processed in accordance with ISO 2631-1 using the basic method and the frequency weightings and multiplying factors for comfort. When considering the overall comfort of the occupant during exposure to vibration, the vehicle design shall meet the following requirements.

5.5.5.1.6.1 Category A: vibration. Acceleration levels for all three orthogonal axes shall be calculated when assessing comfort. The assessment of comfort will use the vector sum of the three orthogonal axes of the seat pan frequency weighted RMS accelerations after applying the respective multiplying factors (also known as the seat pan vibration total value, a_v in accordance with ISO 2631-1). Additional guidelines are given in ISO 2631-1 for including accelerations measured at other locations (seat back, foot support) in the assessment, particularly when significant levels of vibration are present.

5.5.5.1.6.1.1 Exposures less than 6 hours. For exposures lasting 6 hours or less in a 24-hour period, the vector sum of the interface frequency weighted RMS accelerations in the three orthogonal directions shall not exceed 0.5 meters per second squared (m/s^2).

5.5.5.1.6.1.2 Exposures greater than 6 hours. For exposures lasting greater than 6 hours in a 24-hour period, the vector sum of the interface frequency weighted RMS accelerations in the three orthogonal directions shall be limited to the zone labeled “Minimum Risk to Health” below curve A2 on figure 36.

5.5.5.1.6.2 Category B: vibration with occasional shock or transient vibration. Same as category A.

5.5.5.1.7 Whole-body vibration exposure perception criteria. Triaxial acceleration data shall be processed in accordance with ISO 2631-1 using the basic method, the frequency weightings, and multiplying factors for perception. In order to minimize the perception that the occupant is being exposed to vibration, the vehicle design shall meet the following requirements.

5.5.5.1.7.1 Category A: vibration. To minimize the human sensation of vibration, the vector sum of the interface frequency weighted RMS accelerations in the three orthogonal axes shall be below 0.015 m/s^2.

5.5.5.1.7.2 Category B: vibration with occasional shock or transient vibration. Same as category A.

5.5.5.1.8 Whole-body vibration exposure performance criteria. Triaxial acceleration data shall be processed in accordance with ISO 2631-1 using the basic method the frequency weightings, and multiplying factors for health. To minimize the degradation in task performance during vibration exposure, the vehicle design shall meet the following requirements.

5.5.5.1.8.1 Category A: vibration. The seat pan frequency weighted triaxial RMS accelerations in any orthogonal direction or the vector sum for the expected exposure duration shall be limited to the zone labeled “Minimum Risk to Health” below curve A2 on figure 36.

5.5.5.1.8.1.1 Frequency range. Whole-body vibration shall be minimized in the frequency range below 20 hertz where major body resonances occur.

5.5.5.1.8.1.2 Impairment of visual tasks. To preclude impairment of visual tasks due to resonances associated with the visual system, vibration between 20 and 70 hertz shall be minimized.

5.5.5.1.8.2 Category B: vibration with occasional shock or transient vibration. Same as category A.

5.5.5.1.9 Whole-body vibration motion sickness criteria.

5.5.5.1.9.1 Category D: low frequency vibration associated with kinetosis or motion sickness and associated syndromes. The criteria below apply to medium duration exposures to accelerations and angular velocities primarily in the frequency range of 0.1 and 0.5 hertz lasting between 30 minutes and 48 hours and do not account for adaptation (or conversely, classical conditioning) that occurs for longer duration exposures. Vehicles shall be designed to limit oscillatory motion in the frequency range of 0.1 and 0.5 hertz, especially at higher peak velocities.

5.5.5.1.9.1.1 Frequency range. Limit oscillatory motion in the frequency range of 0.1 and 0.5 hertz, especially at higher peak velocities.

5.5.5.1.9.1.2 Exposure guidance. As operational requirements permit, the guidelines below should be followed:

a. Duration – Avoid exposure to problematic frequencies for longer than about 30 minutes.

b. Direction – Limit vertical translational (heave) motion of the body during exposure to the problematic frequencies.

c. Reference – Avoid acceleration exposure in the absence of an earth-fixed sensory reference (e.g., the horizon).

d. Motion sickness dose value (MSDVz) – The MSDVz is calculated using the weighted acceleration in m/sec^2 and the exposure duration in seconds (see ISO 2631-1, Annex D). The percent motion sickness rate is equal to K_m times the $MSDV_z$, where K_m is equal to 1/3 for a mixed population of un-adapted adults (see ISO 2631-1 for further guidance). Limit the MSDV to less than 30 $m/s^{1\ 5}$ in order to maintain a motion sickness rate of less than 10 percent sick (see ISO 2631-1).

5.5.5.1.10 Vehicle seating systems. Vehicle seating systems shall be designed to minimize the transmission of vehicle vibration and shock to the occupant in accordance with the criteria defined in 5.5.5.1.

5.5.5.1.10.1 Seating system resonances. Seating system resonances below 20 hertz shall be avoided but may be necessary to properly mitigate shocks in category C environments.

5.5.5.1.10.2 Minimize operational vibration. Seating systems shall minimize vibration in the operational frequency range of the vehicle.

5.5.5.1.10.3 Visual performance. Where visual performance is critical, higher frequencies at the seatback and headrest shall be avoided.

5.5.5.1.10.4 Relative motion. Seats shall be designed to limit any relative motion between the operator and critical controls and displays. This may require that design consider independent isolation of the seat, controls, and displays from the vehicle.

5.5.5.1.10.5 Back support. Vehicle seating systems shall be designed to provide back support (i.e., lumbar support), buttocks, and leg support so that the occupant can be comfortably seated in order to optimize the posture in vibrating environments.

5.5.5.1.11 Helmet and head-supported systems. Vibration transmission is of special concern where vehicle vibration below 10 hertz may be prevalent and associated with whole-body resonance causing amplification of vibration to the head. The use of helmet- and head-supported equipment in these environments may exacerbate the health, comfort, and performance of the occupant. While current exposure criteria are limited to the seat/occupant interfaces, it is highly recommended that head/helmet translational and, where possible, rotational accelerations be measured synchronously with the seat pan and compared to existing literature. Considerations should be made for the influence of posture and anthropometric characteristics of the occupant as well as helmet mass and configuration on head acceleration. Research efforts investigating the relationship between head supported mass and vibration are on-going, however no guidelines are currently available.

5.5.5.2 Building vibration. Buildings intended for occupation by personnel shall be designed/located to control the transmission of whole-body vibration and limit low frequency vibration that could affect motion sickness and associated syndromes. Guidance is given in ISO 2631-2.

5.5.5.3 Equipment vibration. Where whole-body vibration of the human occupant or parts of the body are not a factor, equipment oscillations shall not impair required manual control or visual performance.

5.5.5.3.1 Design and mounting of visual displays. Special attention should be given to the design and mounting of visual displays in military vehicles where operational vibration can occur.

5.5.5.3.2 Relative motion. The design of controls shall limit the relative motion between the operator and the controls and displays (see 5.5.5.1.10.4).

5.5.5.4 Hand-transmitted vibration.

5.5.5.4.1 Hand-transmitted vibration reduction through design. The design process shall consider hand-transmitted vibration and seek to minimize equipment vibration (see 5.5.5.4.7).

5.5.5.4.2 Automation technologies. Whenever technically practical and economically viable, automation technologies or machines shall be considered to replace manual work with the use of a powered hand tool as much as possible.

5.5.5.4.3 Selection of tools. Powered tools procured for use in support of DoD facilities and equipment should be evaluated, selected, and maintained to optimize productivity, life cycle cost and safety and health factors, including hand-transmitted vibration (see 5.5.5.4.7). SAE AS6228 can be used as a process standard.

5.5.5.4.4 Maintenance of tools and equipment. The tools or machines shall be regularly maintained and kept in good working condition.

5.5.5.4.5 Cutting parts of tools or machines. The cutting parts (e.g., chisels and blades) of a tool or machine shall be kept sharp to ensure their working efficiency.

5.5.5.4.6 Measurement of hand-transmitted vibration. Measurements and processing of hand-transmitted vibration shall be conducted in accordance with the procedures prescribed in ISO 5349-1 and ISO 5349-2.

5.5.5.4.7 Allowable exposure duration. When the exposure duration is unknown or can vary, the following equations may be applied based on the measured accelerations:

a. The maximum exposure duration associated with the daily exposure limit value (DELV) or upper boundary on figure 37 can be as:

$$t = 200/a_{hv(rms)}^2$$

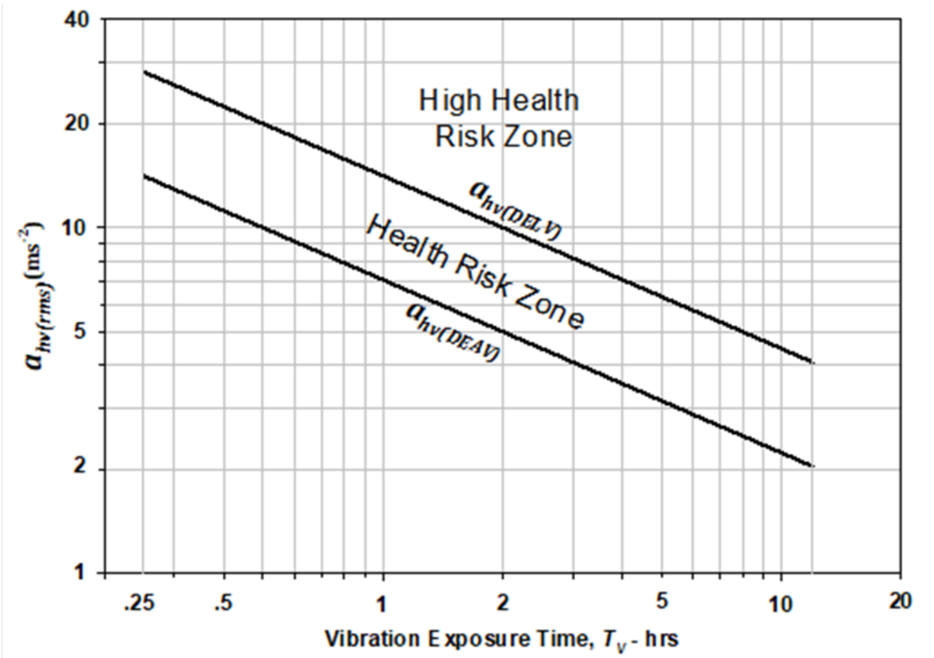
Where $a_{hv(rms)}$ = frequency-weighted vibration total value.

b. The maximum exposure duration associated with the daily exposure action value (DEAV) or the lower boundary on figure 37 can be calculated as:

$$t = 50/a_{hv(\mathrm{rms})}^2$$

c. The assumption is made that the estimate of the frequency-weighted vibration total value is expected to represent the exposure associated with normal tool use.

d. The European Parliament Directive 2002/44/EC provides a daily exposure limit value standardized to 8 hours of 5 m/s^2 and a daily exposure action value standardized to 8 hours of 2.5 m/s^2 for hand-arm vibration. These values are identical to the 8-hour daily exposure limit value and the 8-hour daily exposure action value defined in ANSI/ASA S2.70.



Vibration Exposure Time (hrs)	Weighted Acceleration ($a_{hv(rms)}$ ms^{-2})	
	$a_{hv(DELV)}$	$a_{hv(DEAV)}$
0.25 (15 min)	28.284	14.142
1.0	14.142	7.071
2.0	10.0	5.0
4.0	7.071	3.536
6.0	5.774	2.887
8.0	5.0	2.5
12.0	4.082	2.041

FIGURE 37. Plots of the $a_{hv(DELV)}$ and $a_{hv(DEAV)}$ values for vibration exposure times other than 8 hours.

5.5.5.4.8 Multiple shock vibration assessment. Vibration involving multiple shocks shall be measured and evaluated in accordance with ISO 5349-2 and the related health effects shall be assessed in accordance with ISO 5349-1 with caution.

5.5.6 Sustained G. This section addresses the design considerations for ensuring crew health and performance during linear acceleration vectors and fields. The acceleration environments experienced during flight or other high-G environments have the potential to cause illness and injury as well as affect crew performance. The effect of acceleration on crewmembers depends on the magnitude, duration (sustained or transient), and direction with respect to the crewmember (through the head, chest, or shoulders) of the acceleration (see table XXIV and figure 38). Note that sustained accelerations are events with duration of greater than or equal to 1.0 second. Transient or impact accelerations are events with duration of less than 1.0 second.

TABLE XXIV. Inertial resultant of body acceleration.

Linear Motion	Physiologic Descriptive	Physiologic Standard	Vernacular Descriptive
Forward	Transverse G, chest to back	+Gx	Eyeballs-in
Backward	Transverse G, back to chest	-Gx	Eyeballs-out
To the right	Lateral G	+Gy	Eyeballs-left
To the left	Lateral G	-Gy	Eyeballs-right
Upward	Positive G	+Gz	Eyeballs-down
Downward	Negative G	-Gz	Eyeballs-up

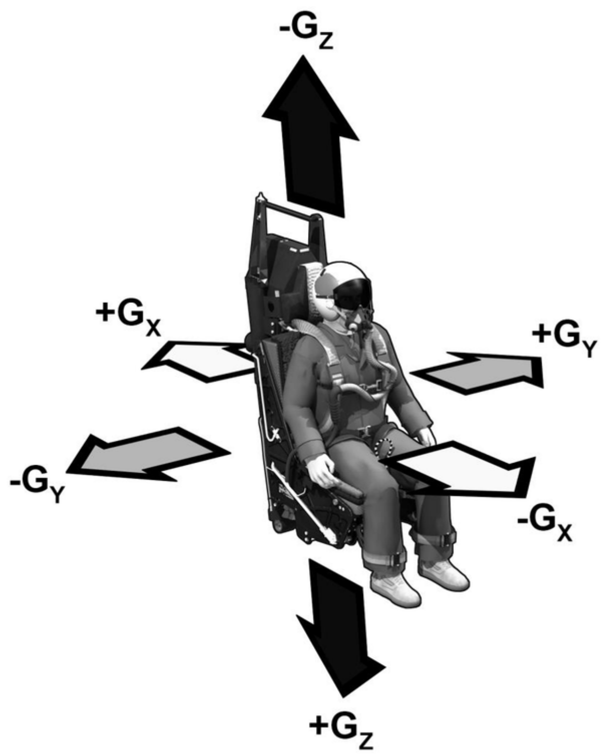


FIGURE 38. Inertial resultant of body acceleration.

5.5.6.1 Terminology. The capital letter G is used to express inertial resultant force due to whole-body acceleration in multiples of the magnitude of the acceleration due to gravity, g = 9.80665 m/s² (32.17405 ft/s²).

5.5.6.2 G-loading description. Table XXV is a summary description of the combined human responses to specific sustained linear acceleration vectors and fields in a relaxed, unprotected individual adapted to Earth's gravity. It should be noted that the physiological effects described below depend on the onset rate (e.g., gradual onset less than 1.0 G per second, rapid onset 1.0 to 2.0 G per second, and very high onset greater than 6.0 G per second). High onset rates of +Gz (gravitational force) will challenge the human cardiovascular system's ability to compensate physiologically. At acceleration levels of +5 Gz and higher, this can result in G-induced loss of consciousness (G-LOC) upon the exhaustion of the brain's 3 to 5 seconds of oxygen reserve if the anti-G garment and anti-G straining maneuver are not employed effectively. The following effects are primarily derived from studies involving gradual onset exposures.

TABLE XXV. Physiological effects of sustained linear acceleration.

Effects of Sustained +Gx Acceleration (Eyeballs-In)	
1.0 Gx	Slight increase in abdominal pressure; respiratory rate increases.
+2.0 to +3.0 Gx	Difficulty in spatial orientation; +2.0 G tolerable for at least 24 hours.
+3.0 to +6.0 Gx	Progressive tightness in chest and abdomen; cardiac rhythm disturbances; loss of peripheral vision; difficulty in breathing and speaking; blurring of vision; effort required to maintain focus; +4.0 Gx tolerable up to at least 60 minutes.
+6.0 to +9.0 Gx	Chest pain and pressure; shallow respiration from position of nearly full inspiration; decreased oxygen uptake during acceleration; pulmonary vascular pressures increase towards the dorsal part of chest and fall in alveolar pressure on the ventral part; arterial oxygen saturation falls below 85%, which can lead to cognitive impairment; further reductions in visual acuity and depth perception, increased blurring, and occasional tunneling; great concentration required to maintain focus; occasional lacrimation (tears); body, legs, and arms cannot be lifted at +8.0 G; head cannot be lifted at +9.0 G; precise manual control compromised.
+9.0 to +12 Gx	Increased severity of symptoms; severe breathing difficulty; increased chest pain; marked fatigue; loss of peripheral vision; diminution of central visual acuity, lacrimation.
>+12 Gx	Extreme difficulty in breathing and speaking; severe viselike chest pain; loss of tactile sensation; total loss of vision possible.
Effects of Sustained –Gx Acceleration (Eyeballs-Out)	
+1 Gx to -1 Gx	Equivalent to the erect or seated terrestrial posture.
All levels	Similar to those of forward acceleration with modifications produced by reversal of the force vector; chest pressure reversed. Total body restraint system is critical and has a direct relationship with the ability to tolerate rearward acceleration exposures.
Effects of Sustained ±Gy Acceleration (Eyeballs Left/Right)	
-1 Gy to +1 Gy	Equivalent to the erect or seated terrestrial posture.
±1.0 to 2.0 Gy	Difficulty maintaining head and shoulders upright without restraints; difficulty of precise manual control; loss of vision in ‘uphill’ eye; requirement for head and body bracing or restraints.
±3.0 Gy	Discomfort after 10 seconds; pressure on restraint system; feeling of supporting entire weight on clavicle; inertial movement of hips and legs; yawing and rotation of head toward shoulder; petechiae and bruising; painful engorgement of dependent elbow; increased work of breathing and risk of atelectasis; full body restraint system is critical.
±5.0 Gy	Conjunctival hemorrhage has been reported; severe headache after exposure.

TABLE XXV. Physiological effects of sustained linear acceleration – Continued.

Effects of Sustained +Gz Acceleration (Eyeballs Down)	
+1.0 Gz	Equivalent to the erect or seated terrestrial posture.
+2.0 to +2.5 Gz	Increased weight; increased pressure on buttocks; drooping of face and body tissues; difficulty in use of touchscreens or other precision hand/arm movements.
+3.0 to +4.0 Gz	Heaviness in arms and legs intensifies and movement of the extremities becomes difficult; head movement difficult at or above +4Gz; dimming of vision; difficulty in viewing head-down displays; loss of color vision ("grayout"), tunneling, or loss of peripheral vision.
+5.0 to +6.0 Gz	Tachycardia or other dysrhythmia; leg swelling; muscle cramps; labored breathing; petechiae in lower extremities; complete loss of vision ("blackout"). Total G-LOC typically occurs at +6.0 Gz or beyond. Following unconsciousness, cognitive and psychomotor function may take 55 seconds to fully recover. Anti-G-suit and Anti-G Straining Maneuver required to maintain physiological and cognitive performance.
>+6.0 Gz	Protection needed to preserve consciousness and health.
Effects of Sustained -Gz Acceleration (Eyeballs Up)	
+1 Gz to -1 Gz	Increased blood pressure to the upper body and head; beginning stages of bradycardia; transition to >+1 Gz may result in decreased physiological performance at lower than normally tolerated +Gz.
-1.0 Gz	Tolerable; sense of pressure and fullness in the head; congestion of eyes; compensatory bradycardia, cerebral vasoconstriction and peripheral vasodilation; compromised physiological performance upon transition to lower than normally tolerated +Gz.
-2.0 to -3.0 Gz	Severe facial congestion; bradycardia; dysrhythmia; throbbing headache; blurring, graying, or occasional reddening of vision after 5.0 seconds; compensatory bradycardia, cerebral vasoconstriction and peripheral vasodilation; compromised physiological performance upon transition to lower than normally tolerated +Gz; congestion disappears slowly; may leave petechial hemorrhages, swollen eyelids.
>-3.0 Gz	Red-out; mental confusion and unconsciousness.

5.6 Ground vehicles. This section does not represent the sum total of all human engineering requirements related to the design of ground vehicles. There are other sections within this standard (e.g., specific requirements for controls, warnings, audio systems, maintenance) that also contain relevant requirements. The reader is cautioned to examine all sections of the standard for requirements relevant to the specific design effort at hand.

5.6.1 General.

5.6.1.1 Ground vehicle accommodation of target population. The system design shall accommodate the target audience population as specified (see 5.8.4 and 6.2) that will interact with the ground vehicle and the clothing and equipment configurations the target audience population will be wearing, carrying, and stowing on the ground vehicle.

5.6.1.2 User interfaces and workspace. All interfaces between the user and his or her equipment and all workspace dimensions shall enable vehicle occupation, operation, maintenance, and support by the full range of the user population in all clothing and equipment as defined by the procuring activity (see 6.2).

5.6.1.3 Maintenance. For maintenance guidance, see 5.9.

5.6.1.4 Sound pressure levels (SPL). The SPL to which any vehicle occupant is exposed shall be in accordance with MIL-STD-1474.

5.6.1.5 General clearances.

5.6.1.5.1 Clearance and size requirements. The relevant suitably clothed and equipped dimensions shall be used when determining clearance and size requirements, such as hatch opening dimensions, access openings, and sizes of foot platforms.

5.6.1.5.2 Exterior components. Components on the exterior of the vehicle shall accommodate operation and maintenance by users in all clothing and equipment configurations.

5.6.1.5.3 Interior components. Components on the interior of the vehicle shall accommodate operation and maintenance by users in all clothing and equipment configurations with the exception of arctic mittens, unless specified elsewhere in this section.

5.6.1.6 Reach. The relevant suitably clothed and equipped dimensions shall be used when determining reach requirements.

5.6.1.7 Controls and displays. All controls and displays shall not interfere with station operations for indirect viewing, periscope, open-protected, or open-hatch operations.

5.6.2 Vehicle seat system. The vehicle seat system is comprised of all components associated with the seat including the seat pan, seat back, head rests and restraints, seat restraints, arm rests, and footrests.

5.6.2.1 Dimensions and clearances. Vehicle occupant seating dimensions and clearances shall be in accordance with figure 39, figure 40, and table XXVI, as applicable.

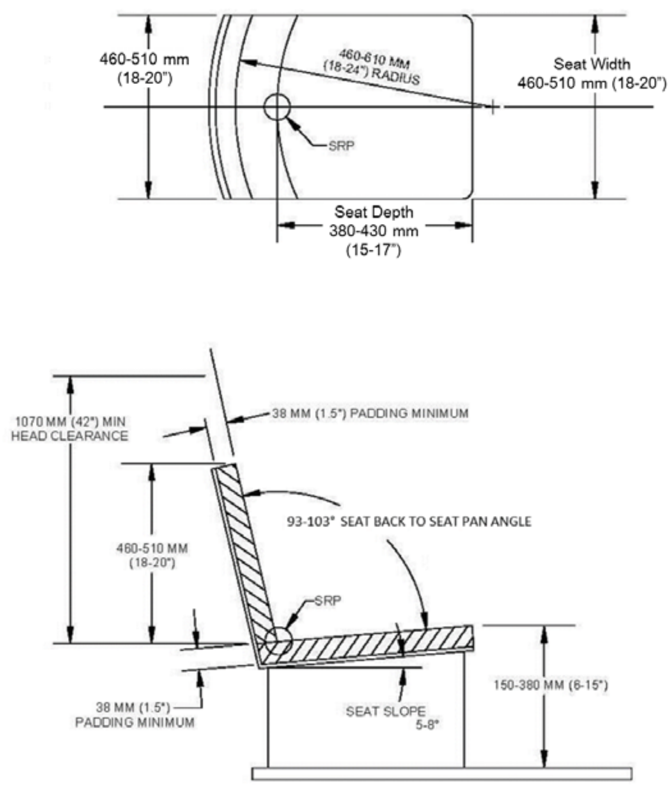


FIGURE 39. Seat dimensions.

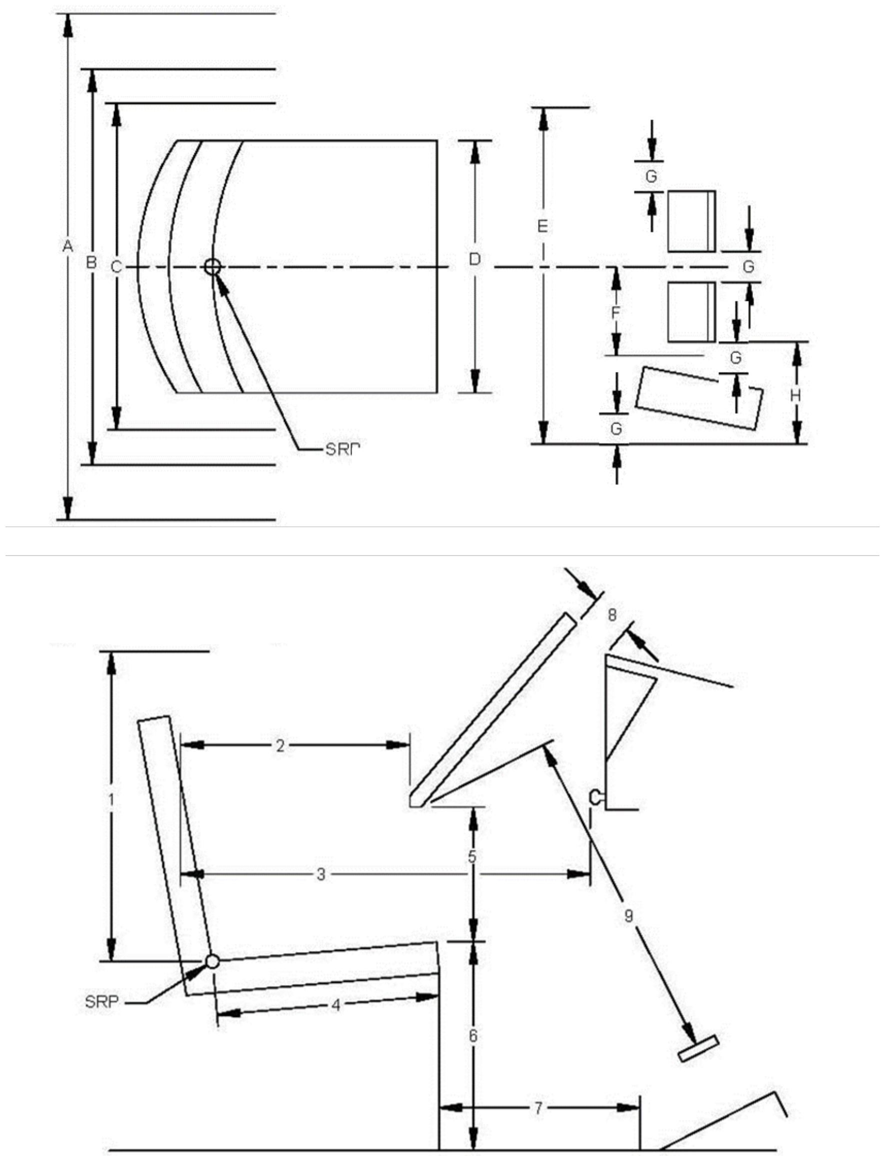


FIGURE 40. Measurements for clearances around equipment. See table XXVI.

TABLE XXVI. Clearances around vehicle stations to accommodate an occupant dressed in arctic clothing.

Parameter	Required Clearance
A. Elbow (dynamic)	91 cm (36 in)
B. Elbow (static)	71 cm (28 in)
C. Shoulder	58 cm (23 in)
D. Knee width (minimum)	46 cm (18 in)
E. Knee width (optimum)	61 cm (24 in)
F. Boot (provide clearance to operate brake pedal without inadvertent accelerator operation)	15 cm (6.0 in)
G. Pedals in all directions (minimum)	5.0 cm (2.0 in)
H. Boot (provide clearance to operate accelerator without interference by brake pedal)	15 cm (6.0 in)
1. Head (seat reference point [SRP] to roof line)	105 cm (42 in)
2. Abdominal (seat back to steering wheel)	40 cm (16 in)
3. Front of knee (seat back to manual controls on dash)	74 cm (29 in)
4. Seat depth (SRP to front edge of seat pan)	40 cm (16 in)
5. Thigh (underside of steering wheel to seat pan)	24 cm (9.5 in)
6. Seat pan height (at front edge of seat pan)	38 cm (15 in)
7. Boot (front of seat pan to heel point of accelerator)	36 cm (14 in)
8. Minimum mitten clearance around steering wheel	8 cm (3 in)
9. Knee-leg-thigh (brake/clutch pedals to lower edge of steering wheel)	66 cm (26 in)

NOTES:

1. See figure 40.
2. Seat pan height is measured from the heel point to the top of the seat pan. The heel point may rest on the floor or on a footrest.

5.6.2.2 Seat clearances.

5.6.2.2.1 Head clearance. A clearance measuring at least 50 mm (2 in) shall be provided between the user's head in appropriate gear and the closest potential head impact.

5.6.2.2.2 Body clearance in the fore-aft direction. A clearance measuring at least 50 mm (2 in) in the fore-aft direction shall be provided between any body part and any hard surface while the occupant is wearing mission clothing and equipment.

5.6.2.2.3 Body clearance in the horizontal direction. A clearance measuring at least 50 mm (2 in) in the horizontal direction should be provided between any body part and any hard surface with the occupant wearing mission clothing and equipment. This clearance does not apply to occupant-to-occupant seating.

5.6.2.2.4 Body clearance in the vertical direction. A clearance measuring at least 50 mm (2 in) in the vertical direction shall be provided between any body part and any hard surface with the occupant wearing mission clothing and equipment.

5.6.2.2.5 Gear accommodation. Seats and associated clearances shall be designed to accommodate required occupant gear as specified (see 6.2).

5.6.2.3 Seat padding.

5.6.2.3.1 Design. Seat padding should meet the requirements of 5.10.3.12.10 to support blood flow to and from the legs to preclude "pinching off" of nerves and to provide protection from bruising.

5.6.2.3.2 Loading. Seat padding should be resilient enough to keep the occupant's body from contacting the seat bottom during the mobility-induced loading conditions predicted for the vehicle while wearing mission clothing and equipment.

5.6.2.3.3 Materials. The padding materials selected shall be impervious to biological organisms, such as molds and fungi, and shall not deteriorate from humidity or perspiration within the thermal environments specified (see 6.2).

5.6.2.3.4 Lateral support. The seat back should be contoured to provide lateral support to the seat occupant.

5.6.2.4 Seats beneath hatches and entryways.

5.6.2.4.1 Dropping onto seat pan. Seats shall accommodate the weight of the occupant dropping from a height of 1.2 m (4 ft) onto the seat pan in any of the seat's adjustment positions while wearing mission clothing and equipment.

5.6.2.4.2 Dropping onto seat back. Seats shall accommodate the weight of the occupant dropping from a height of 1.2 m (4 ft) onto the seat back while wearing mission clothing and equipment. If the seat back can be folded to a horizontal position, this requirement shall be met in any of the seat's adjustment positions.

5.6.2.4.3 Seats used as standing surfaces. Where seats can be used as standing surfaces when operating in the hatch or entryway above the seat, the seat shall accommodate the weight of the occupant wearing mission clothing and equipment in all specified vehicle mobility loading scenarios.

5.6.2.4.4 Open hatch seating. All vehicles with an open-hatch or open-protected hatch seat shall provide the capability for the seat to drop immediately to allow personnel to seek protection during emergencies, including hostile fire or vehicle rollover.

5.6.2.4.5 Durability. The seat surface(s) that will be used as the standing surface shall be durable to accommodate boots with sand, dirt, and oil without damage to seat cushion or covering.

5.6.2.4.6 Surface coating. If the seat surface(s) that will be used as the standing surface is not the seat cushion (i.e., the seat back can fold to a horizontal position), the surface(s) shall have a non-skid surface or coating.

5.6.2.5 Seats adjacent to doorways and entryways. Seats adjacent to doorways or entryways shall accommodate the weight of the heaviest user sliding across the seat during ingress or egress while wearing mission clothing and equipment without damage to the seat cushion or covering.

5.6.2.6 Seat system adjustments.

5.6.2.6.1 Vertical and horizontal adjustments. The seat shall provide vertical (up/down) and horizontal (fore/aft) travel to accommodate the defined occupant population and allow the occupant to see, reach, and use all provided controls; see all displays; and use direct and indirect vision systems (e.g., screens, periscopes).

5.6.2.6.2 Seat travel. The vertical and horizontal seat travel shall allow the occupant to reach the open-protected and open-hatch position if the vehicle is so equipped.

5.6.2.6.3 Accidental activation. Seat adjustment controls and mechanism shall be designed to prevent accidental activation.

5.6.2.6.4 Adjust to alternate position. If a seat blocks an egress path or inhibits the rescue of an incapacitated seated occupant, the seat shall adjust as required in order to accommodate these scenarios.

5.6.2.6.5 Adjustment by personnel. Any action required to adjust the seat to accommodate egress or rescue shall be operable by personnel who are in the seat as well as personnel who are not in the seat.

5.6.2.6.6 Single-handed operation. Adjustment of the seat shall not require more than a single-handed action. Two-handed action is acceptable to accommodate rescue of an incapacitated seat occupant.

5.6.2.6.7 Adjustment by seat occupant. The single-handed action shall be operable by the seat occupant while positioned in the seat. Raising oneself up to remove the weight off the seat when making the adjustment is permissible.

5.6.2.6.8 Force. Controls that implement the seat adjustment shall not require more than 36 newtons (8 lbs) to activate.

5.6.2.6.9 Snag hazard. Controls and mechanisms that implement the seat adjustment shall not present a snag hazard during ingress or egress.

5.6.2.6.10 Return to neutral position. The seat adjustment control shall return to the neutral position when no force is applied to it.

5.6.2.6.11 Crush hazard. The seat shall not create a crush hazard between the seat and any adjacent items in the area.

5.6.2.7 Restraints.

5.6.2.7.1 Vehicle seat restraints. All vehicles shall have safety restraints that are designed for operation with the clothing and equipment worn by the vehicle occupants.

5.6.2.7.2 Latch release mechanism. The latch release mechanism for the restraint shall be able to be disengaged by the seat occupant with a single gloved hand.

5.6.2.7.3 Interference with ingress and egress. Headrests and head restraints shall not interfere with the seat occupant’s ability to ingress or egress the vehicle.

5.6.2.7.4 Open-hatch restraint system. An occupant in a hatch opening (standing or seated) while in a moving vehicle shall be restrained to prevent their ejection from the vehicle in the event of a crash, blast, or rollover event.

5.6.2.8 Spacing between seats.

5.6.2.8.1 Bench seating. Bench seating for embarked personnel shall provide a minimum of 550 mm (22 in), 663 mm (26.5 in) preferred, centerline-to-centerline spacing for adjacent seat positions.

5.6.2.8.2 Discrete seating. Discrete seating for embarked personnel shall provide a minimum of 610 mm (24 in), 663 mm (26.5 in) preferred, centerline-to-centerline spacing for adjacent seat positions.

5.6.3 Controls.

5.6.3.1 Vehicle controls.

5.6.3.1.1 Multiple modes of operation. For vehicles that have multiple modes of operation (e.g., an amphibious vehicle with “land” and “water” modes of operation), common interfaces should be used across the modes (i.e., one accelerator interface should control vehicle acceleration in all modes and one steering interface should control vehicle steering in all modes).

5.6.3.1.2 Dynamic effects. Control use shall not be adversely affected by shock or vibration of the vehicle (see 5.5.5).

5.6.3.1.3 Steering mechanism. The steering mechanism (steering wheel or yoke) shall be no more than 25 mm (1 in) offset from the longitudinal centerline of the seat.

5.6.3.1.4 Steering. In case of power steering failure, the operator shall not have to apply more than 220 newtons (50 lb) of force on the steering wheel in order to guide the vehicle.

5.6.3.1.5 Braking. In case of power brake failure, the operator shall not have to apply more than 800 newtons (180 lb) of force on the brake pedal in order to stop the vehicle.

5.6.3.1.6 Pedals. Foot pedals shall accept the weight of the operator's foot without initiating control action (see 5.1.4.2.2.2 and figure 21).

5.6.3.1.7 Safety restraints. Controls shall be reachable while wearing safety restraints.

5.6.3.2 Weapon system controls.

5.6.3.2.1 Placement. The placement of elevation and azimuth weapon controls shall enable the user to be restrained in his or her seat while simultaneously operating the weapons controls and interfacing with sights and other essential fire control equipment in the station.

5.6.3.2.2 Manual cranks. Manual hand cranks shall be immobilized during powered operation of the weapon system without engaging a lock or detent in any preselected position of rotation.

5.6.3.2.3 Powered weapon system controller. The powered weapon system controller's dead spot shall not exceed ±2 degrees in each direction from the center position.

5.6.3.2.4 Centering. Positive centering of the released power controller shall be provided.

5.6.3.2.5 Trigger guard. A trigger guard(s) shall be provided to prevent inadvertent operation of the trigger(s).

5.6.3.2.6 "Dead man" switch. A "dead man"-type safety switch shall be provided that requires the weapon station operator's continued activation while providing weapon station movement and firing input.

5.6.3.2.7 Release of "dead man" switch. Release of the "dead man" switch shall cease weapon station movement and firing.

5.6.3.2.8 Powered controls. For the crewmember with primary responsibility for weapon system operation, powered weapon system controls should be operable with either hand.

5.6.3.2.9 Multiple operators. For vehicles that have multiple operators of a common weapon station, the operator responsible for the overall command of the vehicle shall be provided with priority relative to weapon station input (i.e., if both operators are providing input to the weapon station, the vehicle commander's input will override the other operator's input).

5.6.4 Displays and markings.

5.6.4.1 Driver's display.

5.6.4.1.1 Fore/aft. The driver's display used for driving via indirect vision should be located not less than 38 mm (15 in) from the driver' eye point and within reach of the driver.

5.6.4.1.2 Horizontal. The driver's primary display used for driving via indirect vision should be centered on the longitudinal centerline of the seat.

5.6.4.1.3 Vertical. The driver's display used for driving via indirect vision should be located between 0 and 15 degrees below the horizontal line of sight.

5.6.4.2 Vehicle operating instructions.

5.6.4.2.1 Provide for vehicles and equipment. Operating instructions shall be provided for all vehicles and vehicle equipment, except where the operation will be obvious to all potential operators.

5.6.4.2.2 Format. Information should be presented in the form of diagrams whenever possible.

5.6.4.2.3 Speed notice. Maximum permissible road speeds in each gear range shall be indicated. On vehicles for which all road speeds are limited by engine speed, a red line at the maximum engine revolutions per minute (RPM) on the tachometer (if so equipped) may be used in lieu of a speed placard.

5.6.4.2.4 Rollover notice. A rollover indicator, if provided, shall be visible to the driver.

5.6.4.2.5 Vehicle pitch and roll. Information should be provided to the driver on real-time vehicle pitch and roll angles as well as the vehicle's safe operating range(s) for these angles.

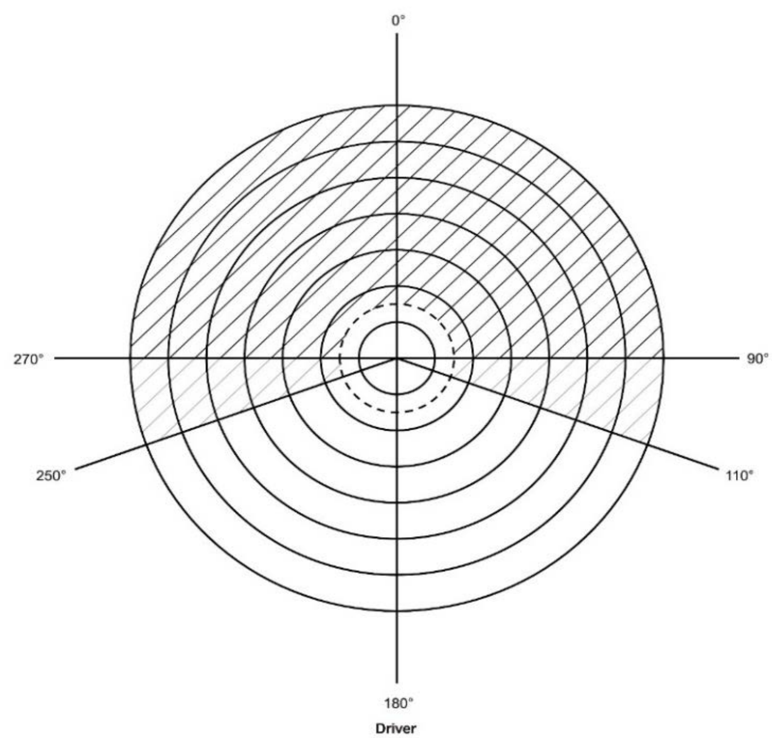
5.6.4.2.6 Shift handle positions. Operating positions of shift handles, such as those on transmission, power takeoff, winch-control, and transfer case mechanisms, shall be labeled.

5.6.4.2.7 Control movements. Control movements shall be shown in planes parallel to the movement of the actual controls.

5.6.4.2.8 Symbols. Symbols for automotive equipment shall be in accordance with 49 CFR 571.101.

5.6.5 Visibility.

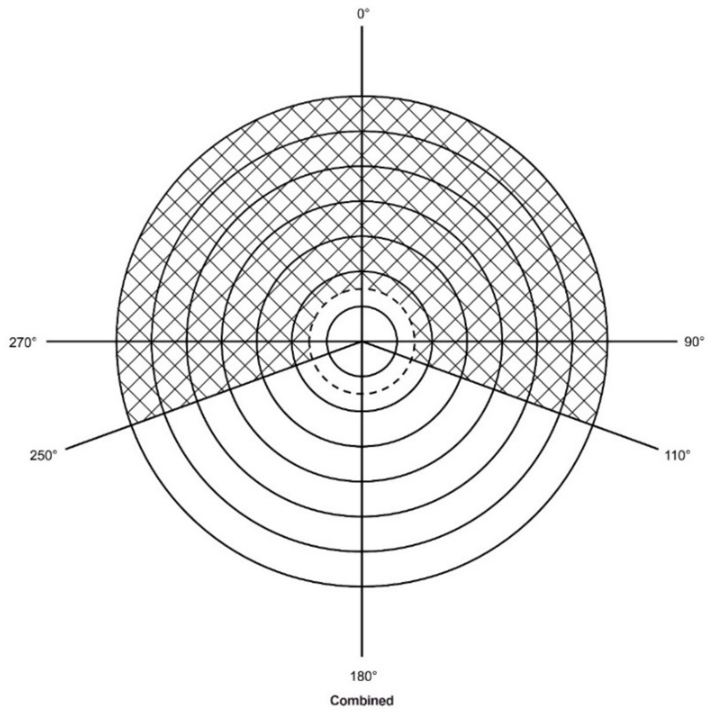
5.6.5.1 Field of regard criteria. The horizontal and vertical fields of regard given in 5.6.5.2 through 5.6.5.7 are minimums; wider fields of regard are preferred. The ground intercept values given in 5.6.5.2 through 5.6.5.7 are maximums; closer ground intercepts are preferred. Figures 41 through 46 provide a visual depiction of the criteria given in the text.



NOTES:

1. Driver sitting left
2. Range ring interval = 2 m
3. Ground intercept = 3 m

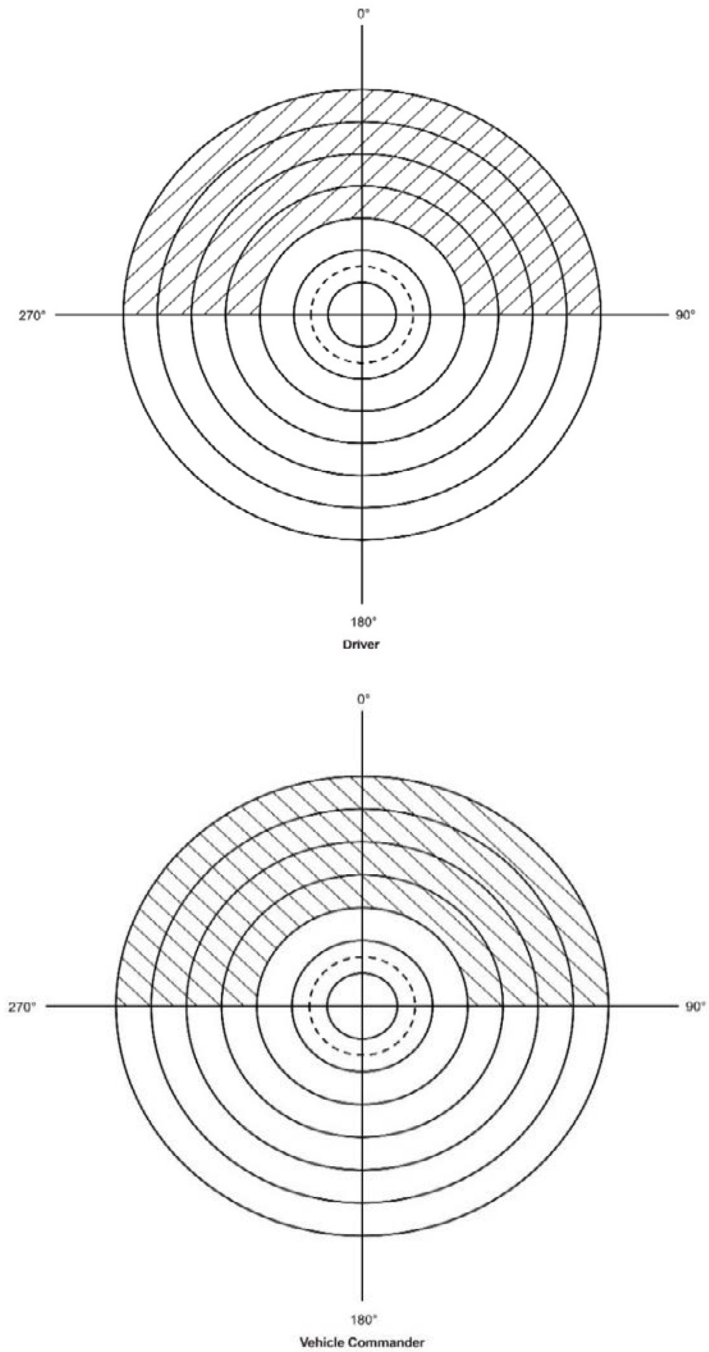
FIGURE 41. Horizontal field of regard: stations with windshields or open-air stations.



NOTES:

1. Driver sitting left
2. Range ring interval = 2 m
3. Ground intercept = 3 m

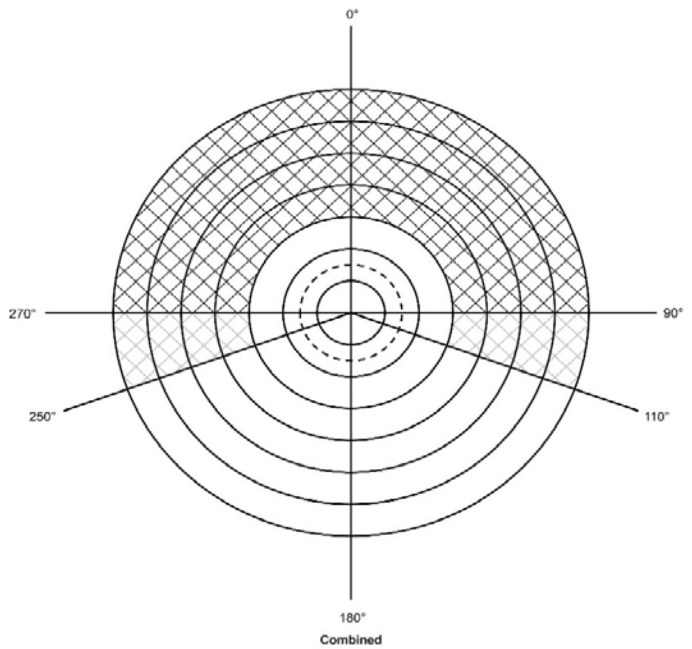
FIGURE 41. Horizontal field of regard: Stations with windshields or open-air stations – Continued.



NOTES:

1. Driver sitting left; vehicle commander sitting right
2. Range ring interval = 2 m
3. Ground intercept = 6 m

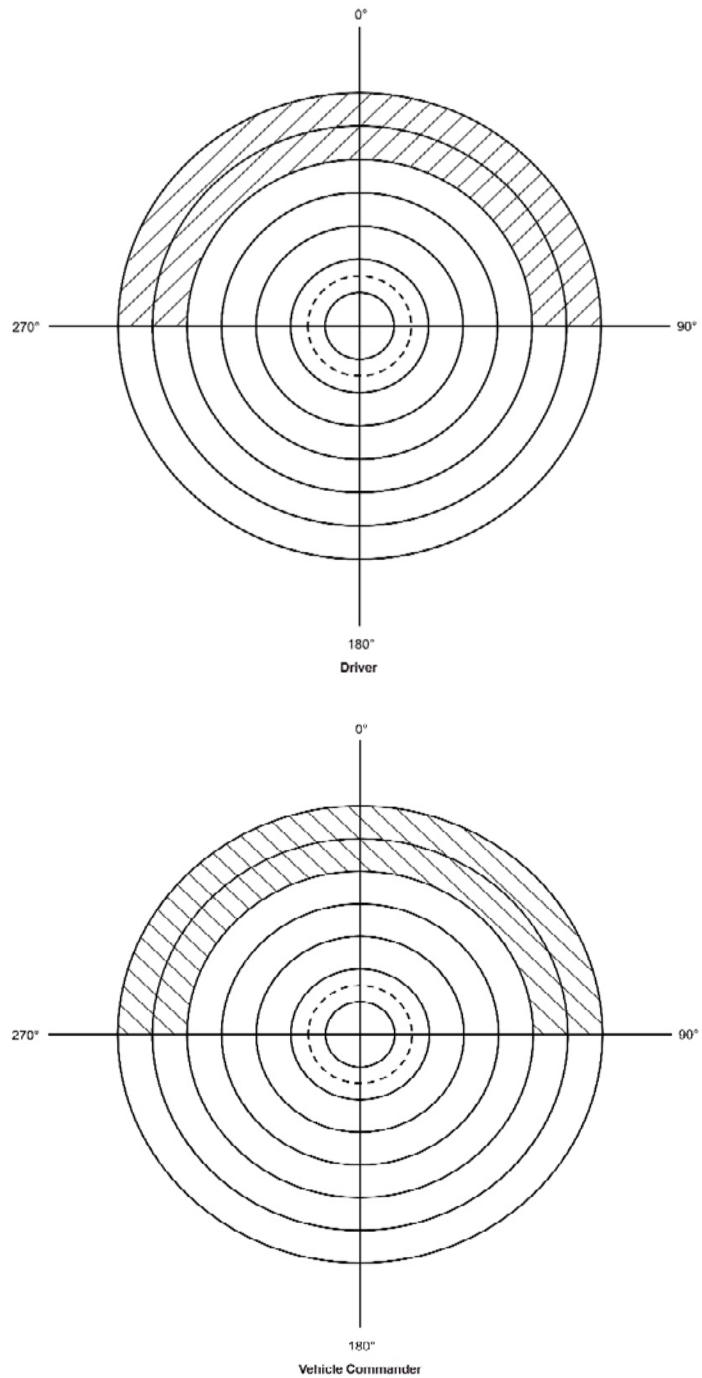
FIGURE 42. Horizontal field of regard: open-hatch stations.



NOTES:

1. Driver sitting left; vehicle commander sitting right
2. Range ring interval = 2 m
3. Ground intercept = 6 m

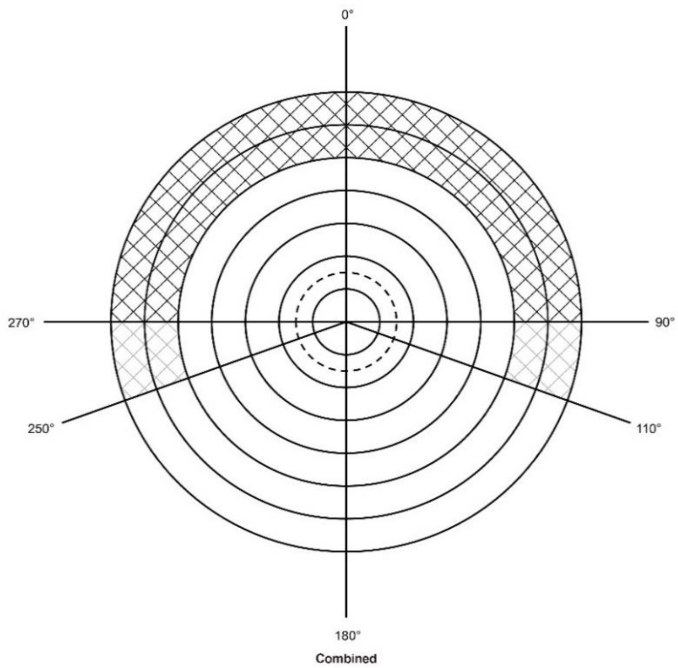
FIGURE 42. Horizontal field of regard: open hatch stations – Continued.



NOTES:

1. Driver sitting left; vehicle commander sitting right
2. Range ring interval = 2 m
3. Ground intercept = 10 m

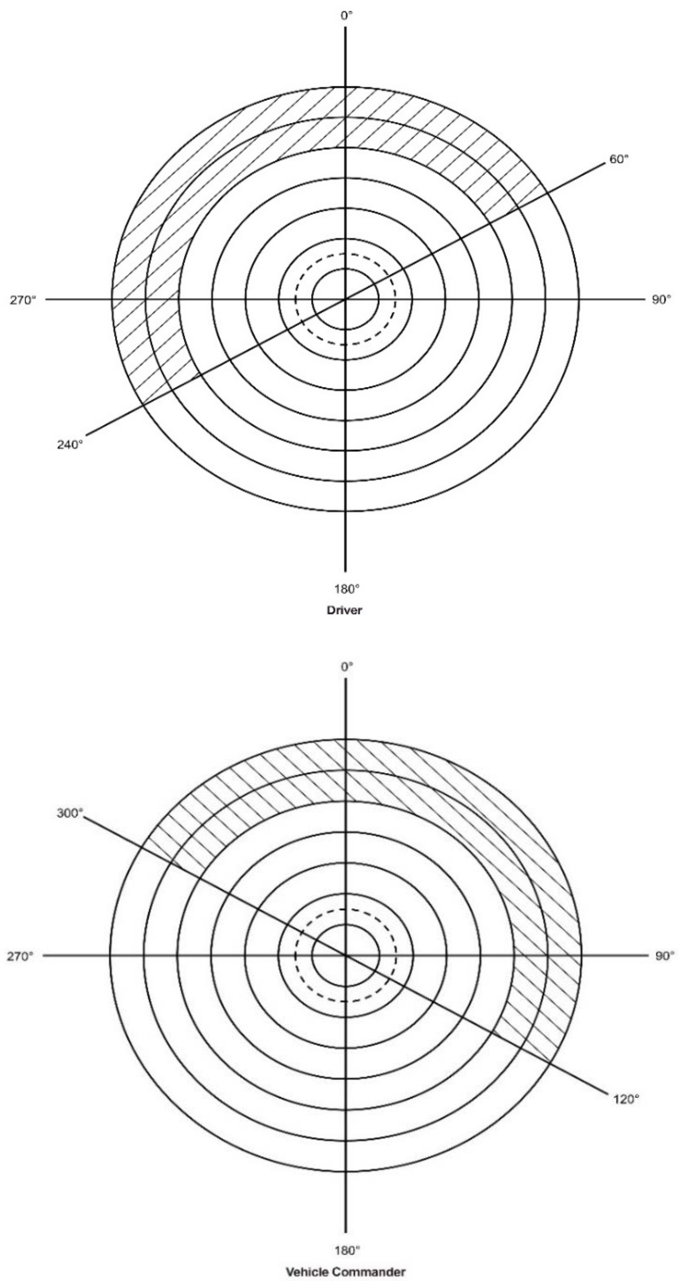
FIGURE 43. Horizontal field of regard: open-protected hatch stations.



NOTES:

1. Driver sitting left; vehicle commander sitting right
2. Range ring interval = 2 m
3. Ground intercept = 10 m

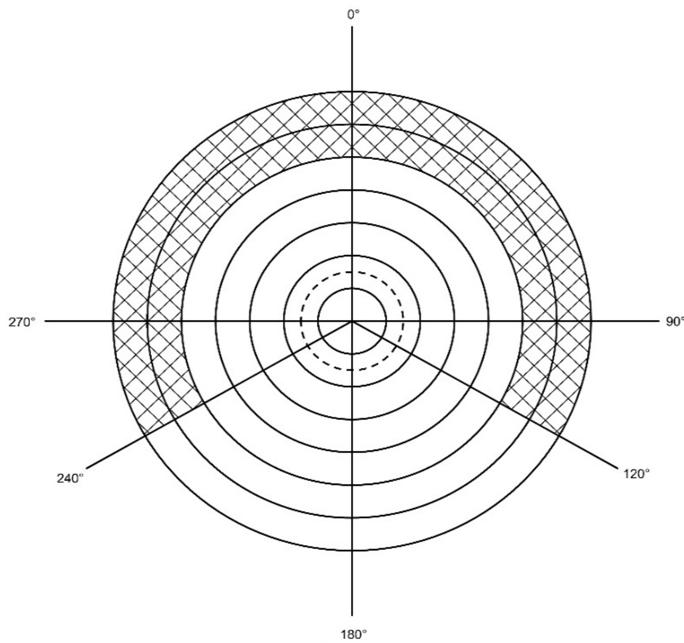
FIGURE 43. Horizontal field of regard: open-protected hatch stations – Continued.



NOTES:

1. Driver sitting left; vehicle commander sitting right
2. Range ring interval = 2 m
3. Ground intercept = 10 m

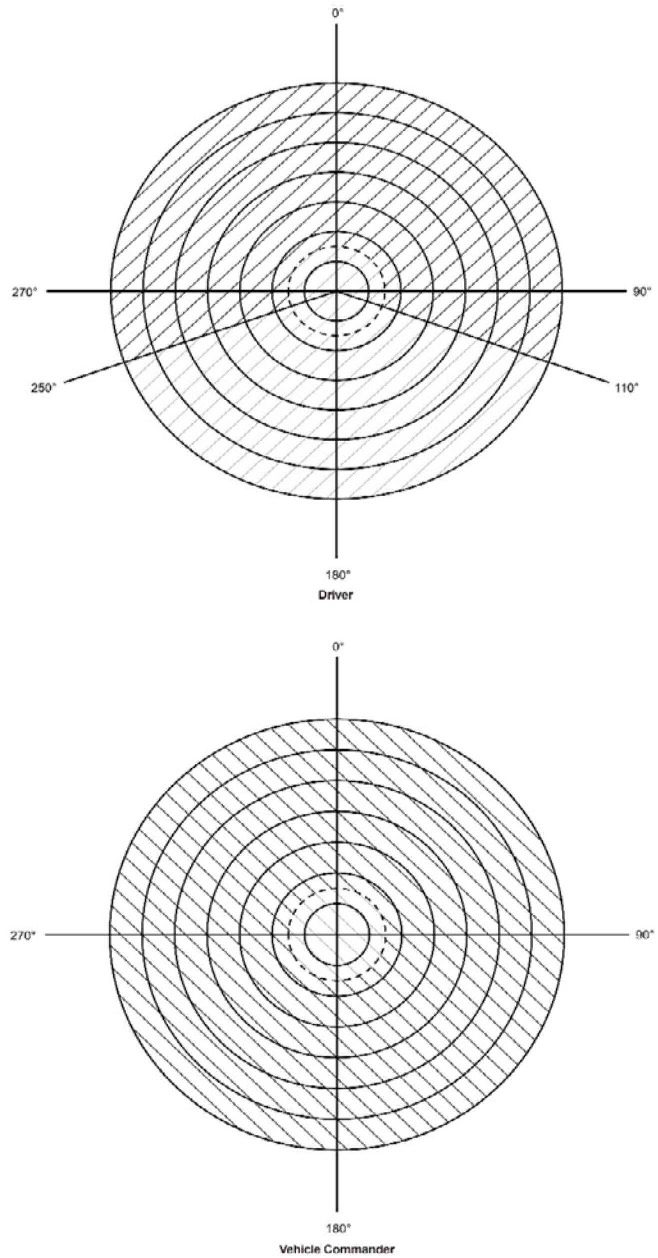
FIGURE 44. Horizontal field of regard: stations with vision blocks or periscopes.



NOTES:

1. Driver sitting left; vehicle commander sitting right
2. Range ring interval = 2 m
3. Ground intercept = 10 m

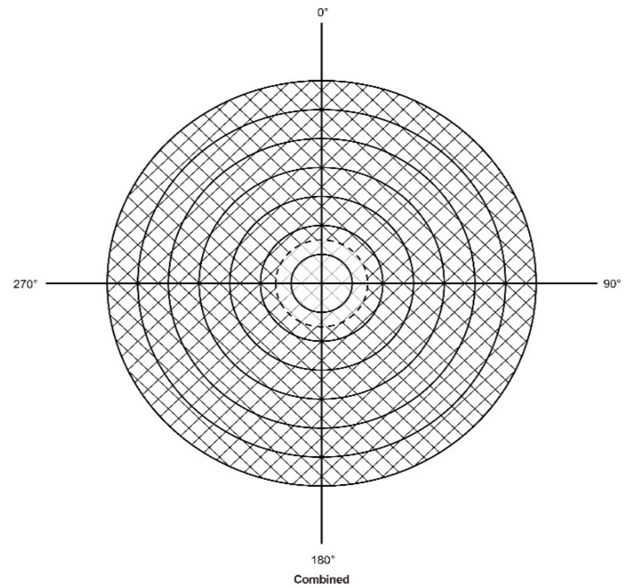
FIGURE 44. Horizontal field of regard: stations with vision blocks or periscopes – Continued.



NOTES:

1. Range ring interval = 2 m
2. Ground intercept = 3 m

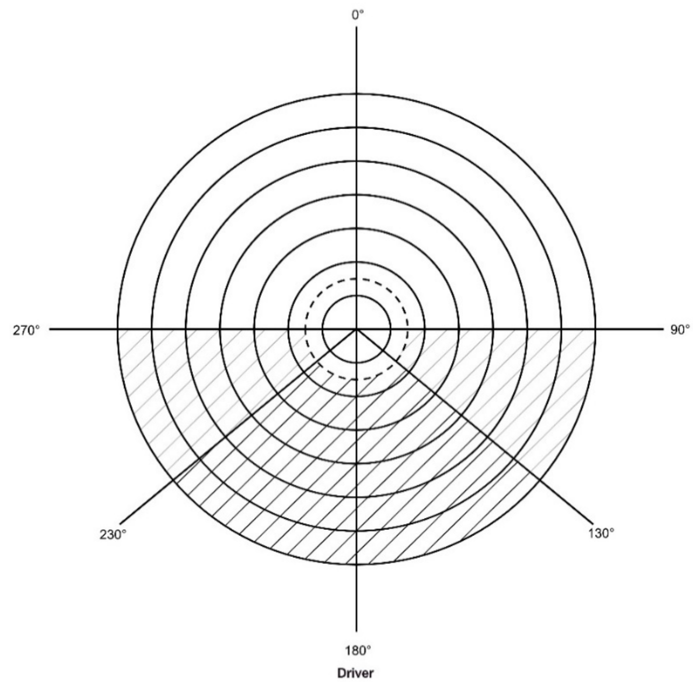
FIGURE 45. Horizontal field of regard: indirect driving stations.



NOTES:

1. Range ring interval = 2 m
2. Ground intercept = 3 m

FIGURE 45. Horizontal field of regard: indirect driving stations – Continued.



NOTES:

1. Driver sitting left
2. Range ring interval = 2 m
3. Ground intercept = 3 m

FIGURE 46. Horizontal field of regard: rear vision.

5.6.5.2 Stations with windshields or open-air stations.

5.6.5.2.1 Horizontal field of regard. The horizontal field of regard from the driver's station shall be at least 180 degrees, 220 degrees preferred, with at least 90 degrees to either side of the driver's seat longitudinal centerline (see figure 41).

5.6.5.2.2 Field restriction. Within the horizontal field of regard, not more than 15 degrees of non-contiguous field of regard shall be blocked due to cab structure or headlights, mirrors, or other externally mounted components.

5.6.5.2.3 Combined horizontal field of regard. The combined horizontal field of regard from the driver's and a second crewmember's stations shall be at least 220 degrees (see figure 41).

5.6.5.2.4 Vertical field of regard. The vertical field of regard shall be at least 15 degrees above the horizontal plane associated with the driver's eye point.

5.6.5.2.5 Ground intercept. The vertical field of regard shall enable the driver to view the ground 3 m (10 ft) in front of the front surface of the vehicle in line with the driver's seat longitudinal centerline. Mirrors or driver's vision enhancers may be used to meet this requirement if tactical requirements permit.

5.6.5.2.6 Vehicles with trailers. For vehicles with trailers, the driver shall be able to observe at least portions of the trailer and the load.

5.6.5.2.7 Windshields. Door posts, windshield wiper motors, and other devices shall not require the driver to move from his or her normal restrained seated position to view around an obstruction. The critical visual area extends to, and often beyond, the vehicle's left corner post. It is preferable to use a narrow corner post than to use a wraparound windshield, which may distort important visual areas.

5.6.5.2.8 Windshields and windows. Transparent materials selected for windshields and windows shall be shatterproof.

5.6.5.2.9 Windshield and window materials. Materials selected for windshields and windows shall neither distort nor obscure vision.

5.6.5.2.10 Windshield tinting or coloring. Windshields or other transparent areas through which high acuity vision is required shall not be tinted or colored.

5.6.5.2.11 Visors. Visors or other means shall be used to preclude performance degradation due to glare from external sources such as sunlight or headlights.

5.6.5.2.12 Interior surfaces. Interior surfaces shall be designed to reduce reflected glare into the driver's eyes or onto the windshield.

5.6.5.2.13 Interior displays. Interior displays shall be located to reduce reflected glare into the driver's eyes or onto the windshield.

5.6.5.2.14 Vehicle occupants. Beyond the driver, reflected glare should be reduced for other occupants of the vehicle.

5.6.5.3 Vision from open hatch position.

5.6.5.3.1 Driver.

5.6.5.3.1.1 Horizontal field of regard. The horizontal field of regard from the driver's station shall be at least 180 degrees, with at least 90 degrees to either side of the longitudinal centerline through the driver's station (see figure 42).

5.6.5.3.1.2 Vertical field of regard. The vertical field of regard from the driver's station shall be at least 15 degrees above the horizontal plane associated with the driver's vision device.

5.6.5.3.1.3 Ground intercept. When in open-hatch conditions, the driver shall be able to view the ground at a distance of 6 m (20 ft) in front of the front surface of the vehicle at the longitudinal centerline of the driver's station.

5.6.5.3.2 Vehicle commander.

5.6.5.3.2.1 Horizontal field of regard. The horizontal field of regard from the vehicle commander's station shall be at least 180 degrees, with at least 90 degrees to either side of the longitudinal centerline through the vehicle commander's station (see figure 42).

5.6.5.3.2.2 Vertical field of regard. The vertical field of regard from the vehicle commander's station shall be at least 15 degrees above the horizontal plane associated with the vehicle commander's vision device.

5.6.5.3.2.3 Ground intercept. When in open hatch conditions, the commander shall be able to view the ground at a distance of 6 m (20 ft) in front of the front surface of the vehicle at the longitudinal centerline of the vehicle commander's station.

5.6.5.3.3 Combined driver's and vehicle commander's fields of regard. The combined horizontal field of regard from the driver's and vehicle commander's stations shall be at least 180 degrees, with 220 degrees preferred (see figure 42).

5.6.5.4 Vision from open-protected hatch position.

5.6.5.4.1 Driver.

5.6.5.4.1.1 Horizontal field of regard. The horizontal field of regard from the driver's station shall be at least 180 degrees with at least 90 degrees to either side of the longitudinal centerline through the driver's station (see figure 43).

5.6.5.4.1.2 Vertical field of regard. The vertical field of regard from the driver's station shall be at least 15 degrees above the horizontal plane associated with the driver's vision device.

5.6.5.4.1.3 Ground intercept. The vertical field of regard from the vehicle commander's station shall enable the vehicle commander to view the ground at a distance 10 m (33 ft) in front of the vehicle at the longitudinal centerline of the driver's station.

5.6.5.4.2 Vehicle commander.

5.6.5.4.2.1 Horizontal field of regard. The horizontal field of regard from the vehicle commander's station shall be at least 180 degrees, with at least 90 degrees to either side of the longitudinal centerline through the vehicle commander's station (see figure 43).

5.6.5.4.2.2 Vertical field of regard. The vertical field of regard from the vehicle commander's station shall be at least 15 degrees above the horizontal plane associated with the vehicle commander's vision device.

5.6.5.4.2.3 Ground intercept. The vertical field of regard from the vehicle commander's station shall enable the vehicle commander to view the ground at a distance 10 m (33 ft) in front of the vehicle at the longitudinal centerline of the vehicle commander's station.

5.6.5.4.2.4 Combined driver's and vehicle commander's fields of regard. The combined horizontal field of regard from the driver's and vehicle commander's stations shall be at least 180 degrees, with 220 degrees preferred (see figure 43).

5.6.5.5 Vision with hard optics (vision blocks or periscopes).

5.6.5.5.1 Driver.

5.6.5.5.1.1 Horizontal field of regard. The horizontal field of regard from the driver's station shall be at least 180 degrees, with at least 120 degrees to the outboard side of the centerline through the driver's station (see figure 44).

5.6.5.5.1.2 Vertical field of regard. The vertical field of regard from the driver's station shall be at least 15 degrees above the horizontal plane associated with the driver's vision device.

5.6.5.5.1.3 Ground intercept. The vertical field of regard from the driver's station shall enable the driver to view the ground at a distance of 10 m (33 ft) in front of the vehicle at the longitudinal centerline of the driver's station.

5.6.5.5.2 Vehicle commander.

5.6.5.5.2.1 Horizontal field of regard. The horizontal field of regard from the vehicle commander's station shall be at least 180 degrees with at least 120 degrees to the outboard side of the longitudinal centerline through the vehicle commander's station (see figure 44).

5.6.5.5.2.2 Vertical field of regard. The vertical field of regard from the vehicle commander's station shall be at least 15 degrees above the horizontal plane associated with the vehicle commander's vision device.

5.6.5.5.2.3 Ground intercept. The vertical field of regard from the vehicle commander's station shall enable the vehicle commander to view the ground at a distance 10 m (33 ft) in front of the vehicle at the longitudinal centerline of the vehicle commander's station.

5.6.5.5.3 Combined driver's and vehicle commander's fields of regard. The combined horizontal field of regard from the driver's and vehicle commander's stations shall be at least 240 degrees with at least 120 degrees to either side of the longitudinal centerline through those stations (see figure 44).

5.6.5.6 Vision from electronic vision systems (indirect driving and situation awareness).

5.6.5.6.1 Driver.

5.6.5.6.1.1 Horizontal field of regard. The horizontal field of regard from the driver's station shall be at least 220 degrees, with 360 degrees preferred, with at least 110 degrees to either side of the driver's station longitudinal centerline (see figure 45).

5.6.5.6.1.2 Vertical field of regard. The vertical field of regard shall be at least 60 degrees above the horizontal plane associated with the driver's vision device.

5.6.5.6.1.3 Ground intercept. The vertical field of regard from the driver's station shall enable the driver to view the ground at a distance of 3 m (10 ft), with 0 m (0 ft) preferred, at the centerline of the driver's station.

5.6.5.6.2 Vehicle commander.

5.6.5.6.2.1 Horizontal field of regard. The horizontal field of regard from the vehicle commander's station shall be 360 degrees (see figure 45).

5.6.5.6.2.2 Vertical field of regard. The vertical field of regard shall be at least 60 degrees above the horizontal plane associated with the vehicle commander's vision device.

5.6.5.6.2.3 Ground intercept. The vertical field of regard from the commander's station shall enable the vehicle commander to view the ground at a distance of 3 m (10 ft), with 0 m (0 ft) preferred, at the longitudinal centerline of the vehicle commander's station.

5.6.5.6.2.4 Combined driver's and vehicle commander's fields of regard. The combined horizontal field of regard from the driver's and vehicle commander's stations shall be 360 degrees. Panning of the sensor system or switching between multiple sensors to achieve this horizontal field of regard is acceptable (see figure 45).

5.6.5.6.3 Glass-to-glass latency and resolution. Low latency and high resolution shall be provided for at least 120 degrees for the driver's horizontal field of regard as specified (see 6.2).

5.6.5.7 Rear vision.

5.6.5.7.1 Horizontal field of regard. The driver shall be provided a horizontal field of regard of at least 100 degrees, 180 degrees preferred, to the rear of the vehicle, measured from the longitudinal centerline of the vehicle at the rearmost surface of the vehicle. An indirect vision system(s) can be used to meet this requirement (see figure 46).

5.6.5.7.2 Vertical field of regard. The vertical field of regard shall cover, at a minimum, the area from the required ground intercept to the horizontal measured at the location of the rear vision device.

5.6.5.7.3 Ground intercept. The operator shall be able to view the ground to the rear of the vehicle at a distance 3 m (10 ft) or less measured from the rearmost surface of the vehicle.

5.6.5.8 Rocket-propelled grenade (RPG) nets. RPG nets, if used, should incorporate a diagonal mesh design as opposed to horizontal and vertical mesh, use colored nodes that have minimal contrast to the background, and limit the movement of the nets while driving. These features reduce motion-induced sickness.

5.6.5.9 Rock strike protection kits. Rock strike protection kits, if used, should incorporate a diagonal mesh design as opposed to a horizontal and vertical mesh or bars. A diagonal mesh results in being able to identify objects more easily and lessens visual contributions to motion sickness.

5.6.6 Heating, ventilation, and air conditioning (HVAC). Air inlets shall be positioned so they cannot ingest either engine or heater exhaust gases.

5.6.6.1 Heating.

5.6.6.1.1 Maintaining temperatures. The crew compartment shall be provided with a heating system capable of maintaining temperatures above 20 °C (68 °F) during occupancy when personnel are not wearing arctic clothing and exposure exceeds 3 hours.

5.6.6.1.2 Time requirement. The heater shall achieve the requirement in 5.6.6.1.1 within 1 hour after the heater is turned on.

5.6.6.1.3 Controls. Heater controls shall be accessible to the operator and a second crewman from their stations.

5.6.6.1.4 Arctic conditions. Heaters shall be capable of maintaining a temperature not less than 5 °C (41 °F) at the lowest operational temperature specified for the system with the defrosters operating at maximum capacity. This temperature shall be measured 60 cm (24 in) above the seat reference point of each operator and passenger position.

5.6.6.1.5 Air temperature. Air temperatures around any part of the occupant's body shall not vary more than ±5.0 °C (±9.0 °F).

5.6.6.1.6 Combustible fuel. Any heater that uses oil, gas, liquefied petroleum gas, or any other combustible fuel for its operation shall discharge its exhaust products outside of the vehicle.

5.6.6.1.7 Location. Heaters shall be located or protected so that personnel cannot touch parts that are hot enough to cause burns (see table XXVII).

TABLE XXVII. Temperature exposure limits.

Exposure	**Temperature Limits**		
	Metal	**Glass**	**Plastic or Wood**
Momentary contact	60 °C (140 °F)	68 °C (154 °F)	85 °C (185 °F)
Prolonged contact or handling	49 °C (120 °F)	59 °C (138 °F)	69 °C (156 °F)

5.6.6.1.8 Heater design. Heaters shall be designed so that they will not come apart, exposing parts (exhaust stacks, pipes, or conduits) if the vehicle overturns.

5.6.6.1.9 Securely fastened. Heaters shall be fastened securely so they will stay in place during normal use or in case the vehicle overturns.

5.6.6.1.10 Replace parts without removal. It shall be possible to replace igniters, resistors, and other "high-failure-rate" items without having to remove the heater from the vehicle.

5.6.6.2 Ventilation.

5.6.6.2.1 General. Outside fresh air shall be supplied at minimum rate of 0.57 m^3/min (20 ft^3/min) per person.

5.6.6.2.2 Hot climate operation. Air flow rates for hot climate operation (temperatures above 32 °C [90 °F]) shall be maintained between 4.2 and 5.7 m^3/min (150 and 200 ft^3/min) per person unless air conditioning or individual (microclimate) cooling is provided. The number of people to be accommodated shall be as specified (see 6.2).

5.6.6.2.3 Air velocity. Air velocity at each person's head location shall be adjustable either continuously or with not less than three settings (OFF, LOW, and HIGH) from near zero to at least 120 m/min (400 feet per minute [ft/min]).

5.6.6.2.4 Visibility. The heating-ventilating system shall be designed to minimize degradation of visibility due to frosting or misting.

5.6.6.3 Air conditioning. If a vehicle mission profile requires personnel to occupy a vehicle cabin for more than 30 minutes in climatic (ambient) conditions greater than 24 °C (75 °F), then the provisions of 5.5.2.1.4 shall apply.

5.6.7 Lighting.

5.6.7.1 Interior lighting. The lighting system shall include adjustable instrument panel lights to illuminate instruments and displays.

5.6.7.1.1 Indicators. Indicators required by the vehicle operator during night operations shall be illuminated.

5.6.7.1.2 Display luminance. The display luminance for night operations shall be adjustable from 0.1 to 3.5 cd/m^2 (0.03 to 1 fL).

5.6.7.1.3 Vehicle occupant task lighting. Task lighting inside vehicles shall be designed to accommodate the specific tasks to be performed within the vehicle while still ensuring that the lighting will neither distract nor impair the driver's performance nor create an unacceptable visual signature. Vehicle occupant task lighting may include continuously variable intensity controls (see 5.5.3).

5.6.7.1.4 Lighting for dark adaptation. When light security or NVD is not a consideration and dark adaptation is required, low-level white lighting shall be used.

5.6.7.2 Exterior lighting. Exterior lighting systems in military vehicles and equipment shall comply with 49 CFR 571.108. Exterior lighting systems may also have to comply with local laws and statutes anywhere in the world the vehicle or equipment is deployed.

5.6.7.2.1 Headlights. Headlights shall provide a choice of either upper (bright) or lower (dim) distribution of light.

5.6.7.2.1.1 Headlight illumination. Headlights shall provide illumination to at least 150 m (492 ft) of roadway in front of the vehicle or equipment under clear atmospheric conditions when the upper headlight beam is in use.

5.6.7.2.1.2 Headlights compatible with blackout system. Headlights shall provide measures to ensure that regular (bright or dim) headlights cannot be turned on when the blackout system is on (see 5.6.7.4).

5.6.7.2.2 Reflectors.

5.6.7.2.2.1 Side and rear reflectors. Side and rear reflectors, if required, shall be mounted between 0.6 m (2 ft) and 1.5 m (5 ft) above the ground.

5.6.7.2.2.2 Vehicles with extending pods. When reflectors are used on vehicles or equipment that have extending pods, arms, or other devices, the reflectors shall remain visible when they are in the extended position and when they are in the stowed position.

5.6.7.3 Egress path lighting.

5.6.7.3.1 No vehicle power. Egress path lighting, once activated, shall provide full illumination levels after vehicle power is off. The duration of this extended lighting time shall be as specified (see 6.2).

5.6.7.3.2 Automatic activation. Egress path lighting shall activate automatically if a vehicle is not resting on its wheels or tracks.

5.6.7.3.3 Automatic activation for amphibious vehicles. For amphibious vehicles, egress path lighting shall activate automatically if sensors indicate that water levels in the vehicle have reached levels that compromise the vehicle's reserve buoyancy. The level of unacceptable compromise to the vehicle's reserve buoyancy shall be as specified (see 6.2).

5.6.7.3.4 Manual activation. Egress path lighting shall be capable of manual activation by the vehicle commander and the driver.

5.6.7.3.5 Activation by vehicle occupants. Egress path lighting should be capable of manual activation by occupants of all areas of the vehicle.

5.6.7.3.6 Illuminate path to appropriate egress points. Egress path lighting should only illuminate paths to appropriate egress points based on the vehicle's operational mode (e.g., topside hatches only if the vehicle is in a water or amphibious mode).

5.6.7.3.7 Underwater visibility. For amphibious vehicles, egress path lighting shall meet underwater visibility requirements as specified (see 6.2).

5.6.7.3.8 G-loading. The egress path lighting shall activate automatically if the vehicle experiences a G-loading and duration as specified (see 6.2).

5.6.7.4 Blackout lighting.

5.6.7.4.1 Blackout lighting systems. Blackout lighting systems shall be in accordance with MIL-STD-1179.

5.6.7.4.2 Deliberate action. To change from the blackout lighting system to the normal lighting system (interior and exterior lights), the operator shall have to perform some preliminary action, such as pressing a release button, so that activating the normal mode becomes a deliberate action.

5.6.7.4.3 Reflectors. It shall be possible to conceal reflectors during blackout conditions.

5.6.8 Ingress and egress.

5.6.8.1 General.

5.6.8.1.1 Squad ingress times. The maximum time for the dismounted squad donned in mission clothing and equipment to ingress from outside the vehicle with all doors and hatches closed, enter the vehicle, and close and secure all doors and hatches on the vehicle through the primary ingress points shall be not more than 30 seconds.

5.6.8.1.2 Two egress paths. At least two vehicle egress paths with associated egress points shall be provided for every occupied position.

5.6.8.1.3 Non-skid surfaces. Non-skid surfaces shall be provided where personnel must step to ingress or egress the vehicle.

5.6.8.1.4 Separate planes. The multiple egress points shall be on separate planes in order to enable occupant egress regardless of vehicle orientation.

5.6.8.1.5 Egress point identification. Means shall be provided to enable all occupants to locate egress points and egress point latching mechanisms in the event of loss of main vehicle power (see 5.6.7.4).

5.6.8.1.6 Crew and squad egress times. The maximum time for the crew and squad to egress the vehicle in an emergency from primary or secondary egress points shall be not more than 30 seconds.

5.6.8.1.7 Primary egress point control. If the primary squad egress point is a vehicle-powered ramp or door, the vehicle shall have a control in the crew compartment and in the squad compartment to open and close the primary egress point.

5.6.8.1.7.1 Priority. The crew compartment control shall take priority over the squad compartment control.

5.6.8.1.7.2 Primary egress emergency stop. If the primary squad egress point is a vehicle-powered ramp or door, the vehicle shall have an emergency stop in the squad compartment that overrides all egress point controls.

5.6.8.1.8 Exterior access. The vehicle shall be equipped with a means to unlock and open at least one ingress and egress point on each of two different planes from the exterior of the vehicle without any degradation to vehicle security.

5.6.8.1.9 Egress tools. Vehicle occupants shall not require tools or special equipment to leave their seated position or to open egress points (e.g., doors, ramps, hatches).

5.6.8.1.10 Trip hazards. Vehicle components or subsystems shall not present a tripping hazard to occupants ingressing or egressing the vehicle.

5.6.8.2 First responder access.

5.6.8.2.1 Rescue of personnel. The ground vehicle design shall accommodate the rescue of a wounded or incapacitated person from the vehicle's interior.

5.6.8.2.2 First responder access. First responders shall be able to access the interior of the vehicle without assistance from personnel on the interior of the vehicle via at least one entry point regardless of vehicle orientation.

5.6.8.2.3 Combat lock. First responder access shall be achievable regardless of combat lock status.

5.6.8.2.4 Rescue tunnel. The space to accomplish the rescue from a standing position should be at least 1,200 mm (48 in) tall, measured from the walking floor to the ceiling, and 600 mm (24 in) wide.

5.6.8.2.5 Obstructions. The rescue tunnel shall be unobstructed and free of fixtures, hinges, or equipment that might impinge upon the space or snag on the wounded member or rescuer.

5.6.8.3 Overhead hatches.

5.6.8.3.1 General.

5.6.8.3.1.1 Operate with either hand. Release latch handle operation shall be possible using either hand.

5.6.8.3.1.2 Distinct and different motions. Release latch handle operation shall require not more than two distinct and different motions.

5.6.8.3.1.3 Hold hatch open. A latch shall be provided to hold the hatch open under all defined vehicle operational loads, including threat-induced events. Damage to a hold hatch open latch should not preclude closing and locking the hatch.

5.6.8.3.1.4 Visual indication. Latches that hold hatches or doors in the open position shall provide visual indication to the operator that the latch is either fully, partially, or not at all engaged.

5.6.8.3.1.5 Visible from seat. The latch engagement status shall be visible to the hatch user when the user is restrained in his or her seat.

5.6.8.3.1.6 Incorrect indication. Fouling or occlusion of the latch mechanism shall not cause the presentation of an inaccurate status of the latch's engagement (i.e., it shall not indicate that the latch is fully engaged when it is in fact only partially engaged).

5.6.8.3.1.7 Padding. Appropriate padding should be provided around the hatch opening and on the underside of the hatch door to prevent injury to crewmembers while using or maintaining the latch.

5.6.8.3.2 Force.

5.6.8.3.2.1 Overhead hatches. Movement of overhead hatches shall require not more than 220 newtons (50 lb) of force for opening or closing under any condition of vehicle tilt.

5.6.8.3.2.2 Latch handles. Release latch handles shall require not more than 110 newtons (25 lb) of force in a lateral direction or 200 newtons (50 lb) of pull.

5.6.8.3.3 Dimensions. The hatch dimensions in the following paragraphs assume 50 mm (2 in) or thinner armor. If armor is thicker than 50 mm (2 in), or if other design features make hatch opening tunnel-like, the dimensions for prone crawl space should be used (see figure 60).

5.6.8.3.3.1 Circular. Circular hatches shall have a minimum diameter of 700 mm (28 in).

5.6.8.3.3.2 Rectangular. Rectangular and contoured hatches shall have minimum dimensions of 650 by 700 mm (26 by 28 in).

5.6.8.3.3.3 Simultaneous use. For simultaneous use of rectangular hatches by two persons, minimum dimensions of 120 by 150 cm (48 by 60 in) shall be provided.

5.6.8.3.3.4 Floor-mounted, circular escape hatches. For floor-mounted circular escape hatches, a minimum diameter of 650 mm (26 in), with 700 mm (28 in) preferred, shall be provided.

5.6.8.3.3.5 Clearance. At least 450 mm (18 in) of clearance shall be provided from the bottom of the hatch to the ground.

5.6.8.4 Emergency pass-throughs.

5.6.8.4.1 Crawling. Pass-throughs designed for emergency egress or rescue while crawling shall be at least 670 mm (26.5 in) high to accommodate a high crawl position (unequipped user) and 817 mm (32 in) high to accommodate a high crawl position (mission equipped user).

5.6.8.4.2 Walking. Pass-throughs designed for emergency egress or rescue while walking shall be at least 1,200 mm (48 in) tall, measured from the walking floor to the ceiling, and 600 mm (24 in) wide.

5.6.8.4.3 Obstructions. The emergency pass-throughs should be unobstructed and free of fixtures, hinges, or equipment that might snag or impinge upon egress or rescue.

5.6.8.4.4 Pass-through obstructed. If the pass-through is obstructed by seat backs, gunner's stands, or other equipment, personnel from either side of the pass-through shall be able to move the obstructions to clear the pass-through.

5.6.8.5 Ramps.

5.6.8.5.1 Ramp slope for vehicles without a step. The ramp slope for ground vehicles without a step shall be not greater than 20 degrees, with 15 degrees preferred.

5.6.8.5.2 Ramp slope for vehicles with a step. The ramp slope for ground vehicles with a step should be not greater than 15 degrees.

5.6.8.5.3 Ramp steps. The height of ramp steps should be not greater than 300 mm (12 in); 225 mm (9 in) preferred.

5.6.8.5.4 Horizontal gap.

5.6.8.5.4.1 Walking surface. Horizontal gaps in the walking surface shall not exceed 100 mm (1 in).

5.6.8.5.4.2 Deployed ramp. The horizontal gap between the aft-most walking surface of the vehicle interior and the deployed ramp should not exceed 100 mm (4 in).

5.6.8.5.5 Non-skid coating. The walking surface of the ramp shall be treated with a non-skid coating.

5.6.8.5.6 Irregularities. Vertical irregularities on the ramp's walking surface shall not result in trip points.

5.6.8.6 Handholds and footholds.

5.6.8.6.1 Spacing. If the height of ingress and egress points, equipment access points, service access points, or exterior step locations is greater than 450 mm (18 in) above the ground, the vehicle shall have handholds and footholds (steps) such that the first step is between 375 and 450 mm (15 and 18 in) above the ground and all subsequent steps are approximately equally spaced between 225 and 375 mm (9 and 15 in) apart, with 300 mm (12 in) preferred.

5.6.8.6.2 Three points of contact. The handholds and footholds shall enable the user to maintain three points of contact during use.

5.6.8.6.3 Horizontal offset. If the footholds are not wide enough to accommodate both feet simultaneously, vertically adjacent footholds shall be offset to align with the user's natural feet positions during the climb.

5.6.8.6.4 Foothold width. Foothold width shall accommodate the arctic boot width of the largest user with a preferred single-foot foothold total width of at least 180 mm (7 in).

5.6.8.6.5 Foothold depth. Foothold depth shall be at least 256 mm (10.25 in). This will enable the largest user equipped with arctic boots to position the foot with the front of the heel resting against the near edge of the foothold.

5.6.8.6.6 Foothold height. Foothold height shall be at least 130 mm (5 in). This will accommodate the arctic boot height of the largest user with a preferred foothold height.

5.6.8.6.7 Toehold dimensions. In some cases, it will not be necessary to accommodate the entire foot, but just the front of the foot (the "toe"). In those cases, toehold dimensions shall have a total width of at least 180 mm (7 in), a height of at least 130 mm (5 in), and a toehold depth of at least 150 mm (6 in).

5.6.8.6.8 Footholds as standing platforms. Footholds that will also be used as standing platforms, such as for performing maintenance operations, shall measure at least 380 mm (15 in) deep by 300 mm (12 in) wide, and preferably measure at least 380 mm (15 in) deep by 380 mm (15 in) wide.

5.6.8.6.9 Footholds as handholds. Footholds that serve also as handholds shall accommodate grasping (tactility, accessibility, clearance, and traction) by the largest user's extreme cold weather hand gear (including mittens).

5.6.8.6.10 Personnel access and movement. All handholds and footholds shall be able to withstand personnel access and movement while wearing or carrying mission clothing and equipment.

5.6.8.6.11 Drainage of liquids. Footholds shall allow for drainage of liquids that enter the foothold area.

5.6.8.6.12 Non-skid surface. Footholds shall be treated with a non-skid coating or have a non-skid surface.

5.6.8.6.13 Pinch hazard. Footholds that serve also as handholds shall not pose a cut or pinch hazard to a user's bare hand.

5.6.8.6.14 Grab handles. Grab handles shall be reachable from the ground by the smallest user.

5.6.8.6.15 Maintain balance. Grab handles should allow the user to maintain balance throughout the ingress and egress process. This may necessitate multiple or extended grab handles.

5.6.8.6.16 Location. Grab handles shall be located in a manner that does not cause or allow the door to close on personnel during ingress and egress. This includes accidental activation of power-operated door controls if so equipped.

5.6.8.7 Ladders for trailers and transportable enclosures.

5.6.8.7.1 Use. Ladders or steps shall be used whenever personnel have to change elevation abruptly (more than 450 mm [18 in]) during operation or maintenance of the vehicle.

5.6.8.7.2 Design considerations. The design of ladders for trailers and transportable enclosures shall accommodate spatial limitations and clearances, weather conditions affecting the use of a ladder (rain, ice, or snow), and traffic flow.

5.6.8.7.3 Remain in position. When trailers or transportable enclosures will remain in one place for an extended period of time, stair ladders should be used.

5.6.8.7.4 Accommodation. Ladders shall be designed to support the user's weight while dressed in arctic clothing plus the weight of any additional equipment that he or she may be wearing or carrying.

5.6.8.7.5 Arctic boot accommodation. Ladders shall have a total width of at least 360 mm (14 in), a toehold height of at least 130 mm (5 in), and a foothold depth of at least 256 mm (10.25 in). This will enable enough width and depth to accommodate two arctic boots, side by side, on any given step or rung (see also 5.6.8.6.4, 5.6.8.6.5, and 5.6.8.6.6).

5.6.8.7.6 Safety measures. Ladders shall have no obstructions, edges, notches, or burrs that could injure personnel or damage hoses or cables.

5.6.8.7.7 Non-skid surface. Surfaces upon which personnel step or walk shall be treated with non-skid coating or have a non-skid surface.

5.6.8.7.8 Lock into place. Ladders should lock into place during use.

5.6.8.7.9 Markings. Markings shall be provided indicating any dangers associated with using the ladder.

5.6.8.7.10 Lifting and positioning. Ladders shall be capable of being carried, handled, and positioned by one person.

5.6.8.7.11 Weight limits and grasp areas. The ladder's weight limits and grasp areas shall be in accordance with 5.20.3, 5.20.4, and 5.20.7.

5.6.9 Ground vehicle safety and survivability.

5.6.9.1 Protection from moving components. Guards or shields shall be provided so that body parts, clothing, and equipment are protected from moving or rotating components.

5.6.9.2 Protection from high temperatures. Guards or shields shall be provided so that body parts are protected from contact with components whose temperatures exceed the limits in table XXVII.

5.6.9.3 Protection from electrical shock. Guards or shields shall be provided so that body parts are protected from contact with components that present a potential electrical shock hazard.

5.6.9.4 Protection from pressurized systems. Guards or shields shall be provided so that personnel are protected from pressurized systems and lines.

5.6.9.5 Loose wires. There shall be no loose wires or other items to entangle or restrict personnel ingressing or egressing the vehicle or during vehicle operations.

5.6.9.6 Expended cartridge cases. Hot expended cartridge cases or links from the vehicle's weapon system shall be expelled so as to not come in contact with personnel.

5.6.9.7 Standing surface. Hot expended cartridge cases or links shall not be cast upon or collect on surfaces on which personnel are standing.

5.6.9.8 Toxic substances. Personnel shall be protected against all toxic or harmful chemical substances.

5.6.9.9 Subordinate power receptacle. When a subordinate power receptacle is provided, it should not be positioned near the fuel refill point.

5.6.9.10 Blast protection. Vehicles that are equipped with the following survivability features shall meet the criteria in 5.6.9.10.1 through 5.6.9.10.8.

5.6.9.10.1 Energy attenuating (EA) systems. Areas under EA systems or devices, or equivalent, should be designed to prevent vehicle occupants from stowing items and equipment that could prevent the seats from stroking and absorbing energy in a blast.

5.6.9.10.2 Placement. EA systems or devices, or equivalent, shall be sized and located so that all vehicle occupants can utilize the systems or devices (placing feet in a protected area) without having to assume awkward or uncomfortable positions.

5.6.9.10.3 Protected areas. Protected areas such as blast mats, footrests, or false floors should be clearly identified.

5.6.9.10.4 Non-protected areas. If a vehicle occupant can easily place his or her feet on a non-protected area while sitting, it shall be clearly labeled with a "NO FEET" warning.

5.6.9.10.5 Blast mats. Blast mats should be secured to prevent their removal from the vehicle and to prevent loose mats from sliding around under feet.

5.6.9.10.6 Warning labels under blast mats. Warning labels should be placed on the floor under blast mats to warn vehicle occupants if a blast mat has been removed.

5.6.9.10.7 Equipment storage. Vehicles shall provide storage, weapon mounts, and tie-downs for equipment to prevent loose gear from becoming projectiles in a blast or collision.

5.6.9.10.8 Warnings, labels, and instructions. Vehicles with blast protection design features shall have warnings, labels, and instructions to inform vehicle occupants of the design features, instruct them on the use of features, and warn them of the potential hazards of not properly utilizing the design features.

5.6.9.11 Crush sensors for power-operated doors.

5.6.9.11.1 Pneumatic or electro-hydraulic power. Crush sensors shall be provided for any power-operated door that utilizes either pneumatic or electro-hydraulic power.

5.6.9.11.2 Remote operation. Crush sensors should be provided for any power-operated door capable of remote operation (e.g., driver has control of the rear door).

5.6.9.11.3 Stop and reverse direction. Crush sensors shall cause the power-operated door to stop closing within 1 second and automatically reverse direction to open the door by 5 to 10 degrees angularly or 150 mm (6 in) linearly.

5.6.9.11.4 Pressure. Crush sensors shall cause the door to stop and reverse after 1 kg (2.2 lb) of pressure.

5.6.9.11.5 Cover perimeter. Crush sensors shall cover the perimeter of the door at the most likely location(s) that an appendage would be at risk of being crushed.

5.6.9.11.6 Override switch. An override switch shall be provided in both the crew and squad compartments that will override the door crush sensor and allow the operator to close the door remotely.

5.6.9.11.7 Override switch-secondary operation. The override switch shall not be able to function as a primary door operation switch. It shall only function after the door crush sensor has been activated and the operator can confirm that there is a fault with the sensor and that the door opening is clear.

5.6.10 Stowage.

5.6.10.1 Stowed gear and equipment. Stowed gear and equipment shall not prevent meeting the vehicle's operational clearances (e.g., height, width, or length limits) or the ingress and egress requirements of 5.6.8.

5.6.10.2 Provisions for stowing gear and equipment. Straps, brackets, and containers for stowing gear and equipment shall not prevent meeting the vehicle's operational requirements of this portion of the standard both when the gear and equipment are stowed and not stowed.

5.6.10.3 Restraints. Accommodations for stowage shall restrain the equipment for all designed loads from vehicle mobility operations and threat-induced events.

5.6.11 Subsystems.

5.6.11.1 Vehicle drains.

5.6.11.1.1 Location. Drains shall be located where crewmembers can clear and check them without removing components. Opening or removing an access panel is not considered removing a component.

5.6.11.1.2 Visual check. A drain's open or close status shall be apparent with a visual check.

5.6.11.1.3 Minimum number. Vehicles should be designed to require a minimum number of drain valves, a minimum number of different drain valves, and a minimum number of different drain and plug sizes.

5.6.11.1.4 Bilge pumps. Vehicles that swim shall be equipped with bilge pumps.

5.6.11.1.5 Hand-operable. Drain valves shall be hand-operable.

5.6.11.1.6 Fording or swimming operations. Drains shall be easy to identify and easy to close and check before fording or swimming operations.

5.6.11.1.7 Interference. Drains, in both the ON and OFF position, shall not interfere with the loading, stowage, or unloading of cargo.

5.6.11.1.8 Drain and vent locations. Instruction plates giving drain and vent locations and procedures for operating them shall be provided.

5.6.11.1.9 Operation. Drain valve handles shall be in line with the corresponding pipe when ON and perpendicular to the pipe when OFF.

5.6.11.1.10 Fluids. Drains shall be designed to allow drainage of fluids into a container that is accessible during normal servicing and designed to contain waste fluids for recovery, recycling, or disposal.

5.6.11.1.11 Drain valve design. Drain valve design should provide threading in the base surface that is as hard or harder than the inserted plug. In the event of misaligned installation (cross-threading), this allows replacement of a small disposable part such as the drain plug rather than a larger, more expensive part such as the oil pan. Use of softer coating materials for the plug-thread assembly may be considered but should only substitute for basic composition of underlying materials if viable alternatives are not readily feasible.

5.6.11.2 Shut-off valve handles. Shut-off valve handles shall be in line with the corresponding pipe when the valve is open and perpendicular to the pipe when the valve is closed.

5.6.11.3 Filling, draining, and checking procedures. Filling, draining, and checking procedures shall meet the criteria in 5.6.11.3.1 through 5.6.11.3.10.

5.6.11.3.1 Determine fluid levels. Items such as the engine, transmission, and hydraulic reservoir sumps shall be equipped with a means to determine fluid levels.

5.6.11.3.2 Fluid level warnings. Warning systems or indicator lights shall notify the vehicle operator if fluid levels are below safe operating levels.

5.6.11.3.3 Location of dipsticks. Dipsticks shall be located where crewmembers can check and top off fluid levels without powering up the vehicle and without removing components. Opening or removing an access panel is not considered removing a component.

5.6.11.3.4 Dipsticks. Dipsticks shall be etched, sandblasted, knurled, or phosphate-coated to facilitate determination of the fluid level.

5.6.11.3.5 Gear cases, differentials, and reservoirs. Other items such as gear cases, differentials, and reservoirs that contain oil shall be equipped with either dipsticks, check plugs, or sight glasses, as appropriate.

5.6.11.3.6 Insertion. Dipsticks and supporting structures shall be easy to reinsert and have a physical or tactile indication when insertion is complete.

5.6.11.3.7 Adjustment or replacement. Components requiring adjustment or replacement, such as distributors, fuel injectors, and fan belts, should be accessible by the user population in all mission clothing and equipment.

5.6.11.3.8 Timing marks. Timing marks and other adjustment indicators shall be designed to minimize parallax and shall be readily accessible for visual inspection.

5.6.11.3.9 Drive belt tensioning. Drive belt tensioning devices shall permit access for tensioning without removal of other components and, if needed, shall be furnished with pry points. Opening or removing an access panel is not considered removing a component.

5.6.11.3.10 Oil samples. If oil samples are required, oil sampling valves shall be accessible to personnel to allow collection of the oil sample.

5.6.11.4 Batteries and subordinate power receptacles.

5.6.11.4.1 Battery compartments. Batteries shall be protected from sources of heat and be environmentally protected to ensure satisfactory functioning within all ambient temperature ranges.

5.6.11.4.2 Roll-out racks. If access to batteries and subordinate power receptacles by reach is not feasible, corrosion-resistant roll-out racks or similar devices shall be provided.

5.6.11.4.3 Accessibility. Subordinate power receptacles shall be accessible to all personnel from ground level.

5.6.11.4.4 Location. Subordinate power receptacles shall be located away from areas where fuel or other explosive vapors are present.

5.6.11.4.5 Handholds and footholds. If the user cannot reach the subordinate power receptacle while standing on the ground, footholds and handholds in accordance with 5.6.8.6 shall be provided to enable the user to access the subordinate power receptacle.

5.6.11.4.6 Access covers. Battery access covers shall be fastened with quick-release fasteners and insulated on the inside of the cover to reduce risk to personnel from potential electrical shorting.

5.6.11.4.7 Cleaning and servicing. Batteries and their compartments shall be designed so they can be cleaned and serviced without removing any other components. Removal of an access panel is not considered removing a component.

5.6.11.4.8 Servicing. Batteries shall be capable of servicing, installation, and removal by one person without removing other items of equipment or requiring special tools. Removal of an access panel is not considered removing a component.

5.6.11.4.9 Battery acid. Battery supports, hold-downs, and areas around the installation that could possibly be affected by dripping or seepage of acids shall be protected with acid-proof paints or coatings.

5.6.11.4.10 Battery cases. Battery cases shall be drained overboard with acid-proof piping when required.

5.6.11.4.11 Battery terminals. A means of protection, such as a dust cap, shall be provided to prevent terminals from contacting metal surfaces during handling, removal, or replacement.

5.6.11.4.12 Identification of battery terminals. Positive and negative battery terminals shall be labeled and color coded.

5.6.11.4.13 Alternate ground. Rather than using the battery terminals, an alternate grounding point near the battery should be provided and appropriately labeled. This alternate grounding point should be selected to minimize the risk of arcing.

5.6.11.5 Fuel system.

5.6.11.5.1 Fill ports. The fill ports for the fuel system shall be located such that fuel spilled during filling does not contact the exhaust system, the batteries, or the vehicle interior.

5.6.11.5.2 Accessibility of fill ports. The fill ports for the fuel system should be accessible by the user while standing on the ground.

5.6.11.5.3 Handholds and footholds. If the user cannot reach the fill port while standing on the ground, footholds and handholds in accordance with 5.6.8.6 shall be provided to enable the user to access the fill port.

5.6.11.5.4 Grounding. Grounding accommodations shall be provided at each fill port.

5.6.11.5.5 Drains. Fuel system drains shall be located where the user population in appropriate clothing and gear can access them without powering up the vehicle and without having to remove any components. Opening or removing an access panel is not considered removing a component.

5.6.11.6 Engine.

5.6.11.6.1 Oil-drain plugs. Removing oil-drain plugs shall allow the oil pan to drain completely if the vehicle is on a level surface.

5.6.11.6.2 Engine accessories.

5.6.11.6.2.1 Accessibility. Engine accessories, such as fuel and coolant pumps, starter motors, generators, filters, and air cleaners, should be accessible without removing the engine from the vehicle.

5.6.11.6.2.2 Replacement. It should be possible to remove and replace any engine accessory without having to remove any other engine accessory.

5.6.11.6.2.3 Location. Fuel filters, oil filters, and fuel and water separators shall be located where they can be accessed and replaced without removing the engine from the vehicle.

5.6.11.6.2.4 Filters. Fuel, oil, and air filters shall be located where they can be removed and replaced without powering up the vehicle and without removing components. Opening or removing an access panel is not considered removing a component.

5.6.11.6.2.5 Tools. All crew-performed removal, servicing, and installation tasks shall be possible using tools and equipment found in the vehicle.

5.6.11.6.2.6 Adjustments. Fan belts and other drives that require adjustment should be designed to be handled while wearing arctic mittens and should be located or protected such that the maintainer is not exposed to burn hazards from hot engine parts.

5.6.11.6.2.7 Timing marks. Engine timing marks and their associated reference points should be located to be capable of being cleaned and viewed by a maintainer when the engine is installed in the vehicle.

5.6.11.7 Exhaust system.

5.6.11.7.1 Positioning. The vehicle's exhaust system shall be positioned such that it does not direct exhaust gases into occupied spaces, including during open hatch operations, or into personnel air inlets when the vehicle is travelling forward and sitting at idle with no prevailing winds.

5.6.11.7.2 Location. The exhaust system shall be located or protected so that personnel will not come into contact with hot surfaces.

5.6.11.7.3 Clogging. The exhaust system shall not be capable of being clogged or its function degraded when the vehicle is engaged in fording or swimming operations.

5.6.11.7.4 Mounting. The exhaust system shall be mounted to the chassis securely, yet still accommodate flexing between components.

5.6.11.7.5 Safety. The exhaust system shall not cause burning, charring, or other damage to the vehicle's electrical wiring, fuel supply, or any other equipment.

5.6.11.8 Trailers and intravehicular connections.

5.6.11.8.1 Coupling devices. Coupling devices shall be long enough so that they do not restrict the maneuverability of towing vehicles during towing operations.

5.6.11.8.2 Mismating of coupling devices. Coupling devices shall be designed to preclude mismating and damage under normal use.

5.6.11.8.3 Intravehicular safety. Measures shall be employed to protect intravehicular couplings from accidental disconnection, kinking, entanglement, dragging, abrasion, or pinching during operation.

5.6.11.8.4 Air and air-over-hydraulic brakes. Vehicles with air-over-hydraulic brakes or air brakes shall have glad hands at the front and rear of the vehicle for connecting to another vehicle's brake system and controlling it during towing operations.

5.6.11.8.5 Positioning controls. Component trailers shall contain precise positioning controls when the trailer will be used to mate parts.

5.6.11.8.6 Trailer brakes.

5.6.11.8.6.1 Parking brakes. Manual parking brake controls for trailers shall be located so that an operator can reach them easily after positioning or parking the trailer.

5.6.11.8.6.2 Control location. The controls shall be located on the side of the trailer not normally exposed to road traffic.

5.6.11.8.6.3 Brake warning. Brake warnings shall meet the following criteria.

5.6.11.8.6.3.1 Air brakes. Vehicles with compressed air brakes shall have warning signals that operate continuously as long as pressure is below a fixed threshold level (not less than one-half the greater of cut-out pressure of the compressor governor or 60 psi).

a. These warnings shall be designed so they are audible or visible to the operator.

b. Each vehicle shall have a pressure gauge that indicates the braking pressure.

5.6.11.8.6.3.2 Vacuum-assisted brakes. Vehicles with vacuum-assisted brakes shall have an audible or visible warning signal that gives a continuous warning as long as the vacuum in the supply reservoir is less than 200 mm (7.9 in) of mercury.

a. These warnings shall be designed so they are audible or visible to the operator.

b. Each vehicle shall have a vacuum gauge indicating the braking assist vacuum.

5.6.11.8.6.4 Brake maintenance. All brake system components requiring maintenance action shall be both visible and accessible to maintenance personnel and operators.

5.6.11.8.6.5 Inspection ports. Appropriate inspection ports, protected by a window or removable cover, shall be provided to permit examination of brake linings.

5.6.11.8.6.6 Glad hands. Glad hands shall meet the following criteria:

a. Where service and emergency air brake components are installed on the front or rear of equipment, the glad hands shall be rigidly mounted with service glad hand on the curb side and emergency glad hand on the roadside.

b. Each glad hand shall be equipped with permanent and clear identification tags.

c. Color coding for glad hands, when specified (see 6.2), shall be blue for service or control and red for emergency/supply.

d. Every air or vacuum reservoir shall have a check valve so that leakage from the air or vacuum supply lines will not deplete the reservoir.

e. Means shall be provided to determine that the check valve is in working order.

5.6.11.8.6.7 Brake adjustment. Brakes shall be adjustable without using special tools (including wheel pullers) or removal of any part.

5.6.11.8.6.8 Adjustments. Adjustments required to tighten brakes shall be clearly marked as to proper rotation or action when operation is not obvious.

5.6.11.9 Tires.

5.6.11.9.1 Checked in stowed position. The spare tire, if the vehicle is so equipped, shall be capable of being checked and inflated when mounted in the stowed position.

5.6.11.9.2 Removal of spare tire. It shall be possible to remove and replace the spare tire with the vehicle fully loaded.

5.6.11.9.3 Dual wheel arrangements. The design of dual wheel arrangement shall allow both the inner and outer tires to be inflated and checked for air.

5.6.11.9.4 Valve location. The location of valves shall permit tires to be checked and inflated when the tires are interchanged.

5.6.11.10 Radiators.

5.6.11.10.1 Fill level. An indication should be provided to allow the operator to determine the radiator fill level.

5.6.11.10.2 Removal. It should be possible to remove the radiator without having to remove the engine.

5.6.11.11 Chassis.

5.6.11.11.1 Chassis components. When in their operational positions, vehicle occupants should be protected from debris picked up and thrown by the vehicle's tires or tracks.

5.6.11.11.2 Vehicle appendages. Vehicle appendages and components that prevent or limit access to the vehicle's suspension, tires, tracks, or final drives should be moveable (e.g., hinged) or removable by the crew using provided tools.

5.6.11.11.3 Accessibility. Hoods and other access panels that must be opened for daily checks should be accessible and operable by a single operator.

5.6.11.11.4 Cargo vehicle. Tarpaulins, camouflage systems, end curtains, and bows should be designed so that two crewmembers can remove or install them in 10 minutes or less (time does not apply to arctic enclosures).

5.6.11.11.5 Removal of tarpaulins and camouflage systems. Tarpaulin and camouflage system removal shall meet the criteria in 5.6.11.11.5.1 and 5.6.11.11.5.2.

5.6.11.11.5.1 Pins and retaining devices. Pins and other retaining devices shall be designed so two crewmembers wearing trigger finger mittens can remove and replace them.

5.6.11.11.5.2 Remove from sockets. Bows shall be designed so that personnel wearing trigger finger mittens can remove them from sockets.

5.6.11.11.6 Retaining pins and devices. Captive hardware shall be used with pins and other retaining devices to prevent loss of these items.

5.6.11.12 Hydraulics. For safety purposes, only nonflammable fluid shall be used.

5.6.11.12.1 Standardization of connectors. Connectors in hydraulic systems shall be of standard design and able to be handled with standard tools.

5.6.11.12.1.1 Standardized parts. Valves and cylinders, hose assemblies, couplings, fittings, and filters shall be standardized.

5.6.11.12.1.2 Standard hardware. Standard hardware shall be used for mounting hydraulic components.

5.6.11.12.1.3 Content of lines. All connectors shall be standardized by content of lines.

5.6.11.12.1.4 Connector sizes. The number of different sizes of connectors should be held to a minimum.

5.6.11.12.1.5 Mismating connectors. If there is danger of mismating connectors for adjacent lines carrying different fluids, physically incompatible connectors for the two lines shall be used.

5.6.11.12.2 Identification. Color coding plus one other coding method shall be used for hydraulic lines and valves at each end of the line.

5.6.11.12.3 Markings. Inlets, outlets, and connecting lines in hydraulic systems shall be identified at least every 450 mm (18 in) and at both ends to facilitate maintenance.

5.6.11.12.4 Hydraulic system drain cocks. Drain cocks shall be fitted to all air receivers and oil reservoirs.

5.6.11.12.4.1 Accessibility. All drain cocks shall be accessible and hand operable without spillage.

5.6.11.12.4.2 Drain cock handles. Drain cock handles shall be in line with the corresponding pipe when ON (flow is allowed) and perpendicular to the pipe when OFF (flow is blocked).

5.6.11.12.4.3 Vertical drain cocks. On vehicular equipment, vertical drain cocks shall be operable only by upward movement of the handle.

5.6.11.12.4.4 Horizontal lines. On horizontal lines, the handle should be on the top or bottom of the line.

5.6.11.12.4.5 Handle on side. If a horizontal line must have a handle on the side of the line, it shall be operable only by upward movement.

5.6.11.13 Transportable enclosures. The criteria in 5.6.11.13.1 through 5.6.11.13.7.2 apply to transportable enclosures that serve as shelters for personnel or equipment and require occupancy by personnel for operational or maintenance tasks in excess of 1 hour.

5.6.11.13.1 Ceiling height. To support standing operations, the ceiling height (distance from the floor to the bottom of any light, cable run, or other protuberance over the aisle or standing workspace) of transportable enclosures shall be not less than 198 cm (78 in).

5.6.11.13.2 Reduction in ceiling height. Unless otherwise specified (see 6.2), when the occupants seldom stand to perform normal operations, the ceiling height can be reduced to 189 cm (74.5 in).

5.6.11.13.3 Personnel access openings. Personnel access openings should be not less than 173 cm (69 in) high and 75 cm (30 in) wide.

5.6.11.13.4 Equipment access openings. Equipment access openings shall accommodate the specific equipment to be transported, including clearances for handling.

5.6.11.13.5 Access doors. Access doors shall have provisions for being locked in open and closed positions.

5.6.11.13.6 Steps, stairs, or ladders. Steps, stairs, or ladders shall be provided when transportable enclosure floors are more than 46 cm (18 in) above ground level (see 5.11.8).

5.6.11.13.7 Inclinometers.

5.6.11.13.7.1 Readout. On workspaces, such as large personnel-occupied transportable enclosures or shelters intended for use as mobile workspaces, inclinometers shall be provided to permit readout of front-rear and side-side tilt within ±2 degrees.

5.6.11.13.7.2 Visible. Inclinometers shall be visible and readable from the ground at all pertinent stages of positioning the enclosure.

5.6.11.14 Cranes, materials handling, and construction equipment.

5.6.11.14.1 General. The positioning of equipment and loads shall be facilitated through the use of center-of-gravity identification, positioning guides, identification of attaching points, detachable probes, and similar measures. The workstation shall be designed to ensure that the operator has visibility of the load at all times.

5.6.11.14.2 Control labels. All controls used with lifting equipment shall be labeled as to function and direction of movement.

5.6.11.14.3 Control placement. Controls shall be located within reach of the operator and afford visibility of the load at all times.

5.6.11.14.4 Foot-operated controls. Foot-operated controls should not be selected for precise adjustments or movements.

5.6.11.14.5 Foot-operated brake pedals. Foot-operated brake pedals that require locking shall lock by foot action alone.

5.6.11.14.6 Load capacity. The load capacity shall be indicated on the equipment.

5.6.11.14.7 Audible warning devices. Audible warning devices shall be provided where necessary to indicate that the allowable load has been exceeded.

5.6.11.14.8 Access. Unless otherwise specified (see 6.2), access dimensions for construction machinery shall be in accordance with SAE J925, as applicable.

5.6.11.14.9 Handholds and footholds. Handholds and footholds shall comply with 5.6.8.6.

5.6.11.14.10 Forklifts. The configuration of forklift mechanisms and forklift truck cabs shall permit the operator to have direct view of the tips of the forks in all typical modes of material loading and in all likely operator positions.

5.6.11.14.11 Jacks. Jacks shall be easily accessible for transportation, handling, and storage.

5.6.11.14.11.1 Small jacks. Small jacks shall be designed to be lifted and carried by one person (see 5.20.3).

5.6.11.14.11.2 Jack handles. Jack handles shall be designed so they can be removed or folded when the jack is not in use.

5.6.11.14.11.3 Labeling. Jacks shall be labeled to indicate the direction to turn the jack handle for raising and lowering and the load they are designed to carry.

5.6.11.14.11.4 Jacking points. Jacking points shall be conspicuously labeled on equipment.

5.6.11.14.11.5 Hydraulic jacks. On hydraulic jacks, there shall be mechanical safety-locking devices to keep the load from falling if the hydraulic system fails.

5.6.11.14.11.6 Hydraulic fluid. Only nonflammable hydraulic fluid shall be used in jacks.

5.6.11.14.12 Winches. Instruction plates describing winch operation shall be mounted in a conspicuous location for operator use.

5.6.11.14.12.1 Vehicle power train. Winch and vehicle power trains shall be capable of being operated simultaneously.

5.6.11.14.12.2 Winch cables. Winch cables should be capable of being paid out by one crewmember.

5.6.11.14.12.3 Operation locations. Winches shall be capable of being operated from both the cab and at a safe location near the winch.

5.6.11.14.12.4 Visibility. The winch cable shall be visible to the operator when positioned near the winch.

5.6.11.14.12.5 Overload switch. Winches should be equipped with an overload switch to turn off the winch if the load exceeds the winch’s capacity.

5.6.11.14.12.6 Cable tensioner. Winches should be equipped with a cable tensioner to help keep the cable level and flat.

5.6.11.14.12.7 Arctic mittens. Winch controls at the winch shall be capable of being operated by personnel wearing arctic mittens.

5.6.11.14.13 Hoists. Hoists shall have an automatic cutoff of power to stop lifting when a bind occurs.

5.6.11.14.13.1 Moving parts. Moving parts, such as belts, chains, and gears, shall be covered or guarded to prevent personnel from accidental contact.

5.6.11.14.13.2 Hoist control box. The hoist control box shall be lightweight and designed to be handheld so the operator may reach the "up" and "down" control while holding the box securely and comfortably.

5.6.11.14.13.3 Hoist controls. Hoist controls shall be spring-loaded to the "OFF" or "STOP" position and protected to prevent inadvertent actuation.

5.6.11.14.13.4 Labeling. The "UP" and "DOWN" hoist controls shall be clearly labeled, preferably on the control.

5.7 Warnings, hazards, and safety.

5.7.1 General. Design shall reflect the safety-related human engineering criteria specified herein.

5.7.1.1 Order of precedence. The order of precedence (in descending order) for satisfying system safety requirements shall be as follows:

a. Eliminate the hazard through substitution or alternative design.

b. Design for minimum risk.

c. Incorporate safety devices and process controls.

d. Provide warning devices.

e. Provide procedures and training.

5.7.1.2 Effective alerting system. An effective alerting system should satisfy the following criteria:

a. Not give audible and visible caution and warning alerts when all systems are operating normally.

b. Reduce information assimilation and memory demands.

c. Minimize the time required for personnel to detect and assess failure conditions and to initiate corrective actions.

d. Provide visual alerts that can be detected and understood easily under all environmental conditions in which the system is expected to operate.

e. Be standardized to maximize recognizability.

f. Provide for alerting system growth capability in a form that does not necessitate additional system components.

5.7.1.3 Accessibility of safety equipment. Safety equipment (e.g., first aid kits, fire extinguishers, breakout knives) should be in a standardized location readily accessible by all system personnel.

5.7.1.4 Location of essential equipment. Locations of rescue and emergency essential equipment shall be clearly marked and accessible through manual means without requirement for specialized tools or equipment unless safety or security requirements mandate controlled activation or access.

5.7.1.5 Medical supplies. Basic medical supplies consistent with the operational deployment of the system shall be provided.

5.7.1.6 Safety factors. As part of facility and equipment design, safety factors shall be given major consideration, including the representative safety requirements herein together with the effective application of the human engineering requirements in other sections of this standard. Safety factors are also determined from the application of MIL-STD-882 to the acquisition program and from 29 CFR 1910 and 29 CFR 1926, as applicable.

5.7.1.7 Signal precedence. Each of the following signals shall take precedence over those below them.

5.7.1.7.1 Warning (alarm). A signal that alerts the user to a dangerous condition requiring immediate action.

5.7.1.7.2 Caution (alert). A signal that alerts the user to an impending dangerous condition requiring attention, but not necessarily immediate action.

5.7.1.7.3 Advisory. 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 including a signal to indicate a change in system status that, while important, does not require immediate action on the part of the user.

5.7.2 Display of warnings and hazards.

5.7.2.1 Warning labels and placards. Warning labels and placards shall be in accordance with 5.4.

5.7.2.1.1 General. Warning labels or placards (signs) shall be attached to or adjacent to any equipment that presents a hazard to personnel (e.g., high voltage, heat, toxic vapors, explosion, radiation, or other bodily hazards).

5.7.2.1.1.1 Facility placards and labels. Facility placards and warning labels on equipment not covered under 5.7.2.1 shall be in accordance with ANSI Z535.2.

5.7.2.1.1.2 Shipboard applications. For shipboard applications, the use of black letters on a yellow background is permissible for warning placards.

5.7.2.1.2 Warning content. Warning labels and placards shall explicitly describe the hazard, how to avoid the hazard, and the consequences of not avoiding the hazard.

5.7.2.1.3 NO-STEP.

5.7.2.1.3.1 Location. NO-STEP markings shall be placed at locations where personnel would likely step but doing so could damage equipment or injure themselves.

5.7.2.1.3.2 Color. NO-STEP markings shall be in all capital letters with black characters on a yellow background.

5.7.2.1.4 Line identification. Pipe, hose, and tube lines for gas, steam, liquids, and high pressure air shall be labeled and coded as to contents, pressure, identification, heat, cold, or other specific hazards.

5.7.2.1.5 Identification of protected area. Areas of operation or maintenance where special safety concerns exist, such as no smoking during fueling operations, crew working aloft, radioactive or chemical material in use for testing purposes, or where special PPE must be worn, shall be specifically identified on warning labels and placards with the hazard and what one must do to prevent exposure to the hazard.

5.7.2.1.5.1 Exclusionary areas. Exclusionary areas where personnel should not enter shall be marked and have barriers preventing personnel from entering the excluded area.

5.7.2.1.5.2 Unauthorized personnel. Exclusionary areas should be isolated so no unauthorized personnel can enter.

5.7.2.2 Readability. Messages on warning labels and placards shall be based on the literacy and reading skills of the target population.

5.7.2.2.1 Target population. Messages shall be written so that the target population can read, understand, and comply with the message.

5.7.2.2.2 Sentence style. Sentences shall be short, direct, and in active voice to increase readability.

5.7.2.2.3 Multi-lingual or non-reading populations. For multi-lingual or non-reading populations, consider commonly understood icons. These should be supplemented by written labeling in languages relevant to the user population in order to augment or clarify the meaning of icons.

5.7.2.3 Visibility. Warning placards and labels shall be legible from a safe distance. For guidance on minimum text size for placards and labels, see 5.4.7.2, ANSI Z535.2, and ANSI Z535.4, as applicable.

5.7.2.3.1 Location. Warning labels and placards shall be unobstructed, conspicuous relative to their surroundings, and located to be obvious to operators, maintainers, and transient personnel before being exposed to the hazard.

5.7.2.3.2 Illumination of warning labels and placards. Warning labels and placards shall be visible under all lighting conditions anticipated in the concept of operations. If required, special illumination may be used to meet this criterion.

5.7.2.3.3 Night vision systems. Illumination of warning labels and placards shall be compatible with night vision systems.

5.7.2.4 Hazards. Warning labels and placards shall not create hazards or be hazardous themselves.

5.7.2.5 Signal word. Warning placards or labels shall display the appropriate signal word (DANGER, WARNING, CAUTION, or NOTICE) formatted in accordance with ANSI Z535.2 or ANSI Z535.4, as applicable.

5.7.2.5.1 DANGER. DANGER shall be used when failure to avoid the hazard will almost certainly result in serious injury or death. DANGER is reserved for the most serious hazards only.

5.7.2.5.2 WARNING. WARNING shall be used when failure to avoid the hazard may result in serious injury or death.

5.7.2.5.3 CAUTION. CAUTION shall be used when failure to avoid the hazard may result in minor or moderate injury.

5.7.2.5.4 NOTICE. NOTICE should be used when failure to obey precautions may result in system damage or to indicate important information not directly associated with a hazard or hazardous situation.

5.7.2.6 Other equipment labels. The following labels shall be in accordance with 5.4, ANSI Z535.2, or ANSI Z535.4, as applicable.

5.7.2.6.1 Center of gravity and weight. When equipment must be transported by person or machinery, the center of gravity and the weight of equipment shall be distinctly marked.

5.7.2.6.2 Weight capacity. The weight capacity shall be indicated on stands, hoists, lifts, jacks, vehicles, and similar weight-bearing equipment to prevent overloading.

5.7.2.6.3 Lift requirement markings. When equipment must be transported by more than one person, the lifting requirement (two-person, three-person, machinery) shall be marked in accordance with 5.20.4.6. Unless otherwise specified (see 6.2), single-person lift markings shall specify maximum weight for the smallest female in the user population. For lift marking for more than one person, lift markings shall specify the maximum weight for mixed male-female teams.

5.7.2.6.4 Electrical labels. Each receptacle shall be marked with its voltage, phase, and frequency characteristics, as appropriate. For other electrical labeling and warning guidance, see MIL-HDBK-454.

5.7.2.6.5 Hand grasp areas. Hand grasp areas shall be identified on the equipment.

5.7.3 Visual alerting systems. For visual display and information presentation requirements, see 5.2 and 5.17, respectively.

5.7.3.1 General. Visual displays shall be used to provide the user with a clear indication of warning for off-normal equipment or system conditions.

5.7.3.2 Warning and caution. A warning and caution display should indicate the triggering condition. The intent of such a display is to provide the user with a greater probability of detection of the off-normal event than normal observation would provide in the absence of the display.

5.7.3.2.1 Use. Visual danger signals (i.e., warnings and cautions) shall be used to alert the user that a specific condition exists by providing information about the nature and priority of the condition.

5.7.3.2.2 Characteristics. Danger signal displays shall be illuminated to be visible under all anticipated lighting conditions.

5.7.3.2.2.1 Different from general lighting. Danger signal displays shall be conspicuously different from general area lighting.

5.7.3.2.2.2 Specific meaning. Danger signal displays shall have specific meaning within the operational area in which they are used.

5.7.3.3 Warnings, cautions, and advisories. Visual warnings, cautions, and advisories shall be in accordance with MIL-STD-411.

5.7.3.4 Signal integration. Visual warnings, cautions, and advisories shall be integrated with those presented in other sensory modalities (e.g., auditory, tactile).

5.7.3.5 Priority coding. To establish the priority of visual signals, discriminatory characteristics, such as flashing, color, shape, symbols, color contrast, size, luminance contrast, and location, shall be used.

5.7.3.5.1 Warning signals. Visual warning signals shall be presented using flashing red with flash frequency between 3 and 5 hertz with a 50 percent duty cycle.

5.7.3.5.1.1 Flashing text. If warning text that must be read flashes, the text should alternate intensities with a lower intensity that remains legible.

5.7.3.5.1.2 Synchronized flash rate. The flash rate for all such warning signals shall be synchronized.

5.7.3.5.1.3 Use with caution signals. If used in conjunction with caution signals, warning signals shall be coded to be easily distinguished from caution signals.

5.7.3.5.2 Caution signals. If cautions take the form of flashing text, the text shall flash at a rate not greater than 2 hertz with an ON/OFF interval of approximately 70 percent on to ensure text legibility when required.

5.7.3.5.2.1 Color. Visual caution signals shall be yellow.

5.7.3.5.2.2 Rapid identification. A minimum of two discriminatory characteristics shall be employed to ensure rapid identification and interpretation of caution signals.

5.7.3.6 Text height. Text for visual warning and caution signals shall be presented using characters between 8.7 and 17.4 milliradians (30 and 60 minutes of subtended arc) as measured from the longest anticipated viewing distance with the larger size used where conditions may be adverse.

5.7.3.7 Co-location. Warning and caution signals and the information required to respond to them shall be grouped in a single location.

5.7.3.7.1 Grouped separately. When textual information about warning conditions is listed in a single location, warnings and caution information shall be grouped separately.

5.7.3.7.2 Sorting options. The user shall have the option to sort warning and caution messages by priority, chronological, or recency order.

5.7.3.8 Master warning, caution, and advisory lights. Master warning, caution, and advisory signals shall be set apart from signals that show the status of the subsystem components when used to indicate the condition of an entire subsystem, except as required for maintenance-only displays. For aviation systems, use MIL-STD-411.

5.7.3.9 Additional warnings. Additional warnings shall be indicated by redundant coding.

5.7.3.10 False and nuisance alerts. The system should be designed to minimize the effects of undetected, false, or nuisance alerts or any condition that would cause a user to perceive an alert signal to be energized when it is not.

5.7.4 Auditory warnings and hazards. For auditory warnings, see 5.3.2. For noise hazards, see 5.5.4.

5.7.5 General workspace hazards.

5.7.5.1 Alerting device. An auditory and visual hazard-alerting device shall be provided to warn personnel of impending danger or existing hazards (e.g., fire or the presence of combustible or asphyxiating gas, smoke, radiation).

5.7.5.1.1 Auditory perception. An auditory hazard-alerting device shall be perceptible in all expected conditions of ambient noise and personnel ear covering (see 5.3.5.2).

5.7.5.1.2 Visual perception. A visual hazard-alerting device shall be perceptible under all anticipated ambient lighting conditions.

5.7.5.1.3 Confusion with other signals. The auditory and visual hazard-alerting device shall not be confused with other alarms and alerting signals.

5.7.5.2 Emergency doors and exits. Design of emergency egress routes, markings, and related hardware (doors and openings) shall conform to life safety codes and accommodate the intended population and the number of occupants, including mobility hampered personnel, if appropriate. Guidance can be found in NFPA 101. Also see 5.11.7.4.

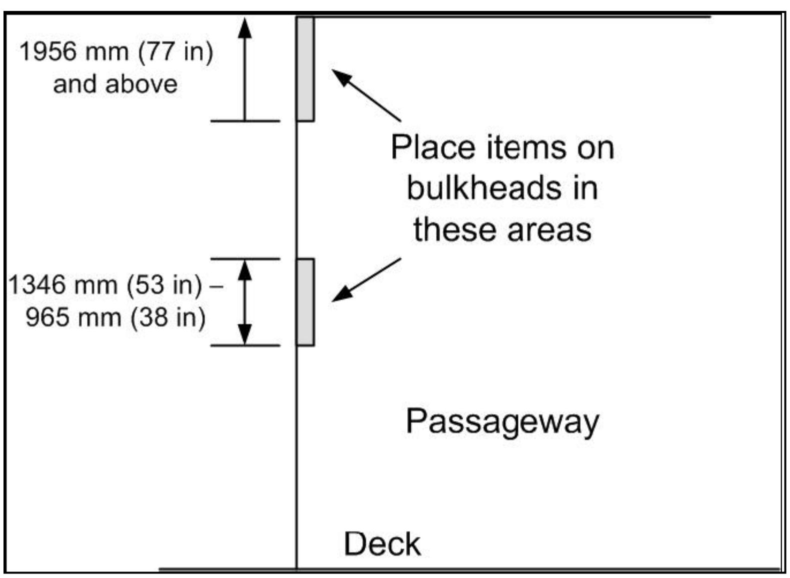
5.7.5.3 Stairs. See 5.11.8.3.

5.7.5.4 Obstructions. The workspace around areas where maintenance is performed shall be free of obstructions that could cause injury to personnel, either through accidental contact with the obstruction or because the obstruction requires an awkward or dangerous body position.

5.7.5.5 Mounted items.

5.7.5.5.1 Mounted overhead. Pipe hangers or any other item mounted in the overhead of passageways, walkways, or other dedicated walking areas shall not protrude below 203 cm (80 in) (213 cm [84 in] preferred) above the walking surface.

5.7.5.5.2 Mounted on bulkheads. Items (e.g., pipe hangers) mounted to bulkheads to support pipe or wireways shall be placed only in the areas shown on figure 47.



NOTE: Dimensions measured from the walking surface.

FIGURE 47. Areas to place items on a bulkhead.

5.7.5.6 Storage racks.

5.7.5.6.1 Not impede traffic flow. Storage racks located in passageways and secured to bulkheads for gas bottles, casualty cables, firefighting equipment, or other items shall not impede traffic flow.

5.7.5.6.2 Protrude into passageway. Storage racks located in passageways and secured to bulkheads shall not have securing studs or other sharp objects (e.g., corners) protruding into the passageway.

5.7.5.7 Cabinet doors. Hinges for doors on lockers, electrical cabinets, storage bins, equipment lockers, or other spaces shall be located so that a partially- or fully-opened door will not interfere with personnel or equipment flow or cause injury to personnel moving past these spaces. Accordion style, rolling (garage door type), or other non-protruding styles of doors may be considered to avoid obstruction of workspaces or passageways.

5.7.5.8 Illumination.

5.7.5.8.1 Illuminate all areas. Illumination shall be provided in all areas, including storage areas.

5.7.5.8.2 Illumination levels. Warning placards, stairways, and all hazardous areas shall be illuminated in accordance with 5.5.3.

5.7.5.9 Thermal contact hazards.

5.7.5.9.1 Exposure limits. Equipment that exposes personnel to surface temperatures greater than those shown in table XXVII or less than 0 °C (32 °F) in normal operation shall be guarded. For temperatures at or below 0 °C (32 °F), pain, tissue damage (freezing), or both can occur. Surface temperatures induced by climatic environment are exempt from this requirement.

5.7.5.9.2 Cryogenic systems. Cryogenic systems shall be guarded.

5.7.5.9.3 Burn hazards. Measures shall be taken, such as guarding, to prevent inadvertent skin contact with surfaces at high or low temperature.

5.7.5.9.3.1 Surfaces that personnel touch. Surfaces that personnel touch (gearshift levers, steering wheels, dash controls, seats, side panels, and compartment walls) shall have low heat conductivity.

5.7.5.9.3.2 Hot metal surfaces. If personnel can touch metal surfaces that may get as hot as 49 °C (120 °F), special precautions shall be incorporated, such as shielding, insulating, PPE (such as gloves), relocating components, or adding warning decals, signs, or labels. Figure 48 shows the burn criteria for human skin.

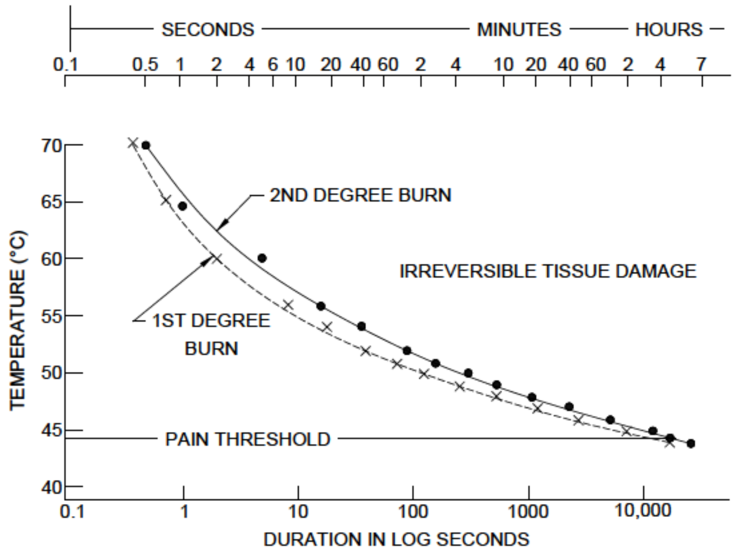
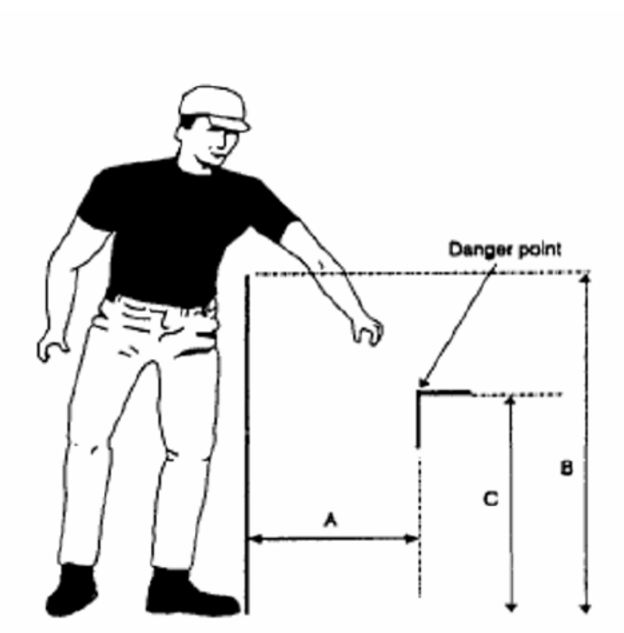


FIGURE 48. Burn criteria for human skin.

5.7.5.10 Safety barriers. Safety barriers shall be used to protect a person from contacting a hazard (e.g., rotating machinery, electrical contact, or hot pipe) as shown on figure 49.



There should be no interpolation of the values in the table; see the following examples:

Example 1

The height of the danger point, "C", is 1,500 mm (59.1 in) and its horizontal distance, "A", from the proposed barrier is 700 mm (27.6 in). Using the table, the height of the barrier, "B", should be 1,800 mm (71.1 in).

Example 2

The height of the barrier, "B", is 1,300 mm (51.3 in) and the height of the danger point, "C", is 2,300 mm (90.6 in). Using the table, the barrier should be positioned 600 mm (23.7 in) from the danger point.

Example 3

The height of the barrier, "B", is 1,700 mm (66.9 in) and the horizontal distance, "A", from the danger point is 550 mm (21.7 in). Using the table, the danger point should not be between 1,200 and 2,200 mm (47.4 and 86.8 in).

FIGURE 49. Safety barriers.

Distance of danger point from floor “C”, mm (in)	**Height of Edge of Barrier “B”, mm (in)**							
	2,400 (94.7)	2,200 (86.8)	2,000 (78.9)	1,800 (71.1)	1,600 (63.2)	1,400 (55.3)	1,200 (47.4)	1,000 (39.5)
	Horizontal Distance “A” from Danger Point, mm (in)							
2,400 (94.7)	--	100 (3.9)	100 (3.9)	100 (3.9)	100 (3.9)	100 (3.9)	100 (3.9)	100 (3.9)
2,200 (86.8)	--	250 (9.9)	350 (13.8)	400 (15.8)	500 (19.7)	500 (19.7)	600 (23.7)	600 (23.7)
2,000 (78.9)	--	--	350 (13.8)	500 (19.7)	600 (23.7)	700 (27.6)	900 (35.5)	1,100 (43.4)
1,800 (71.1)	--	--	--	600 (23.7)	900 (35.5)	900 (35.5)	1,000 (39.5)	1,100 (43.4)
1,600 (63.2)	--	--	--	500 (19.7)	900 (35.5)	900 (35.5)	1,000 (39.5)	1,300 (51.3)
1,400 (55.3)	--	--	--	100 (3.9)	800 (31.6)	900 (35.5)	1,000 (39.5)	1,300 (51.3)
1,200 (47.4)	--	--	--	--	500 (19.7)	900 (35.5)	1,000 (39.5)	1,400 (55.3)
1,000 (39.5)	--	--	--	--	300 (11.8)	900 (35.5)	1,000 (39.5)	1,400 (55.3)
800 (31.6)	--	--	--	--	--	600 (23.7)	900 (35.5)	1,300 (51.3)
600 (23.7)	--	--	--	--	--	--	500 (19.7)	1,200 (47.4)
400 (15.8)	--	--	--	--	--	--	300 (11.8)	1,200 (47.4)
200 (7.9)	--	--	--	--	--	--	200 (7.9)	1,100 (43.4)

FIGURE 49. Safety barriers – Continued.

5.7.5.10.1 Interlock. Safety barriers should be interlocked with operating machinery and hazardous energy sources and provide emergency shut-off when removed.

5.7.5.10.2 Test and evaluation. Test and evaluation should be feasible with the safety barriers in place.

5.7.5.10.3 Bypass. Where interlocks need to be bypassed for maintenance or testing, special precautions and warnings shall be present.

5.7.6 General equipment-related hazards. In evaluating equipment safety characteristics, the following areas shall be reviewed:

a. Failure modes and hazardous effects.

b. Electrical and electronic safety factors.

c. Mechanical safety factors, including hydraulics and pneumatics.

d. Toxicity.

5.7.6.1 Interlocks and warnings.

5.7.6.1.1 Locking control. The operation of switches or controls that initiate hazardous operations (e.g., ignition, movement of a crane) shall require the prior operation of a related or locking control.

5.7.6.1.2 Warning device. Where practicable, the critical position of switches or controls that initiate hazardous operations (e.g., ignition, movement of a crane) shall activate a visual and auditory warning device in the affected work area.

5.7.6.2 Access. Items shall be located and mounted so that access to them can be achieved without danger to personnel from electrical, thermal, mechanical, chemical, radiological, or other hazards.

5.7.6.2.1 Hazardous access. Where access areas must be located over dangerous mechanical or electrical components, the access door or cover should be designed to turn on an internal light when opened.

5.7.6.2.2 Warning label. A warning label shall be provided on the outside of the door or cover that is within the unobstructed field of view.

5.7.6.3 Edge rounding. Where applicable, all exposed edges and corners with which personnel can come into contact (including internal components accessed during maintenance evolutions) shall be rounded to a radius not less than 0.75 mm (0.03 in).

5.7.6.4 Sharp edges and corners. Sharp edges and corners that can present a personnel safety hazard or cause equipment damage during regular operational usage shall be protected or rounded to a radius not less than 1.3 mm (0.05 in). In shipboard environments, motor vehicles, or other application where there are safety hazards with an operator falling into an edge or corner, the radius should be increased accordingly to not less than 13 mm (0.5 in).

5.7.6.5 Safety pins and streamers. Personnel shall have unobstructed visual and physical access to safety pins and streamers during maintenance.

5.7.6.6 Handholds and footholds. Handholds and footholds shall be furnished where needed to assist personnel in climbing onto equipment or performing intended tasks.

5.7.6.7 Stored energy devices. Devices that possess stored energy (e.g., compressed or expanded springs, air bottles, shock absorbers under compression, capacitors) shall contain safeguards to protect personnel and be labeled for safety during operation and maintenance.

5.7.6.8 Emergency release. Where feasible, stored energy devices shall contain provisions for emergency release of stored energy in event of overpressure, fire, or major system failure that could create a risk of catastrophic rapid energy release.

5.7.7 Platforms.

5.7.7.1 Locks. Self-locking or other fail-safe devices shall be incorporated on elevating stands, work platforms, and "draw bridges" to prevent accidental or inadvertent collapsing or falling.

5.7.7.2 Handrails, safety bars, and chains.

5.7.7.2.1 Installation on platforms. Handrails, safety bars, or chains shall be installed around platforms and across stair or step openings on platforms, ledges, and catwalks.

5.7.7.2.2 Height. Handrails, safety bars, or chains shall be placed 91 to 110 cm (36 to 43 in) above the standing surface and include an intermediate guard.

5.7.7.2.3 Chains. Chains should only be used where it is not feasible to install handrails or safety bars.

5.7.7.2.4 Kickboards. Kickboards that are 15 cm (6 in) high shall be installed around platforms, ledges, and catwalks.

5.7.7.2.5 Resistance to lateral pressure. The railings and toe boards shall meet the following resistance to lateral pressure:

a. Top rail – 900 newtons (200 lb)

b. Mid rail – 450 newtons (100 lb)

c. Toe board – 225 newtons (50 lb)

5.7.7.3 Safety mesh. Screen or safety mesh shall be installed on the underside of open gratings, platforms, or flooring surfaces where small tools, parts, or debris may fall through the grating onto workers or equipment beneath the platform.

5.7.7.4 Weight capacity. To prevent overloading, weight-sharing equipment, such as stands, hoists, lifts, and jacks, shall be marked to show weight capacity.

5.7.7.5 Strain gauges. Strain gauges or functionally equivalent technology should be used as a means of detecting when the weight capacity limit is being approached.

5.7.7.6 High centers of gravity.

5.7.7.6.1 Equipment stability. Equipment with a high center of gravity that may tip over and injure personnel shall have anchors or outriggers for stability.

5.7.7.6.2 Warning label. Equipment with a high center of gravity shall have a warning label that depicts the high center of gravity condition of the equipment either pictorially or through text.

5.7.8 Electrical hazards. The principal electrical hazard is shock. The effects of electric shock depend on the body's resistance, the current path through the body, the duration of the shock, the amount of current and voltage, the frequency of an alternating current, and the individual's physical condition. The most critical determinant of injuries is the amount of current conducted through the body. Besides the obvious risk of burns and injuries to the nervous system, electric shock can produce involuntary muscular reactions that injure people and can damage equipment. All electrical systems of 30 volts or more are potential shock hazards. Research indicates that most shock deaths result from contacts with electrical systems ranging from 70 to 500 volts. Table XXVIII summarizes typical effects of various levels of electrical current.

TABLE XXVIII. Shock current intensities and their probable effects.

Current (milliamperes [mA])		**Effects**
AC (60 Hz)	**DC**	
0 to 1.0	0 to 4.0	Perception
1.0 to 4.0	4.0 to 15	Surprise
4.0 to 21	15 to 80	Reflex action
21 to 40	80 to 160	Muscular inhibition
41 to 100	160 to 300	Respiratory block
Over 100	Over 300	Usually fatal

5.7.8.1 Arc flash hazards. Electrical safety in design should identify the potential for arc flash hazards and evaluate the risk in accordance with IEEE 1584.

5.7.8.2 Labeling. Arc flash hazards shall be labeled in accordance with NFPA 70, or equivalent, and precautions for safety and training shall be developed and administered in accordance with NFPA 70.

5.7.8.3 Diagnostic systems. Diagnostic systems and equipment shall be designed, implemented, and installed to avoid or minimize the potential for close or direct contact between the worker and energized systems.

5.7.8.4 Power lines. Both ends of the power line and all branches shall be fused.

5.7.8.5 Rubber insulating equipment. Insulated rubber gloves and live line tools shall be provided for personnel working on or near energized power circuits and equipment rated over 600 volts.

5.7.8.6 Means for removing power. Personnel shall be provided a means for removing power while they are installing, replacing, or repairing components or equipment.

5.7.8.7 Power interruption. The system shall provide personnel with capability to control the power to an electrical circuit.

5.7.8.8 Energized status. The system shall provide a display of the energized/de-energized status of the circuit.

5.7.8.9 Electrical currents. The system or equipment shall protect personnel from exposure to electrical currents that exceed the limits in table XXIX.

TABLE XXIX. Electrical currents exposure limits for all systems.

Frequency (Hz)	**Maximum Current (mA) (AC + DC Components Combined)**
DC	40.0
15 to 2,000	8.5
3,000	13.5
4,000	15.0
5,000	16.5
6,000	17.9
7,000	19.4
8,000	20.9
9,000	22.5
>10,000	24.3

5.7.8.10 Personnel protection. Personnel shall be protected from electrical shock by interlocks, grounding, and enclosures or other protective devices. The main method of alerting personnel to potential shock hazards is through effective visual and audible warnings.

5.7.8.10.1 Color. Equipment designed for safety, protective, or emergency functions should be colored using the guidance of MIL-HDBK-1473.

5.7.8.10.2 Danger markings. Danger markings shall warn personnel about the dangers of hazardous voltages and inform them of the safety precautions they should take to avoid the shock.

5.7.8.10.3 Markings on electrical equipment. Markings on electrical equipment shall be in accordance with the requirements in Article 510 of NFPA 70.

5.7.8.10.4 Danger signs. Danger signs shall be supplemented by physical barriers or other positive protection where feasible.

5.7.8.10.5 Content. Signs, reading “DANGER – HIGH VOLTAGE” or “DANGER (insert maximum voltage) VOLTS” shall be displayed prominently on safety covers, access doors, and inside equipment where hazardous voltages are exposed.

5.7.8.10.6 Durability. Danger signs shall be durable in that they will last over time and after exposure to environmental conditions.

5.7.8.10.7 Visibility. Danger signs shall be placed in an unobstructed location such that they can be read from any expected viewing point.

5.7.8.10.8 Location. Danger signs shall be located where dust and foreign matter will not eventually obscure wording.

5.7.8.11 Warning signals. Warning signals, such as lights, bells, horns, or other devices, shall be used to alert personnel of danger.

5.7.8.11.1 Location. Warning signals shall be located where the people who must take corrective action can perceive them most easily.

5.7.8.11.2 Redundant signals. Multiple redundant warning signals, lights, and bells may be required if ambient noise could mask the audible signal or personnel might not be looking at a warning light.

5.7.8.12 Diagnostic equipment. Diagnostic systems and equipment should be incorporated into system design in order to avoid or minimize the potential for close or direct contact with energized systems.

5.7.8.13 Screening techniques. Infrared screening, sensing, or other "remote" evaluation techniques should be used to detect undesired hazardous energy flow and system faults prior to contact with energized systems.

5.7.8.14 Safety switches. The two basic types of safety switches for preventing electric shock are interlocks and main-power switches.

5.7.8.14.1 Interlocks. An interlock is a switch that automatically turns power off when the access door, cover, or lid of the equipment is open. These switches are ordinarily wired into the "hot" lead to the power supply and operate whenever an access cover is opened, thus breaking the circuit whenever personnel enter the enclosure.

5.7.8.14.1.1 Access to high-voltage potential. Every door or cover that provides access to high-voltage potentials shall have an interlock.

5.7.8.14.1.2 Selection. Selection of the type of interlock switch to be used should be based on use, access type, and reliability. The door interlock switch shown on figure 50 has proven most satisfactory.

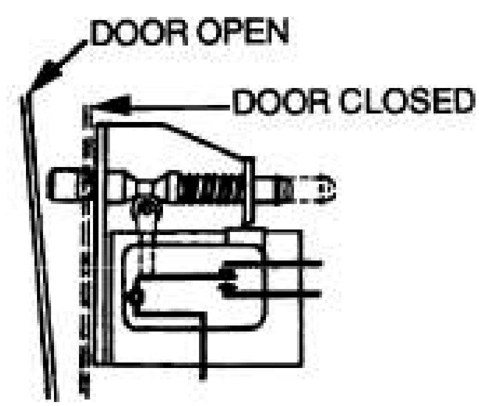


FIGURE 50. Door interlock switch.

5.7.8.14.1.3 Maintenance. The use of interlocks ensures that power is off during maintenance. If maintenance personnel must open the equipment and work on it while the power is on, there shall be provision for bypassing interlocks.

5.7.8.14.1.4 Bypass. Bypass switches shall be located inside the equipment in a position where closing the access door or cover automatically restores interlock protection.

5.7.8.14.1.5 Warning signal. Wherever bypass switches are used, there shall be a warning signal to alert personnel that there is a danger because the interlock has been bypassed.

5.7.8.14.1.6 Visual warning signal color. Visual warnings shall consist of a flashing red light and an appropriate warning placard or sign.

5.7.8.14.1.7 Battle-short switch. Wherever complicated interlocks are used on high priority equipment, there shall be a battle-short switch (or terminals for connecting one) that bypasses all interlocks. The battle-short switch circuit consists of a single switch wired in parallel with the interlock system. Closing the battle-short switch thus short circuits all the interlock switches, turning power on regardless of whether interlocks have been opened.

5.7.8.14.1.8 Emergency use. Battle-short switches, whether mounted on the equipment panel or remotely, shall be marked for emergency use only.

5.7.8.14.1.9 Accidental operation. Battle-short switches shall have protection against accidental operation, such as seals, that must be broken before the switch can be operated.

5.7.8.14.1.10 Visual and auditory warning. Battle-short switches shall have appropriate visual and auditory warning devices to alert personnel that interlocks have been bypassed.

5.7.8.14.1.11 Non-bypassable interlocks. Doors, covers, or lids that provide access to voltages in excess of 500 volts or allow exposure to microwave and radiofrequency radiation in excess of 300 kilohertz (kHz) shall have non-bypassable interlocks.

5.7.8.14.2 Main-power switch. Each item of equipment shall have a labeled main-power switch that turns off all power to the item by opening all leads from the main-power service connection.

5.7.8.14.2.1 Arcing. Main-power switches shall be safeguarded to prevent heavy arcing.

5.7.8.14.2.2 Switch box. The main-power switch box shall have provisions such that the box cannot be opened when the switch is turned on. Such switches are available as standard commercial equipment.

5.7.8.14.2.3 Main-power switch location. Main-power switches shall be located so that accidental contact by personnel will not place the equipment in operation.

5.7.8.14.2.4 Main-power switch lockout. A main-power switch lockout shall be provided.

5.7.8.14.2.5 Main-power switch protection. The “hot” side of the main-power switch and the incoming power line connections shall be physically protected against accidental contact by personnel.

5.7.8.15 Discharging devices (bleeders). Because high-quality filter capacitors can store lethal charges for relatively long periods of time, all medium- and high-voltage power supplies shall have devices that discharge them when they are turned off.

5.7.8.15.1 Bleeder incorporation. Bleeders shall be incorporated in all power supplies where the product of resistance (in ohms) and capacitance (in farads) is 3 seconds or more.

5.7.8.15.2 Discharge rate. Bleeders shall be incorporated in all power supplies unless they can discharge 30 volts within 2 seconds after power removal.

5.7.8.15.3 Shorting rods. Shorting rods shall be provided with all equipment having voltages in excess of 70 volts alternating current (VAC) or volts direct current (VDC).

5.7.8.16 Insulation of tools. Tools and test leads to be used near high voltages shall be insulated.

5.7.8.17 Plugs and receptacles. Plugs and receptacle configurations shall preclude inserting a plug of one voltage rating into a receptacle of another rating.

5.7.8.18 Voltage exposure. All “hot” contacts shall be socket contacts.

5.7.8.19 Dangerous voltage or current. Guards, grounding, interlocks, and warning placards shall be provided, as necessary, to minimize exposing personnel to dangerous voltages or currents.

5.7.8.20 Ground potential. All external parts of equipment other than antenna and transmission line terminals shall be at ground potential.

5.7.8.20.1 Grounding techniques. A terminal spot welded to the chassis provides a reliable ground connection. Where welding is not feasible, as with an aluminum chassis, the ground terminal shall be fastened down by a machine bolt, lock washer, and nut (see figure 51).

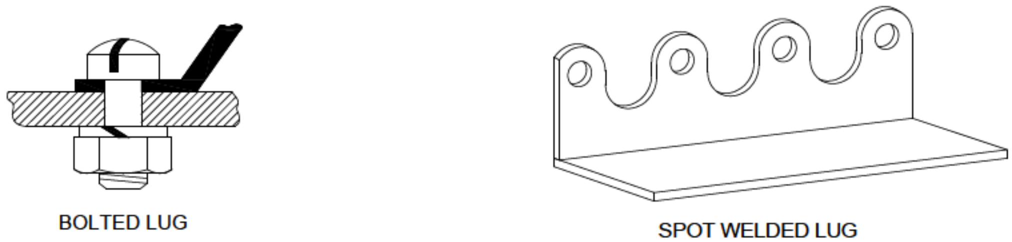


FIGURE 51. Grounding methods.

5.7.8.20.1.1 Ground lugs. Ground lugs shall not be stacked on bolts with any material subject to cold flow.

5.7.8.20.1.2 Machine bolts. The machine bolts used to mount ground lugs shall be large enough that eventual relaxation will not loosen the ground connection.

5.7.8.20.1.3 Lock washer. A lock washer shall be used to keep the ground tight.

5.7.8.20.1.4 Non-conductive finish. Any non-conductive finish on the chassis shall be removed before bolting down the ground lug.

5.7.8.20.1.5 Rivets. Ground lugs shall not be attached with rivets.

5.7.8.20.2 Common ground. The common ground of each chassis shall connect to a through-bolt mounted on the enclosure.

5.7.8.20.2.1 Marking. The common ground of each chassis shall be clearly marked “ENCLOSURE GROUND”.

5.7.8.20.2.2 Safety ground strap. An external safety ground strap shall be connected to the through-bolt.

5.7.8.20.2.3 Composition. The external ground strap shall be a plated flexible copper strap with a current-carrying capacity at least twice as large as the equipment requires (see figure 52).

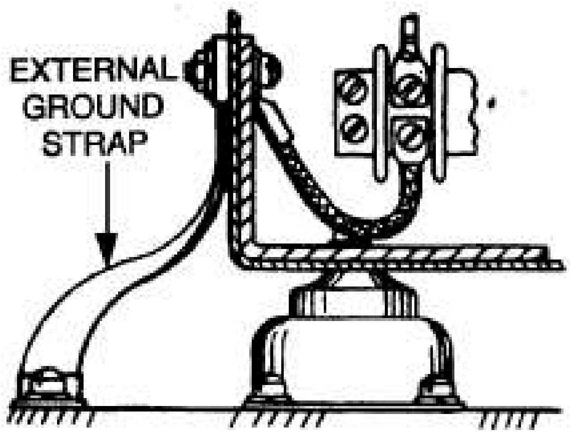


FIGURE 52. Cabinet grounding system.

5.7.8.20.3 Panel-mounted components. Panel-mounted components, especially meters and test jacks, are occasionally used to monitor current in power lines. Panel-mounted components shall be connected into the grounded side of the power line rather than into the ungrounded side. This precaution limits current flow if the component shorts to the grounded chassis.

5.7.8.20.4 Non-grounded lines. Some power-supply lines shall not be grounded as a means of reducing interference.

5.7.8.20.4.1 Bypassed to ground. Power-supply lines shall be bypassed through capacitors to ground.

5.7.8.20.4.2 Total current. The total current to ground, including any leakage through the capacitor, shall be not greater than 5 milliamps (mA).

5.7.8.20.5 Electrically operated hand tools. Electrically operated handheld power tools shall include three-wire power cords with one wire at ground potential.

5.7.8.20.5.1 Exposed surfaces. Electrically operated handheld power tools shall have exposed surfaces that are either non-conducting or are electrically connected to the ground wire. Exposed surfaces include cases, grips, handles, switches, triggers, chucks, and other surfaces that are capable of being contacted during operation.

5.7.8.20.5.2 Portable tools. Portable tools protected by an approved system of double insulation or its equivalent may be used without a ground wire when approved by the procuring activity.

5.7.8.20.5.3 Ground fault protection. Where ground fault protection cannot be incorporated into system wiring, portable ground fault interrupters shall be provided for use with portable electric hand tools, pumps, and other equipment.

5.7.8.20.6 Dead-man switch. Hand tools with the potential for injury to personnel (e.g., sanders, large drills) shall be equipped with a dead-man switch.

5.7.8.20.6.1 Single-hand operation. The use of a dead-man switch is intended as a safety critical operation and shall require single-hand operation.

5.7.8.20.6.2 Switch. The dead-man switch itself shall not require more than one hand to engage or disengage grounding potential.

5.7.8.21 Electronic equipment. See MIL-HDBK-454, Guideline 1, for safety design criteria guidance.

5.7.8.21.1 Test equipment. Electronic test equipment (signal generators, amplifiers, and oscilloscopes) that are plug connected shall have an integral ground prong to ensure automatic ground connection.

5.7.8.21.2 Fusing. Circuits shall be fused so that other parts of the circuit will not be damaged if a fuse is removed or if it ruptures.

5.7.8.21.3 Power line leads. All leads from the primary power lines shall be protected by fuses.

5.7.8.21.4 Connection. Fuses shall be connected between the main-power switch and the load.

5.7.8.21.5 Branch-line holders. When correctly wired, branch-line holders shall facilitate the changing of fuses without risk of accidental shock.

5.7.8.21.6 Fuse-holder contacts. Where feasible, both of the fuse-holder contacts shall be recessed so users cannot touch them.

5.7.8.21.7 Recessed contact. If both ends cannot be recessed, at least one of the fuse-holder contacts shall be recessed where personnel cannot touch it.

5.7.8.21.8 Single contact. The single contact shall be connected to the supply line and the accessible contact connected to the load.

5.7.8.21.9 Wiring. Figure 53 shows how an instrument-type fuse holder shall be wired to keep users from touching the high-potential contact.

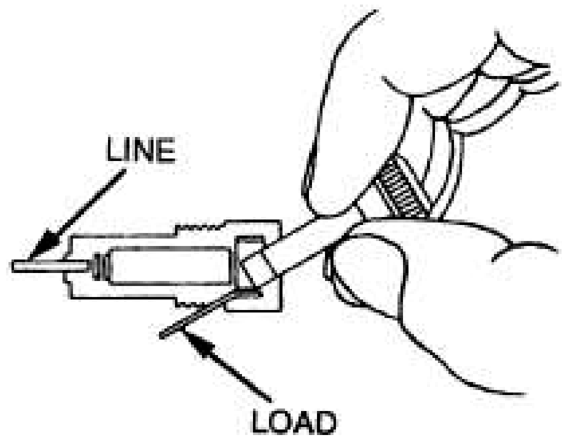


FIGURE 53. Correct instrument-type fuse holder wiring.

5.7.8.22 Batteries. Batteries that have ratings greater than 25 ampere-hours shall have terminal guarding to prevent inadvertent short circuit.

5.7.8.22.1 Eyewash fountain and shower. All rooms designed for battery storage and charging shall be provided with an eyewash fountain and shower. Fountains and showers may be placed outside the room provided they are placed immediately adjacent to the entrance.

5.7.8.22.2 Drainage. Drainage from emergency eyewashes shall ensure run-off does not create a conductive environment and associated electrical hazard.

5.7.8.22.3 Entrances. Entrances into the room shall permit the use of hand trucks or dollies to move batteries into and out of the space.

5.7.8.22.4 Battery storage. Battery storage racks shall have accessibility provisions in accordance with anthropometric data for the user population to permit the smallest user to install or remove the largest batteries to be stored or charged.

5.7.8.22.5 Electrical conductors. Electrical conductors that personnel might contact shall be insulated.

5.7.8.22.6 Protective covers. Grounded or nonconductive protective covers shall be provided for all electrical equipment.

5.7.9 Mechanical hazards.

5.7.9.1 Guards. A guard shall be provided on all moving parts of machinery and transmission equipment, including pulleys, belts, gears, and blades, on which personnel may become injured or entangled.

5.7.9.1.1 Tools. Guards shall be installed to require a tool to be removed. Quick-acting fasteners or any hand-operated guard fasteners shall not be used.

5.7.9.1.2 Moving and rotating equipment. All moving and rotating equipment shall be disabled and unable to function as long as the guard is not permanently installed.

5.7.9.1.3 High-temperature parts. High-temperature parts shall be guarded or located so users will not touch them in normal operation or maintenance.

5.7.9.1.4 Warning signs. If high-temperature parts cannot be guarded, there shall be prominent warning signs.

5.7.9.1.5 Parts inspection. Wherever possible, a guard shall provide unobstructed access for the inspection of parts without having to remove the guard.

5.7.9.1.6 Size of opening. The guard size opening shall be a function of the distance between the guard and the mechanical hazard.

5.7.9.2 Telescoping ladders. Finger clearance shall be provided between rungs of telescoping ladders.

5.7.9.3 Protrusions.

5.7.9.3.1 Sharp edges. Units shall employ protections so that users can carry the units without risk of cutting their hands on sharp edges.

5.7.9.3.2 Flat-head screws. To minimize protrusions from equipment surfaces, flat-head screws shall be used where possible; otherwise, pan-head screws shall be used.

5.7.9.3.3 Exposed surfaces. To reduce the risk of skin abrasion, all exposed surfaces shall be machined smooth, covered, or coated.

5.7.9.3.4 Projecting components. In areas where users must make rapid movements, small projecting components should be avoided or covered.

5.7.9.3.5 Recessed mounting. If small projecting parts, such as toggle switches or small knobs, must be mounted on a front panel, they should be recessed.

5.7.9.4 Exhaust openings. Any air-exhaust openings shall be located where personnel are not exposed to direct drafts.

5.7.9.5 Perforations. Housings, cabinets, and covers shall be perforated, as necessary, to allow air circulation. Many small perforations are better than a few large ones.

5.7.9.5.1 Size of perforations. Perforations shall be not larger than 13 mm (0.5 in) in diameter.

5.7.9.5.2 Protect against touch. Any component that rotates, oscillates, or carries high voltage shall be spaced back from perforations so personnel cannot touch it accidentally.

5.7.9.6 Equipment instability. Equipment shall not pose a tripping hazard during operation and maintenance. Portable equipment, such as maintenance stands, tables, benches, platforms, and ladders, often pose such hazards.

5.7.9.6.1 Walkways and catwalks. Walkways, catwalks, and any surfaces used for climbing shall have non-skid metallic materials, expanded metal flooring, or abrasive surfaces. See 5.7.7.2 for additional safety considerations.

5.7.9.6.2 Ladders and steps. Ladders and steps shall use materials that can be de-iced with hot water or steam.

5.7.9.6.3 Hand grips. Platforms, walkways, stairs, and areas around floor openings shall have hand grips.

5.7.9.6.4 Fixed hand grips. Hand grips shall be fixed, unless this poses a hazard to users.

5.7.9.6.5 Fold away. When required, hand grips shall fold or telescope so they are concealed or flush with the surface except when being used.

5.7.9.6.6 Securely folded. Folding grips shall remain securely folded when not in use.

5.7.9.6.7 Tools. Users shall not require tools to open folding grips for use.

5.7.9.7 Center of gravity. Equipment should be designed to maximize safety and stability when moved on inclines, such as cargo ramps, or lifted by cranes for shipping (see figure 54).

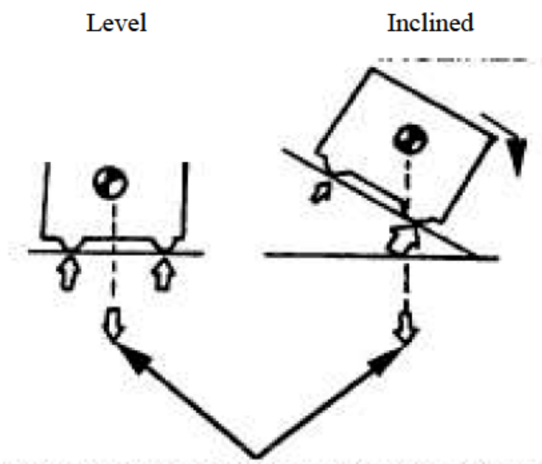


FIGURE 54. Effects of incline on center of gravity location of equipment.

5.7.9.7.1 Marking. The center of gravity and jacking points shall each be marked on equipment to show their locations.

5.7.9.7.2 Visibility. Skids or pieces of equipment, uniquely shaped boxes or packages, or loads in excess 45.5 kg (100 lb) shall have unobstructed markings of the center of gravity.

5.7.9.7.3 Lifting capability. The weight lifting or supporting capacity of stands, hoists, cranes, jacks, padeyes, rigging, and any other items used to lift, transport, or support equipment during operation or maintenance shall be marked in accordance with 5.4 to indicate their capabilities.

5.7.10 Explosion hazards.

5.7.10.1 Explosion. Equipment that may be operated, maintained, or stored in an explosive atmosphere shall employ features to prevent the possibility of an explosion.

5.7.10.2 Flammable gases or vapors. All electrical equipment that will be used near flammable gases or vapors shall be explosion-proof.

5.7.10.3 Hazardous substances. Spark arrestors, vents, drains, and other safety techniques shall be used to isolate hazardous explosive substances from heat sources.

5.7.11 Fluid hazards.

5.7.11.1 Connectors. Each connector used in handling or controlling hazardous fluids, including propellants, solvents, toxic materials, hypergolics, and asphyxiants, shall be incompatible with other connectors within the access area of that connector.

5.7.11.2 Fluid and fuel servicing equipment. Automatic shutoff devices shall be provided on fluid and fuel servicing equipment to prevent overflow and spillage.

5.7.11.3 Flammable liquid lockers. Flammable liquid lockers shall be installed not closer than 1.8 m (5 ft) to a door or exit if it is the only means of egress from the space or compartment, to an open control station, or from a door or exit leading to a control station used for emergency operations.

5.7.11.4 Spraying fluids. Lines shall be kept from spraying or draining fluid on personnel or equipment during disconnection by locating connections away from work areas and sensitive components, shielding sensitive components where required, and providing drains and bleed fittings so lines can be drained or depressurized before they are disconnected.

5.7.11.5 Hazardous gases and liquids. System handling of hazardous liquids and gases shall be in accordance with 29 CFR 1910.101 through 29 CFR 1910.111 or the most current version of standards cited in that reference and relevant NFPA standards such as NFPA 91 as well as CGA S-1.1 and CGA G-8.1.

5.7.12 Toxic hazards.

5.7.12.1 General. Personnel shall not be exposed to concentrations of toxic substances in excess of the limits specified in either the DoD Occupational Safety and Health (OSH) standards or specialized standards applicable to military unique equipment, systems, or operations (including 29 CFR 1910, OSHA Standards, and also in the Federal Register). All efforts should be made to limit exposures to the lowest level consistent with economy and efficiency.

5.7.12.2 Inhalation hazards. In sufficient concentrations, exposure to toxic substances may incapacitate personnel or substantially decrement their performance through eye irritation, nausea, reduced mental alertness, and unconsciousness. Consultation with a subject matter expert (SME, such as an analytical chemist, industrial hygienist, toxicologist, etc.) experienced in toxic gas sampling and analysis is critical to aid in both the identification of all potential hazards and the development of the appropriate measurement strategies.

5.7.12.2.1 Potential sources and critical contaminants. From the practical standpoint of controlling inhalation hazards, it is important to identify all potential sources and understand the chemistry of the associated contaminants. Listed below are three common sources and the associated contaminants that should be measured to evaluate the potential for exposure to personnel.

a. Engine and fuel fired heater exhausts. Exhaust gases from the combustion of hydrocarbon fuels may contain numerous toxic compounds. The composition of exhaust gases varies depending upon many factors, to include the following: the fuel type, application, operating conditions, and ambient temperature. The critical contaminants to monitor, at a minimum, are carbon monoxide (CO), carbon dioxide (CO_2), nitric oxide (NO), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2). Additional sampling for aldehydes (formaldehyde, acrolein, etc.) may be necessary to investigate any complaints of irritation (to the eyes or respiratory tract) and nausea. Measurement of oxygen depletion is recommended for enclosed areas with poor ventilation where these gases may accumulate and displace the air.

b. Confined/poorly ventilated enclosed spaces. Oxygen concentrations should be measured prior to entry of a confined space as the levels may be depleted by multiple causes, to include the following: combustion, microbial consumption, rust or corrosion, or displacement by other gases. Other critical contaminants to monitor are CO, ammonia, nitrogen oxides, hydrogen sulfide (H_2S), sulfur dioxide, aldehydes, and flammable gases (methane or other hydrocarbons). Consideration for the potential buildup of volatile organic compounds (VOCs – i.e., solvents) vapor in enclosed spaces may result from the off-gassing of materials, paints, and from container leaks. In sufficient concentrations, these substances may incapacitate personnel or substantially reduce their performance through eye irritation, nausea, reduced mental alertness, and unconsciousness.

c. Weapons firing activities. The ammunition fired from most modern weapons systems, from small arms to cannons, contains nitrate-based propellants. When the weapon is fired, it is the combustion of these propellants that produces the gases encountered during weapons firing activities. The critical gaseous contaminants to measure typically include, at a minimum, CO, CO_2, NO, NO_2, ammonia (NH_3), and hydrogen cyanide (HCN). Some ammunition types also contain various metals or metal salts. For example, the primers currently used in many ammunition types contain lead styphnate. It is this material that is responsible for much of the lead exposure to personnel firing weapons. Therefore, additional air filter sampling to collect airborne particulates must be performed and the filters analyzed for metals, particularly lead (Pb). For weapons that use propellant formulations that may include chlorine-containing materials (i.e., some missiles and rockets), monitor hydrogen chloride (HCl) concentrations as well. Lastly, when investigating new propellants or novel energetics, their chemical composition must be disclosed as additional sampling and analysis may be required.

5.7.12.2.2 Military unique standard for CO exposure. Personnel shall not be exposed to concentrations of CO that will result in carboxyhemoglobin (COHb) levels in their blood greater than 5 percent for aviation system performance limits. Personnel shall not be exposed to concentrations of CO that will result in COHb levels in their blood greater than 10 percent (threshold) and 5 percent (objective) for all other system performance limits.

a. This standard was adopted as an appropriate and acceptable evaluative tool that assesses CO hazard for military personnel during activities where CO exposures are usually transient (such as weapons firing) and can, in certain cases, be at high concentrations.

b. Carbon monoxide (CO). The prediction of COHb blood content is determined by the following empirical equation:

$$\%\ COHbt = \%\ COHbo\ (\exp[-t/A]) + 218\ (1-\exp[-t/A]) \times (1/B + [ppm\ CO]/1403)$$

where:

% COHbt is the predicted carboxyhemoglobin in the exposed individual.

% COHbo is the amount of COHb usually found in nonsmoking adults.

t is the exposure duration in minutes.

ppm CO is the carbon monoxide exposure in parts per million of contaminated atmosphere.

A and B are constants that are obtained from table XXX and depend on the estimated physical activity level of the individual during the exposure.

c. It should be noted that the equation accounts for the minute respiratory volume of contaminated atmosphere actually inhaled by an exposed individual whose level of physical activity is either estimated or specified. The equation also accounts for the elimination of CO by the body.

TABLE XXX. Constants for predicting COHb blood content.

Work Effort Scale	Work Effort Description	A Value	B Value
1	Sedentary	425	806
2	--	241	1,421
3	Light work	175	1,958
4	--	134	2,553
5	Heavy work	109	3,144

NOTES:

1. When using the equations to estimate the percent COHb blood levels for combat vehicle occupants, the following work effort levels shall be applied, as appropriate: activities involving weapons fire – level 4; all other mission activities – level 3.
2. An initial value of COHb = 1 percent shall be assumed for all estimates.

5.7.12.2.3 Control measures. The primary control measures shall be through engineering controls and feedback systems to include performance monitoring, provision for supply and exhaust air movement, emission monitoring systems, and workspace ventilation.

5.7.12.3 Control of contact exposure. Contact exposure with chemical materials, particularly those associated with skin absorption, caustic and corrosive properties, and skin sensitization, shall be minimized.

5.7.12.4 Drainage. Provision for proper drainage or run-off capture, recovery, clean-up, and containment of spills and aerosols should be built into systems and equipment design and installation.

5.7.12.5 Protective equipment. Where gloves and other protective equipment are utilized, they should be considered secondary controls and complement other control measures. Gloves and other protective equipment should be evaluated and selected to ensure resistance to chemical permeation by the materials in use, but should be composed of the lightest and most flexible protective materials most applicable for the job in order to limit heat stress and optimize manual dexterity.

5.7.12.6 Chemical materials. When chemical materials with similar biological effects or target organs (site of biological action) are present concurrently, total exposure shall be limited to reflect the combined effects and the time period of exposure. Guidance of the ACGIH TLVs should be used to calculate combined allowable exposures.

5.7.13 Radiation hazards.

5.7.13.1 Radiation-emitting systems. To minimize hazards to personnel, radiation-emitting systems and equipment shall emit their radiation at the lowest levels possible but shall maintain dependability for mission accomplishment.

5.7.13.2 Internal ionizing radiation. If internal ionizing radiation hazards (e.g., breakage of a tritium-illuminated source in a fire-control device) cannot be eliminated, they shall be minimized.

5.7.13.3 Ionizing radiation exposure rates. Ionizing radiation exposure rates produced by any device shall not exceed 0.5 milliroentgens per hour at a distance of 5 cm (2 in) from any point on the external surface.

5.7.13.4 Radiation limits. Electronic or electrical devices capable of producing microwave, radiofrequency, X-ray, and laser radiation limits should reference guidance in MIL-HDBK-454. Non-laser high intensity ultraviolet, visible, and infrared radiation limits are defined in accordance with ACGIH TLVs.

5.7.13.5 Radiation exposures. Radiation exposures should be controlled by a prioritized application of the hierarchy of controls to include:

a. Limiting the number of radioactive emitters and their type.

b. Providing engineering controls.

c. Providing administrative controls and training.

d. Providing protective equipment to augment other controls when they are not fully effective.

5.7.13.6 Nuclear radiation. The maximum nuclear radiation to which personnel may be exposed shall be in accordance with 10 CFR 20.

5.7.14 Laser hazards.

5.7.14.1 Laser radiation. Laser equipment and system design, installation, and procedures shall conform to 21 CFR 1040 to the greatest extent possible. Military-specific laser systems that have been exempted from compliance with 21 CFR 1040 shall meet the performance requirements in MIL-STD-1425.

5.7.14.2 Laser exposure limits. In accordance with 21 CFR 1040 and DoDI 6055.15, personnel shall not be exposed to laser radiation in excess of the appropriate maximum permissible exposure.

5.7.14.3 Potential exposure. Personnel working within a laser's nominal ocular hazard distance (NOHD), NOHD with magnifying optics (NOHD-M), and nominal skin hazard distance (NSHD) in which a potential exposure to the direct or reflected laser beam exists may be exposed to hazardous non-ionizing radiation.

5.7.14.4 Eye protection.

5.7.14.4.1 Class 3B and class 4 lasers. When engineering and administrative controls do not control potential exposures to class 3B and class 4 lasers, appropriate laser eye protection shall be provided to personnel who may be exposed to the laser beam within the NOHD or NOHD-M.

5.7.14.4.2 Class 3R lasers. Laser eye protection should be considered during class 3R laser use.

5.7.14.4.3 Proper use of laser eye protection. The proper use of laser eye protection shall be in accordance with 29 CFR 1926.102 (c)(2)(i) and ANSI Z136.1.

5.7.14.5 Optical density. The laser eye protection shall meet the minimum optical density requirements to ensure persons are protected to the maximum permissible exposure for a laser's specific operating wavelength and its maximum output irradiance (watts per square centimeter) or radiant exposure (joules per square centimeter).

5.7.14.6 Labeling of laser protective goggles. Labeling of laser eye protection devices shall be governed by 29 CFR 1926.102 (c)(2)(ii). Labels shall include the following information:

a. Laser wavelengths for intended use.

b. Optical density of those wavelengths.

c. The visible light transmission.

5.7.15 Fire.

5.7.15.1 Precautions. All reasonable precautions should be taken to minimize fire hazards.

5.7.15.2 Non-combustible enclosures. If capacitors, inductors, or motors are potential fire hazards, they shall have non-combustible enclosures with minimal openings.

5.7.15.3 Avoidance of materials that produce pyrolysis. Materials that can produce pyrolysis (a thermochemical decomposition of organic material at elevated temperatures in the absence of oxygen) or any halogen products shall not be used.

5.7.15.4 Avoidance of materials that liberate combustible materials. Materials that might liberate combustible materials shall be avoided.

5.7.15.5 Flammable gases. Equipment shall not emit flammable gases during storage or operation.

5.7.15.6 Unavoidable emissions. If flammable gases are unavoidably emitted during operation, there shall be automatic cutoffs and warnings.

5.7.15.7 Avoidance of dangerous smoke and fumes. Equipment shall not produce undesirable or dangerous smoke and fumes.

5.7.15.8 Fire extinguishers.

5.7.15.8.1 Presence of fire extinguishers. Where fire hazards are known to exist or may be created by the equipment, there shall be portable, hand-operated fire extinguishers, or automated fire-suppression systems present.

5.7.15.8.2 Extinguishing systems. Extinguishing systems shall have the capacity to suppress fires of the size potentially created by combustibles in the relevant areas.

5.7.15.8.3 Placement of portable, hand-operated fire extinguishers. Portable hand-operated fire extinguishers shall be located so they are immediately and easily accessible.

5.7.15.8.4 Selection of fire extinguishers. Fire extinguishers shall be selected for suitability to the class of fires most likely to occur in the area.

5.7.15.8.4.1 Class A. Class A fire extinguishers shall be used for ordinary combustible materials (wood, paper, and rags) that can be extinguished with water or aqueous solutions.

5.7.15.8.4.2 Class B. Class B fire extinguishers shall be used for fires involving flammable liquids (gasoline and other fuels, solvents, greases, and similar substances) that must be extinguished by diluting, eliminating air, or blanketing.

5.7.15.8.4.3 Class C. Class C fire extinguishers shall be used for fires in electrical equipment (motors, transformers, and switches) that must be extinguished by a material that does not conduct electricity.

5.7.15.8.4.4 Class D. Class D fire extinguishers shall be used for fires involving combustible metals.

5.7.15.8.4.5 Class K. Class K fire extinguishers shall be used for cooking fires in which animal or vegetable fats or oils are present.

5.7.16 Dust.

5.7.16.1 Dust concentration. The dust concentrations to which personnel are exposed vary widely from imperceptible levels to dense clouds that may reduce visibility to almost zero; therefore, process controls augmented by a ventilation system shall be used.

5.7.16.2 Ventilation system. The ventilation system intake shall be located in an area where concentration of dust is minimal, including when a vehicle is moving.

5.7.16.3 Ventilation system filters. Ventilation system filters shall be capable of removing dust particles above 5 microns in diameter, unless toxicity or other characteristics require a smaller size.

5.7.16.4 Vehicle dust skirts. Dust skirts, which are of great value in reducing the dust raised around a vehicle, should be provided.

5.7.16.5 Personnel protection. Dust causes temporary eye and throat irritation and at times degrades performance and interferes with operations. Goggles and disposable dust mask respirators shall be provided for use where needed.

5.7.17 Mud and water. Mud and water are analogous to dust in that they affect the same aspects of design. As with dust, it may be impractical to eliminate mud and water as problems, but design should minimize any issues.

5.7.18 Training systems.

5.7.18.1 Embedded training. Training materials, devices, simulators, and other equipment using embedded training shall incorporate safeguards, safety warnings, and procedures developed for the operational system.

5.7.18.2 Safe execution of training. Training devices, simulators, and other equipment shall incorporate safeguards, warnings, and procedures necessary for safe execution of training.

5.7.19 Software safety.

5.7.19.1 Software safety effort. System hazards may result from one specific cause or a combination of the following causes primarily attributed to hardware failures: human errors; software defects, anomalies, the software propagation of hardware failures, and human error (see SURVIAC-TR-12-169 and MIL-STD-882). System hazard analysis and a hazard tracking log should be used to identify and categorize initial causes and contributing factors. Software-related hazards may occur as a result of software defects that are activated during the execution of input causing erroneous system behavior, from inaccurate information displayed to the user by the software leading to incorrect input, or due to weak safety features that fail to detect incorrect user input. This section focuses on the mitigation of system hazards associated with the interface between the user and software.

5.7.19.2 Process cancellation.

5.7.19.2.1 Cancel current process. The software shall cancel current processing with a single-user action and have the system revert to a designed safe state.

5.7.19.2.2 Reaction time. Where operator reaction time is not sufficient to prevent a mishap, the software shall revert the system to a known safe state, report the failure, and report the system status to the operator.

5.7.19.3 Hazardous function initiation.

5.7.19.3.1 Two or more actions. The system shall require two or more unique operator actions in order to initiate any potentially hazardous function or sequence of functions.

5.7.19.3.2 Inadvertent actuation. The actions required shall minimize the potential for inadvertent actuation and shall be checked for proper sequence. Refer to separation distances for specific control types in 5.1.3 and 5.1.4.

5.7.19.4 Safety-critical displays. Safety-critical operator displays, legends, and other interface functions should be clear, concise, and unambiguous and, where possible, be duplicated using separate display devices.

5.7.19.5 Operator entries.

5.7.19.5.1 Positive confirmation. The software shall provide positive confirmation of valid data entry or actions taken (i.e., the system shall provide visual or aural feedback to the operator such that the operator knows that the system has accepted the action and is processing it).

5.7.19.5.2 Real-time indication. The system shall provide a real-time indication that it is functioning.

5.7.19.5.3 Status indication. Processing functions with delays of 2 seconds or longer shall require a status indicator to the operator during processing.

5.7.19.5.4 Operator entry errors.

5.7.19.5.4.1 Improper operator entries. The software shall be capable of detecting improper operator entries or sequences of entries or operations (so as to prevent execution of safety-critical functions) (see 5.1.2.1.7).

5.7.19.5.4.2 Alert the operator. The software shall alert the operator to the erroneous entry or operation and indicate the error and corrective action.

5.7.19.6 Safety-critical alerts.

5.7.19.6.1 Distinguish from routine alerts. Routine alerts shall be coded visually, audibly, or both in a different manner than safety-critical alerts.

5.7.19.6.2 Clear a safety-critical alert. The operator shall not be able to eliminate a safety-critical alert without taking corrective action or performing subsequent actions required to complete the ongoing operation.

5.7.19.6.3 Unsafe situation alerts. The system shall provide signals alerting the user to unsafe situations via the user interface.

5.7.19.7 Safety-critical timing.

5.7.19.7.1 Computer control. Safety-critical timing functions shall be controlled by the computer rather than relying on human input.

5.7.19.7.2 Not modifiable by operator. The system shall prevent the operator from modifying safety-critical timing values from system consoles, unless specifically required by the system design and in accordance with approval protocols.

5.7.20 Health hazards. Risk evaluation should be conducted by a process consistent with MIL-STD-882, Task 207 (Health Hazard Assessment) or other recognized process standard such as Army Regulation 40-10. Specific health hazards identified should be eliminated. When hazards cannot be eliminated, they should be controlled using the hierarchy of controls approach. Engineering design changes that eliminate the identified health hazard are the most effective means and the best approach to eliminate health hazards. Specific health hazards and impacts that should be considered in any assessment include:

a. Chemical hazards (e.g., materials that irritate or are hazardous because of physical properties such as flammability, toxicity, carcinogenicity, or propensity to deprive an organism of oxygen).

b. Physical hazards (e.g., acoustical energy, vibration, radiation, acceleration and deceleration, barostress, and heat or cold stress).

c. Biological hazards (e.g., bacteria, viruses, fungi, and mold).

d. Ergonomic hazards (e.g., hazards that occur as a consequence of engaging in activities that impose excessive physical or cognitive demands, such as assuming non-neutral postures, sustaining harsh body contacts or load-bearing stress, performing taxing muscular exertions, or sustaining long duration activity).

e. Other hazardous or potentially hazardous materials that may be formed by the test, maintenance, operation, or final disposal or recycling of the system.

5.8 Anthropometric accommodation.

5.8.1 General. Required tasks for anthropometric accommodation are defined in 3.2.4.

5.8.2 Target populations.

5.8.2.1 Full range of personnel. The target user population and percentage of that population to be accommodated shall be as defined in the system specification.

5.8.2.1.1 Systems, equipment, and facilities. Systems, equipment (including life support and emergency escape), and facilities used by operators, maintainers, and supporters shall be designed for full use by the range of personnel with applicable operational clothing, protective clothing, and specialized equipment.

5.8.2.1.2 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 the size range of using personnel.

5.8.2.2 Regular populations. The population(s) to be accommodated, including operators, maintainers, and support personnel, shall include both genders of applicable military, non-military, and foreign military personnel.

5.8.2.3 Special populations. Where equipment will be used exclusively by selected or specialized segments of the population, the characteristics of the sub-population may be used in lieu of the requirements in 5.8.4 if specified (see 6.2).

5.8.2.3.1 Gender-specific populations. Systems, equipment, and facilities intended for use by one gender only may limit the population to males or females only in lieu of the requirements in 5.8.4 if specified (see 6.2).

5.8.2.3.2 Foreign military personnel. For systems, equipment, and facilities intended for use by foreign military personnel, the characteristics of the population to be accommodated may be used in lieu of the requirements of 5.8.4 if specified (see 6.2).

5.8.2.3.3 Joint service personnel. For systems, equipment, and facilities intended for use by joint service personnel, the characteristics of the population to be accommodated may be used in lieu of the requirements of 5.8.4 if specified (see 6.2).

5.8.2.3.4 Mixed populations. Where equipment may be used by a variety of sub-populations, each sub-population shall be afforded the population accommodation as specified (see 6.2).

5.8.3 Design limits.

5.8.3.1 General. Unless otherwise specified (see 6.2), the design of DoD systems, equipment, and facilities shall accommodate the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped males of the target user population and the multivariate central 90 percent (95 percent preferred) of the suitably clothed and equipped females of the target user population using dimensions applicable to the tasks (see 3.2.10).

5.8.3.2 Life-critical systems and equipment. Unless otherwise specified (see 6.2), for systems and equipment that are life-critical (e.g., accessibility of safety interlocks, clearances for ejection seats, fit of gas masks), the design for all physical factors (size, shape, weight, reach, strength, and endurance) shall accommodate the multivariate central 99 percent of suitably clothed and equipped males of the target user population and the multivariate central 99 percent of suitably clothed and equipped females of the target user population using dimensions applicable to the tasks (see 3.2.10).

5.8.4 Anthropometric design.

5.8.4.1 General. Designers shall use the appropriate anthropometric data and should take advantage of technologies and capabilities, such as human figure modeling and three-dimensional body scans, to obtain measurement, size, shape, and volumetric data to meet requirements in 5.8.3.

5.8.4.2 Use of anthropometric data. The application of anthropometric data shall consider the following information:

a. The nature, frequency, safety, and difficulty of the tasks to be performed by the user.

b. The position(s) of the body during performance of the tasks.

c. Mobility, strength, or flexibility requirements imposed by the tasks.

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

5.8.4.2.1 Safety and health considerations. Where design limits based on safety and health considerations are more demanding than performance and accommodation criteria, the safety and health considerations shall be satisfied.

5.8.4.2.2 Anthropometric databases. As specified (see 6.2), the appropriate anthropometric database(s) shall be used for anthropometric dimensions and three-dimensional body scan data. Designers should utilize the most current sources of anthropometric data from their target population, which may be more recent than the sources listed below.

a. Army. NATICK/TR-15/007 and NATICK/TR-16/013.

b. Air Force. AFRL-RH-WP-TR-2014-0113.

c. Marine Corps. NATICK/TR-13/018.

d. Additional anthropometric data may be found in DOD-HDBK-743. These data should be used only in cases where the most recent service-specific anthropometric sources above prove to be inadequate. In some cases, it may be more appropriate to derive new anthropometric data empirically.

5.8.4.2.3 Clothing and equipment considerations. Because the above-cited anthropometric data represent semi-nude body measurements, adjustments in design-critical dimensions shall be made for all applicable clothing and equipment, such as uniforms, helmets, boots, body armor, load carrying equipment, protective equipment, hydration packs, and other worn or carried items. Additional appropriate factors to be added to dimensions can be found in NATICK/TR-14/019. If the appropriate factor is not available in NATICK/TR-14/019, designers shall derive it empirically.

5.8.4.2.4 Clearance dimensions. Clearance dimensions (e.g., minimum dimensions for passageways and accesses) shall accommodate or allow passage of the body or parts of the body, including applicable clothing and equipment.

5.8.4.2.5 Adjustable dimensions. Seats, restraint systems, safety harnesses, belts, controls, or any equipment that must be adjusted for the safety, comfort, or performance of the individual user shall be adjustable for the range of personnel using them to include any clothing and equipment they may be wearing.

5.8.4.2.6 Accounting for human variability. Anthropometric dimension percentiles are not additive, and appropriate accommodation of one dimension does not guarantee equal accommodation for any other. Most designs require simultaneous accommodation of multiple dimensions as well as accounting for size and shape variability. In these cases, designers shall utilize other appropriate anthropometric methods. Several viable methods are discussed in detail in AFRL-HE-WP-TR-2007-0016. Topical areas include:

a. Jointed or multivariate distributions of all relevant design variables.

b. Multivariate dimension reduction techniques such as principal component analysis.

c. Development of “boundary cases” on a multivariate accommodation envelope that represent the most limiting combination of dimensions.

d. Development of 3-D digital human models that represent multivariate "boundary cases" for use in appropriate modeling software.

e. Development of parametric accommodation models.

f. Morphometric or shape analyses on the corresponding vertices of a 3-D template matched to a database of 3-D human segment scans in order to quantify and visualize design relevant size and shape variation.

5.8.4.3 Range of motion. Design of systems shall not require operators, maintainers, and supporters to exceed human range of motion limitations. Table XXXI gives the range of motion the body can make, in angular degrees, for a selection of voluntary movements as illustrated on figure 55. The designer should be aware of the following:

a. The upper and lower limits reported in table XXXI are one standard deviation above and below the mean value recorded, respectively. These are upper and lower limits measured with semi-nude personnel, and therefore do not reflect the restrictions that clothing and protective equipment would impose.

b. These data originate from WADC-TR 55-159 and WADC-TN-57-311. These studies are not considered recent and included only male participants; therefore, they may not be appropriate to represent the current military population.

c. Other sources of range of motion data should be considered to include NATICK/TR-17/010 and NATICK/TR-13/033.

d. These data sources are limited. If the appropriate data are not available, designers shall derive them empirically.

TABLE XXXI. Range of human motion.

Body Member Movement		**Lower Limit (Degrees) (Mean – One SD)**	**Upper Limit (Degrees) (Mean + One SD)**
A. Shoulder	1. Flexion	176	190
	2. Extension	47	75
	3. Lateral rotation	21	47
	4. Medial rotation	75	119
	5. Horizontal adduction	39	57
	6. Horizontal abduction	117	151
B. Elbow	1. Flexion	132	152
C. Forearm	1. Supination	91	135
	2. Pronation	53	101
D. Wrist	1. Flexion	78	102
	2. Extension	86	112
	3. Ulnar deviation	40	54
	4. Radial deviation	18	36
	5. Wrist carry angle	95	109
E. Hip	1. Flexion	100	126
	2. Adduction (supine)	19	43
	3. Abduction (supine)	41	65
	4. Abduction (standing)	16	30
	5. Adduction (standing)	15	33
	6. Lateral rotation (prone)	24	44
	7. Medial rotation (prone)	29	49

TABLE XXXI. Range of human motion – Continued.

Body Member Movement		**Lower Limit (Degrees) (Mean – One SD)**	**Upper Limit (Degrees) (Mean + One SD)**
E. Hip (Cont.)	8. Medial rotation (sitting)	22	40
	9. Lateral rotation (sitting)	21	39
F. Knee	1. Flexion (prone)	115	135
	2. Flexion (standing)	100	126
	3. Flexion (kneeling)	150	168
	4. Lateral rotation	31	55
	5. Medial rotation	23	47
G. Ankle	1. Posterior tibial angle	26	50
	2. Anterior tibial angle	28	42
H. Neck	1. Extension (backward)	44	88
	2. Flexion (forward)	48	72
	3. Lateral flexion (right)	34	48
	4. Lateral flexion (left)	34	48
	5. Rotation (right)	65	93
	6. Rotation (left)	65	93

NOTES:

1. Refer to 5.8.4.3 for detailed limitations of these data.
2. Flexion: Bending or decreasing the angle between parts of the body.
3. Extension: Straightening or increasing the angle between parts of the body.
4. Adduction: Moving toward the midline of the body.
5. Abduction: Moving away from the midline of the body.
6. Medial rotation: Turning toward the midplane of the body.
7. Lateral rotation: Turning away from the midplane of the body.
8. Pronation: Rotation of the palm of the hand downward.
9. Supination: Rotation of the palm of the hand upward.
10. Radial deviation: Hand moving toward radius (bone).
11. Ulnar deviation: Hand moving toward ulna (bone).
12. Plantar flexion: Movement that increases angle between the foot and leg.
13. Dorsi flexion: Movement that decreases the angle between the foot and leg.
14. Tibial angle (posterior and anterior) is relative to a reference line formed at a right angle to the base of the foot.

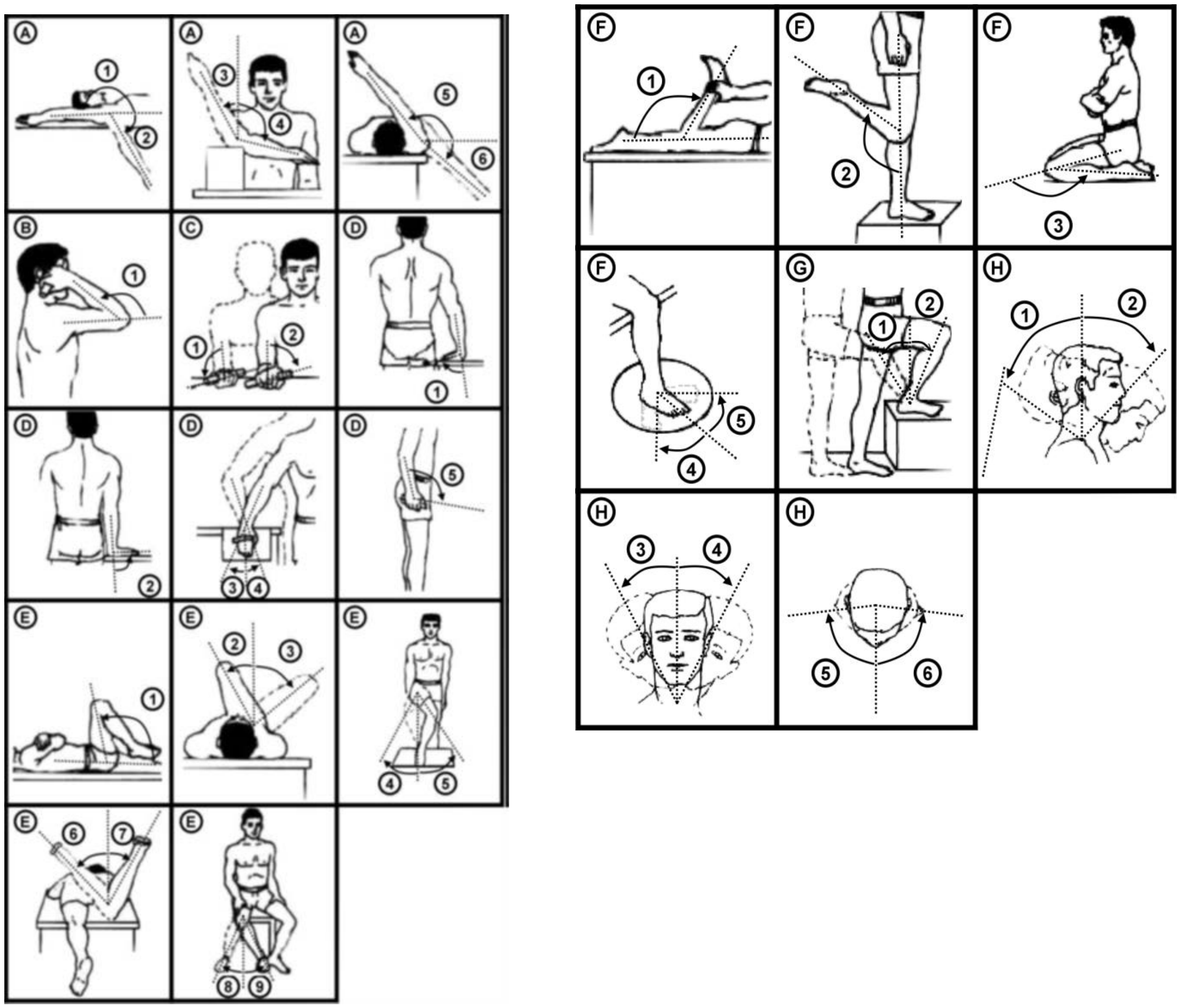


FIGURE 55. Range of human motion.

5.8.4.4 Body movement.

5.8.4.4.1 Trunk movement. All operating positions shall allow enough space for the user to move their torso without interference through any potential action.

5.8.4.4.2 Whole body movement. When large forces (more than 13.6 kg [30 lb)]) or large control displacements (more than 380 mm [15 in] in a fore-aft direction) are required, the user shall have enough space to move their entire body.

5.9 Design for maintainability.

5.9.1 General. Quite often, an operator, driver, crewmember, or supporter may perform a task that is generally considered to be a maintenance-associated task (e.g., changing a flat tire, filling fluid levels). For the purpose of this standard, when performing a maintenance-associated task, all the requirements herein that apply to the maintainer shall also apply to all other personnel.

5.9.1.1 Minimize skill and training requirements. Equipment should be designed to minimize skills and training requirements of maintenance personnel.

5.9.1.2 Minimize material deterioration. Materials should be selected and equipment designed to minimize material deterioration due to environmental extremes.

5.9.1.3 Minimize corrosion effects. Equipment should be designed to minimize corrosion and its effects.

5.9.1.3.1 Corrosion-resistant materials. Corrosion-resistant materials and materials that reduce negative environmental impacts should be used.

5.9.1.3.2 Mechanically fastened joints. Mechanically fastened joints should be supplemented with anti-seize, non-metallic washers and sleeves or strippable coatings to enhance corrosion resistance as appropriate.

5.9.1.3.3 Ferrous parts. Ferrous parts that are susceptible to corrosion and used internally in instruments should be appropriately plated. Phosphate finishes (especially where not oiled) do not provide sufficient protection and should not be used.

5.9.1.4 Standard parts. Standard parts shall be used to the maximum extent possible (standardizing mounting hardware, fasteners, electrical/hydraulic/pneumatic/data, and other connections) to reduce the training required for maintainers and reduce Mean Time to Repair (MTTR).

5.9.1.4.1 Parts selection. Off-the-shelf parts selected shall meet the human engineering criteria contained within this standard.

5.9.1.5 Modular replacement. When possible, equipment shall be designed to be replaced as modular packages.

5.9.1.5.1 Removal of modular components. Grasp areas or handles shall be incorporated into any design where equipment or components are located such that full muscular strength cannot be applied (e.g., confined spaces, extended reach, or awkward positioning) or where equipment or components are heavier than 25 lbs.

5.9.1.5.2 Mechanical lifting assists. Where equipment or components without grasping or anchor points cannot be avoided, provision shall be made for mechanical lifting assists, and access for such support equipment shall be incorporated in the design.

5.9.1.5.3 Ease of removal. Equipment shall be configured for removal and replacement by one person where permitted by structural, functional, and weight limitations (see 5.20.3).

5.9.1.6 Removal and replacement of stowed items. Stowed items shall be capable of being removed and replaced without having to remove or replace other stowed items or components of the system.

5.9.1.6.1 Mission-critical items. Mission-critical maintenance items shall be stowed in a manner to permit rapid access by personnel.

5.9.1.6.2 Retaining devices. Retaining devices shall be simple, capable of quick removal and replacement, and not require the use of tools. Retaining devices should be standardized across as many items of equipment as possible.

5.9.1.6.3 Retaining device attachment. Retaining devices shall be attached to either the stowage space or the stowed item to prevent loss.

5.9.1.6.4 Drainage. All stowage locations should be designed to drain when the system is on level ground. Drain holes should be arranged so that they will not be blocked by normal stowage, mud, or debris.

5.9.1.6.5 Flammable items. Items that are flammable or subject to damage by leakage of lubricants, fuels, or water should be stowed in a manner to protect them as well as personnel.

5.9.1.7 Operational environment. Equipment shall be capable of being removed, replaced, repaired, assembled, and disassembled in its operational environment by personnel wearing any clothing and equipment appropriate to the environment and maintenance concept, including CBRNE or other mission-required PPE clothing.

5.9.1.8 Error-proof design. Designs shall incorporate error-proofing measures in equipment mounting, installing, interchanging, connecting, and operating.

5.9.1.8.1 Physical features. Equipment shall include physical features (e.g., supports, guides, size or shape differences, fastener locations, alignment pins) to preclude improper mounting.

5.9.1.8.2 Same form and function. Equipment that has the same form and function shall be interchangeable throughout a system and related systems.

5.9.1.8.3 Different form and function. If equipment is not interchangeable functionally, it shall not be interchangeable physically.

5.9.1.8.4 Prevent damage to equipment. Design, location, procedural guidance, and warning labels shall be provided to prevent damage to equipment while it is being handled, installed, operated, or maintained.

5.9.1.9 Ease of access.

5.9.1.9.1 Complete visual and physical access. Insofar as possible, equipment design and installation shall provide the maintainer with complete visual and physical access and a favorable working level for all parts of a system on which maintenance is performed, including workstand interfaces, support equipment interfaces, access openings, adjustment points, test points, servicing points, and connections.

5.9.1.9.2 Connections. Connections shall be arranged by equipment design or installation layout to provide the maintainer ready and functional access. Speed and accuracy of making or removing connections as well as the reliability of the connectors themselves should be a consideration in selection of the connection type.

5.9.1.10 Safety. Emergency shutdown devices, lockable controls, electrical cutout switches, warning signs, or guards shall be used to ensure safety of personnel when it is necessary to perform maintenance on or near a live or working system.

5.9.1.11 Delicate items. Items susceptible to maintenance-induced damage, (e.g., rough handling, static electricity, abrasion, contamination) shall be clearly identified and physically and procedurally guarded from abuse.

5.9.1.12 Work from ladders. Items to be maintained from a ladder shall require only one hand.

5.9.1.13 Maintenance of elevated structures. Maintenance on antennae, masts, lights, and other elevated structures shall be performed from a permanent or temporary work platform, vertical ladder with a hands free climber safety rail, work basket supported by a crane, another stable standing surface, or by using anchor points, a safety lanyard, and a safety harness.

5.9.1.14 High-speed applications. In high-speed applications, mating gears should be of materials having dissimilar wear characteristics.

5.9.1.15 Backlash and torque lash. Backlash and torque lash should be minimized. The effects of backlash and lost motion should be taken into consideration in the selection or design of movable parts.

5.9.1.16 Arc flash hazards. Where arc flash hazards may exist, their potential strength shall be calculated in accordance with NFPA 70 (see also 5.7.8).

5.9.1.16.1 Protective equipment. Requirements for protective equipment shall be determined using the Incident Energy Analysis Method specified in NFPA 70.

5.9.1.16.2 Isolation switches. Where feasible, isolation switches shall be located outside of the arc flash boundary.

5.9.1.16.3 Diagnostic methods. Diagnostic methods for remote fault detection, such as infrared visualization, shall be implemented unless specific well-documented technical requirements prevent such controls.

5.9.1.17 Task times. Guidance on representative task times for many maintenance-associated activities can be found in MIL-HDBK-472.

5.9.2 Mounting of items within units.

5.9.2.1 General. Maintenance required on a given unit or components should be able to be performed with the unit or component in place, where possible, and without disconnection, disassembly, or removal of other items.

5.9.2.1.1 Accessibility of components. Components should be arranged and located to provide rapid access to those components with lower reliability and those that have been found to require greater maintenance or whose failure would critically degrade operational availability or system reliability.

5.9.2.1.2 Removal of functioning components or parts. It should not be necessary to remove a part or component that is functioning to remove, repair, or maintain a part or component that is not functioning.

5.9.2.1.3 Components maintained by the same individual. Components maintained by the same individual should be grouped together to minimize moving from position to position during system checking.

5.9.2.1.4 Frequent access. Components that require frequent access for visual inspection, check points, adjustment points, cable-end connectors, and labels shall be located in positions that can be easily viewed.

5.9.2.1.5 Safety. All components shall be located to minimize the possibility of equipment damage or personnel injury.

5.9.2.2 Stacking avoidance. Whenever possible, units shall not be stacked.

5.9.2.2.1 Mounted in an array. Whenever possible, parts shall be mounted in an orderly array on a "two-dimensional" surface, rather than stacked (i.e., a lower layer not supporting an upper layer) so subassemblies do not have to be removed to access other subassemblies within the equipment.

5.9.2.2.2 Stacking necessary. If stacking is necessary because of space limitations, the unit requiring the least frequent access shall be placed in the back or on the bottom.

5.9.2.3 Similar items. Similar items shall utilize a common mounting design and orientation within the unit. This mounting design shall preclude the interchange of items that are not functionally interchangeable.

5.9.2.4 Symmetrical components. Symmetrical components should be coded, labeled, or keyed to indicate the proper orientation for mounting or installation.

5.9.2.5 Hinge-mounted units. Small hinge-mounted units that require access to the back shall be free to open their full distance. These units shall also be capable of remaining open without being held.

5.9.2.6 Frames and structural members. Frames and structural members shall not interfere with personnel accessing components for maintenance, inspection, or operation.

5.9.3 Mounting.

5.9.3.1 Improper mounting. Improper mounting shall be precluded either through equipment configuration or mounting design.

5.9.3.2 Tools. Removal and replacement should require minimal tools and equipment and only common hand tools where practicable.

5.9.3.3 Removal. Replaceable items, particularly disposable modules, should be removable without removal or disassembly of other items or units and along a straight or slightly curved line rather than through an angled course.

5.9.3.3.1 Heavy, large, or awkward units. Heavy, large, or awkward units should be located so they may be slid out or pulled out rather than lifted out, do not prevent access to other removable items, and are mounted on sliding drawers and racks wherever practicable.

5.9.3.3.2 Structural members. Structural members of items, chassis, or enclosures shall not prevent access to removable items, their connectors, or fasteners.

5.9.3.3.3 Accomplished by one person. Removal and replacement should be accomplished by one person, two persons, or handling equipment, in that order of preference.

5.9.3.3.4 Extensions on unit. Fragile or awkward extensions, such as cables and hoses, that can be damaged or make handling difficult should be easily removable before the unit is handled.

5.9.3.4 Alignment. Items that must be precisely located or incorporate rack and panel connectors shall have guide pins, or their equivalent, to assist in alignment during mounting.

5.9.3.4.1 Bottom-mounted aligning pins. Bottom-mounted aligning pins should be used for components weighing less than 9 kg (20 lb).

5.9.3.4.2 Side-aligning devices. Side-aligning devices or brackets should be used for heavier components (over 9 kg [20 lb)]) so the components can be slid rather than lifted into and out of place.

5.9.3.5 Labeling and coding. Where an item can be mounted and oriented any way other than intended, proper mounting and orientation shall be indicated by labels or a type of coding (e.g., color).

5.9.3.6 Rollout racks, slides, or hinges. Items that are pulled out of their installed positions shall be mounted on rollout racks, slides, or hinges.

5.9.3.6.1 Center of gravity. Rollout racks pulled to the fully extended position shall not shift the center of gravity to the point where the rack or console becomes unstable.

5.9.3.6.2 Pull-out or slide-out racks. Pull-out or slide-out racks and drawers shall be designed such that:

a. They operate with a force less than 17.8 newtons (4 pounds-force).

b. They automatically lock in both servicing and operating positions.

c. Handles are provided, as necessary, to facilitate operation and handling.

d. Assemblies may be opened without breaking internal connections necessary for required maintenance.

e. Guards and shields are provided, as necessary, to prevent damage to fragile or sensitive parts when the assembly is moved.

5.9.3.6.3 Service loops. Equipment items mounted on pull-out or slide racks should be fitted with service loops (cabling slack) that allow the rack to be moved to the servicing position prior to disconnecting any equipment connectors.

5.9.3.7 Limit stops. Limit stops shall be provided on racks and drawers that are required to be pulled out of their installed positions.

5.9.3.7.1 Override. The limit stop design shall permit convenient overriding of stops for rack or drawer removal.

5.9.3.7.2 Self-locking. Rollout racks and drawers shall be self-locking in the retracted and extended positions.

5.9.3.8 Interlocks. Interlocks shall be provided to ensure disconnection of equipment that might otherwise be damaged by withdrawal of racks or drawers.

5.9.3.9 Hinged mounting. Hinged items shall be provided with a brace or other means of support to hold the item in the "out" position for maintenance if it is not free to rotate and remain in the "out" position without support.

5.9.3.10 Layout. Units shall be laid out so that a minimum of place-to-place movements will be required during checkout.

5.9.3.11 Handling.

5.9.3.11.1 Removable components. Removable components to be handled by one person should weigh less than 13.6 kg, with 30 lb preferred, and shall weigh less than 20.5 kg (45 lb) maximum.

5.9.3.11.2 Heavy components. Whenever possible, heavier components shall be placed so they are the easiest to reach and can be slid out rather than lifted out.

5.9.3.11.3 Difficult-to-reach items. Difficult-to-reach items shall weigh less than 11.3 kg (25 lb).

5.9.3.11.4 Two-person lift. Items weighing over 20.5 kg (45 lb) shall be located for two-person handling.

5.9.3.11.5 Hoist lugs. Hoist lugs should be provided for assemblies over 40.8 kg (90 lb).

5.9.3.12 Covers or panels. The number of covers and panels that must be opened or removed to access a replaceable item shall be minimized.

5.9.3.13 Test probes. Space should be provided for use of test probes and other service or test equipment.

5.9.3.14 Favorable working level. Components to be serviced or repaired should be located at the most favorable working level, generally between hip and shoulder level.

5.9.3.15 Mounted containers. Mounted containers and supports should drain and prevent entrapment of mud, grass, or debris.

5.9.3.16 Faying surfaces. Mounts should avoid mechanically fastened faying surfaces, unless separation or sealing of the surfaces is provided by non-metallic washers or sealants.

5.9.4 Unit design for efficient handling.

5.9.4.1 Rests and stands.

5.9.4.1.1 Provide rests or stands. When required for maintenance tasks, rests or stands shall be provided for holding units, test equipment, tools, and technical manuals.

5.9.4.1.2 Part of basic unit. When permitted by design requirements, such rests or stands shall be part of the basic unit, rack, or console chassis.

5.9.4.2 Extensions. Extensions and connected appurtenances, accessories, utilities, cables, hoses, and similar items shall not interfere with removing, replacing, or carrying an item.

5.9.4.2.1 Interference. If such extensions and connected appurtenances interfere with the above tasks, they shall be easily removed or disconnected from the item before handling.

5.9.4.2.2 Disconnects. Disconnects shall consist of hand-operable quick disconnects or standard hand tool operable disconnects, in that order of preference.

5.9.5 Adjustment controls. Controls required for maintenance purposes shall comply with the basic control design requirements (see 5.1) and labeling requirements (see 5.4).

5.9.5.1 Separate adjustability. It shall be possible to individually check and adjust each item or function of an item.

5.9.5.2 Knob adjustments. Knobs, rather than screwdriver controls, shall be used whenever adjustments must be performed more often than once per month and where access, weight, and related considerations permit their use.

5.9.5.3 Screwdriver adjustments. Screwdriver adjustments made without visual access shall be used only if mechanical guides are provided to align the screwdriver.

5.9.5.4 Screw travel. Screw travel shall be limited to prevent the screw from falling out of its intended position.

5.9.5.5 Reference scale for adjustment controls. A scale or other appropriate reference shall be provided for all adjustment controls.

5.9.5.6 Reference scales visibility. Reference scales shall be readily visible to the person making the adjustment.

5.9.5.7 Mirrors or flashlights. Mirrors or flashlights shall not be required for adjustments.

5.9.5.8 Control limits. Calibration or adjustment controls that are intended to have a limited degree of motion shall have mechanical stops strong enough to prevent damage by a force or torque 100 times greater than the resistance to movement within the range of adjustment.

5.9.5.9 Critical controls. Critical and sensitive adjustment controls shall incorporate features to prevent inadvertent or accidental actuation.

5.9.5.10 Locking device. Operating any locking device used to prevent inadvertent actuation shall not change the adjustment setting.

5.9.5.11 Hand or arm support. Where maintenance personnel are subjected to disturbing vibrations or acceleration during the adjustment operation, hand or arm support shall be provided to facilitate making the adjustment.

5.9.5.12 Hazardous locations. Adjustment controls shall not be located within 300 mm (12 in) of unprotected dangerous voltages, moving machinery, or any other hazards.

5.9.5.13 Shielded and labeled. If hazardous locations cannot be avoided, the adjustment controls shall be shielded and labeled to protect maintenance personnel.

5.9.6 Access and accessibility.

5.9.6.1 Structural members. Structural members or permanently installed equipment shall not visually or physically obstruct any required maintenance tasks.

5.9.6.1.1 Panels, cases, and covers. Panels, cases, and covers that have to be removed in order to access equipment shall have the same access requirements as the equipment to be maintained.

5.9.6.1.2 Mounting provisions. Mounting provisions shall be directly visible and physically accessible to maintenance personnel.

5.9.6.2 Large items. Large items that are difficult to remove shall be located so that they will not prevent convenient access to other items.

5.9.6.3 Use of tools and test equipment.

5.9.6.3.1 Accessibility. Check points, adjustment points, test points, cables, connectors, and labels shall be accessible and visible during maintenance.

5.9.6.3.2 Sufficient space. Sufficient space shall be provided for the use of test equipment and other required tools without difficulty or hazard.

5.9.6.4 Rear access. Sliding, rotating, or hinged equipment to which rear access is required shall be free to open or rotate their full distance and remain in the open position without being supported by hand.

5.9.6.5 Relative accessibility.

5.9.6.5.1 Mission-critical items. Mission-critical items that require rapid maintenance shall be the most accessible.

5.9.6.5.2 Frequent access. When criticality is not a factor, items that require the most frequent access shall be the most accessible.

5.9.6.5.3 High failure rate items. High failure rate items shall be accessible for replacement without having to move non-failed items.

5.9.6.6 Workspace.

5.9.6.6.1 Workspace features. The workspace shall allow maintenance personnel to change their body positions if the task requires kneeling, crawling, or crouching for prolonged periods of time.

5.9.6.6.1.1 Protection against potential hazards. Protection shall be provided against any potential hazards that might exist while maintenance personnel are performing their tasks.

5.9.6.6.1.2 Features to assist personnel. Auxiliary hooks, holders, lights, outlets, non-skid treads, expanded metal flooring, or abrasive coating on surfaces used for walking, climbing, or footholds shall be provided at the workstation to assist maintenance personnel in performing their jobs, as appropriate.

5.9.6.6.1.3 Non-skid surfaces. Top surfaces of equipment shall be reinforced and provided with non-skid surfaces whenever they are used as work platforms.

5.9.6.6.2 Visual inspection. Items requiring visual inspection shall be located so maintenance personnel can see them without removing panels or other components.

5.9.6.7 Access.

5.9.6.7.1 Access to components and equipment. Access shall be provided to all components and equipment, points, items, units, and components that require testing, calibrating, servicing, adjusting, removing, replacing, and repairing.

5.9.6.7.2 Access openings. Access openings shall be large enough to accommodate hands, arms, and tools; provide full visual access to the task area; and be free of personnel hazards, such as sharp edges and hot surfaces.

5.9.6.7.3 Access considerations. The type, size, shape, and location of accesses (see figure 56) shall be based on a thorough understanding of the following considerations:

a. Operational location, setting, and environment of the system.

b. Frequency of use.

c. Maintenance tasks performed through the access and the intricacy of the tasks.

d. Time required to perform maintenance functions.

e. Tools and accessories required to perform maintenance functions.

f. Workspace required.

g. Type of clothing likely to be worn by maintenance personnel.

h. Necessary access reach.

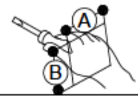
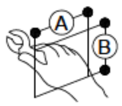
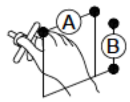
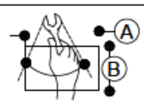
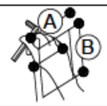
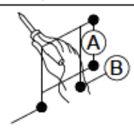
i. Visual requirements and the intricacy of the tasks.

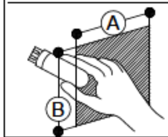
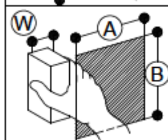
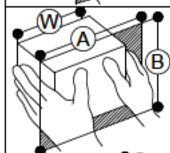
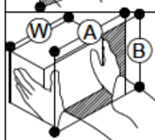
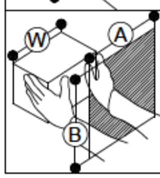
j. Packaging of items and elements behind the access.

k. Mounting of items, units, and elements behind the access.

l. Hazards in using the access.

m. Size, shape, weight, and clearance requirements for logical combinations of human appendages, tools, and items that will enter the access.

OPENING DIMENSIONS	DIMENSIONS (MM) A	DIMENSIONS (MM) B	TASK
	110	120	USING COMMON SCREWDRIVER, WITH FREEDOM TO TURN HAND THROUGH 180°.
	130	115	USING PLIERS AND SIMILAR TOOLS.
	135	155	USING "T" HANDLE WRENCH, WITH FREEDOM TO TURN HAND THROUGH 180°.
	270	200	USING OPEN-END WRENCH, WITH FREEDOM TO TURN WRENCH THROUGH 60°
	120	155	USING ALLEN-TYPE WRENCH WITH FREEDOM TO TURN WRENCH THROUGH 60°
	90	90	USING TEST PROBE.

OPENING DIMENSIONS	DIMENSIONS (MM) A	DIMENSIONS (MM) B	TASK
	110	120	GRASPING SMALL OBJECTS (UP TO 50MM WIDE) WITH ONE HAND.
	W + 45	125*	GRASPING LARGE OBJECTS (50MM OR MORE WIDE) WITH ONE HAND.
	W + 75	125*	GRASPING LARGE OBJECTS WITH TWO HANDS, WITH HANDS EXTENDED THROUGH OPENINGS UP TO FINGERS.
	W + 150	125*	GRASPING LARGE OBJECTS WITH TWO HANDS, WITH ARMS EXTENDED THROUGH OPENINGS UP TO WRISTS.
	W + 150	125*	GRASPING LARGE OBJECTS WITH TWO HANDS, WITH ARMS EXTENDED THROUGH OPENINGS UP TO ELBOWS.

*** 125MM OR THE HEIGHT OF THE OBJECT + 50MM (WHICHEVER IS GREATER)**

FIGURE 56. Access opening dimensions.

5.9.6.8 Physical access. Physical access designs shall meet the criteria in 5.9.6.8.1 through 5.9.6.8.5.

5.9.6.8.1 Physical space. Physical space shall be designed into and within the system and equipment so that accessibility for all required maintenance activities is provided for the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped males of the maintainer population and the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped females of the maintainer population using dimensions applicable to the task.

5.9.6.8.2 Body postures. Where maintenance tasks require the assumption of various body postures, the access opening and the physical space requirements for these body postures shall be provided in accordance with 5.10.

5.9.6.8.3 Maintenance from above and outside. Whenever possible, equipment design shall permit maintenance from above and outside rather than from underneath or inside components.

5.9.6.8.4 Space. Floor space of 0.4 square meters (m^2) (4.0 square feet [ft^2]) minimum per person shall be provided for maintenance personnel and their clothing (including required PPE, tools, and equipment) as well as free space for the movements and activities required to perform maintenance tasks.

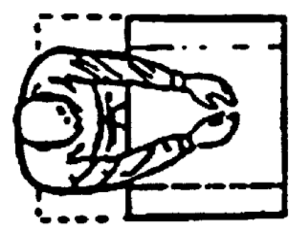
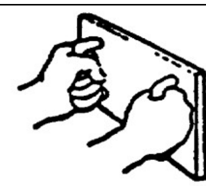
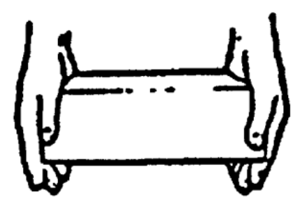
5.9.6.8.5 Working space. When maintenance requires the removal of large internal parts, the working space provided shall accommodate the maintenance personnel performing the task, the physical size of the removed component, and any laydown area needed for the component, tools, or equipment.

5.9.6.9 Arm and hand access. Arm and hand access designs shall meet the criteria in 5.9.6.9.1 through 5.9.6.9.4.

5.9.6.9.1 Location and size. Openings provided for access shall be located and sized to permit the required adjustment or handling.

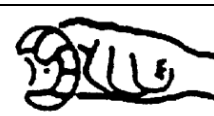
5.9.6.9.2 Viewing. Openings shall provide a view of the item being manipulated.

5.9.6.9.3 Reach access dimensions and shape. The dimensions of arm and hand access openings shall be not less than those shown on figure 57.

Minimal Two-Hand Access Opening without Visual Access			
Reaching with Both Hands to Depth of 150 to 490 mm (6 to 20 in):			
Light clothing:	Width:	200 mm (8 in) or the depth of reach [1/]	
	Height:	125 mm (5 in)	
Arctic clothing:	Width:	150 mm (6 in) plus ¾ the depth of reach	
	Height:	180 mm (7 in)	
Reaching Full Arm's Length (to Shoulders) with Both Arms:			
	Width:	500 mm (20 in)	
	Height:	125 mm (5 in)	
Inserting Box Grasped by Handles on the Front:			
13 mm (0.5 in) clearance around box, assuming clearance around handles			
Inserting Box with Hands on the Sides:			
Light clothing:	Width:	Box plus 115 mm (4.5 in)	
	Height:	125 mm (5 in) or 13 mm (0.5 in) around box [1/] [2/]	
Arctic clothing:	Width:	Box plus 180 mm (7 in)	
	Height:	215 mm (8.5 in) or 15 mm (0.6 in) around box [1/] [2/]	

Minimal One-Hand Access Opening without Visual Access			
	Height	Width	
Empty Hand, to Wrist:			
Bare hand, rolled	95 mm (3.75 in) sq or dia		
Bare hand, flat	55 mm (2 in)	100 mm (4 in) or 100 mm (4 in) dia	
Glove or mitten	100 mm (4 in)	150 mm (6 in) or 150 mm (6 in) dia	
Arctic mitten	125 mm (5 in)	165 mm (6.5 in) or 165 mm (6.5 in) dia	

FIGURE 57. Arm and hand access dimensions.

Minimal One-Hand Access Opening without Visual Access (cont.)			
	Height	Width	
Clenched Hand, to Wrist			
Bare hand	95 mm (3.75 in)	125 mm (5 in) or 125 mm (5 in) dia	
Glove or mitten	115 mm (4.5 in)	150 mm (6.0 in) or 150 mm (6.0 in) dia	
Arctic mitten	180 mm (5 in)	215 mm (8.5 in) or 215 mm (8.5 in) dia	
Hand Plus 1 in (25 mm) Dia Object, to Wrist:			
Bare hand	95 mm (3.75 in) sq or dia		
Gloved hand	150 mm (6 in) sq or dia		
Arctic mitten	180 mm (7 in) sq or dia		
Hand Plus Object Over 1 in (25 mm) in Dia, to Wrist:			
Bare hand	45 mm (1.75 in) clearance around object		
Glove or mitten	64 mm (2.5 in) clearance around object		
Arctic mitten	90 mm (3.5 in) clearance around object		
Arm to Elbow:			
Light clothing	100 mm (4 in)	115 mm (4.5 in)	
Arctic clothing	180 mm (7 in) sq or dia		
With object	Clearances as above		
Arm to Shoulder:			
Light clothing	125mm (5.0 in) sq or dia		
Arctic clothing	215 mm (8.5 in) sq or dia		
With object	Clearances as above		
Minimal Finger Access to First Joint			
Push Button Access:			
Bare hand	32 mm (1.25 in) dia		
Gloved hand	38 mm (1.5 in) dia		
			
Bare hand	Object plus 50 mm (2 in)		
Gloved hand	Object plus 65 mm (2.5 in)		

NOTES:

1/ Whichever is larger.

2/ If hands curl around the bottom, allow an extra 38 mm (1.5 in) for light clothing and 75 mm (3 in) for arctic clothing.

FIGURE 57. Arm and hand access dimensions – Continued.

5.9.6.9.4 Type of opening. Where arm and hand access is required, the list below shall be followed in order of preference:

a. An opening with no cover, unless this is likely to degrade system performance, safety, CBRNE, or other mission-required PPE survivability.

b. A hand-operated (latched, sliding, or hinged) cap or door where dirt, moisture, or other foreign materials might otherwise create a problem.

c. A quick-opening cover plate using ¼-turn captive fasteners if a cap will not meet stress requirements or space prevents a hinged cover.

d. A screw-down cover when captive fasteners cannot be used because of stress, structure, or pressurization constraints.

5.9.6.10 Whole-body access. Where whole-body access is required, the opening shall accommodate the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped males of the maintainer population and the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped females of the maintainer population using dimensions applicable to the task.

5.9.6.11 Rescue of personnel. Where rescue of personnel may be required because of environmental hazards (e.g., toxic fumes inside fuel tanks), access openings for rescue personnel shall be provided.

5.9.6.12 Guarding hazardous conditions. If a hazardous condition, such as exposed high voltage conductors exists behind the access, a physical barrier over the access shall be equipped with an interlock that will de-energize the hazardous equipment when the barrier is open or removed.

5.9.6.13 Interlock. Both the presence of the hazard and the fact that an interlock exists shall be noted on the equipment case or cover such that it remains visible when the access is open (see 5.9.7.4).

5.9.7 Access openings and covers.

5.9.7.1 Application. An access shall be provided if frequent maintenance would otherwise require removing a case or covering, opening a fitting, or dismantling an item of equipment.

5.9.7.2 Access cover attachment. Hinged or removable covers shall be fastened with the fewest practical number of simple-to-use fasteners.

5.9.7.3 Self-supporting covers. Hinged access covers that are not completely removable shall be self-supporting in the open position.

5.9.7.3.1 Visual or physical access. The cover in the open position shall not obstruct required visual or physical access to the equipment being maintained or to related equipment during maintenance.

5.9.7.3.2 One-hand opening. Self-supporting covers shall be capable of being opened and closed with one hand.

5.9.7.4 Labeling. Each access shall be labeled with nomenclature for items visible or accessible through it, nomenclature for auxiliary equipment to be used with it, and recommended procedures.

5.9.7.4.1 Warning signs. Accesses shall be labeled with warning signs disclosing any hazards existing beyond the access and prescribing precautions.

5.9.7.4.2 Access cover. Opening or removing an access cover shall not remove or visually obstruct any hazard warning.

5.9.7.4.3 Instructions on hinged door. If instructions applying to a covered item appear on a hinged door, the lettering shall be oriented to be read when the door is open.

5.9.7.4.4 Clear and direct. Warning notices shall be clear, direct, attention-getting, and have a 25-percent larger letter height than any detailed instructions that follow.

5.9.7.5 Visual access. Where visual access is required, the opening shall provide a visual angle large enough to allow maintenance personnel to view all required information from their normal maintenance position.

5.9.7.5.1 Unrestricted visual access. Maintenance personnel shall be provided unrestricted visual access from the workstation without bending.

5.9.7.5.2 Visual access only. Where visual access only is required, the following practices shall be followed in order of precedence:

a. Opening with no cover, except where this might degrade system performance, CBRNE, or other mission-required PPE survivability.

b. Transparent window if dirt, moisture, or other foreign materials might otherwise create a problem.

c. Break-resistant glass window if physical wear, heat, or contact with solvents would otherwise cause optical deterioration.

d. Quick-opening opaque cover if glass will not meet stress or other requirements.

5.9.8 Cover and case mounting.

5.9.8.1 Location and mounting. Covers, cases, and shields shall be designed, located, and mounted so that they can be removed and replaced if damaged.

5.9.8.2 Cover and case alignment. Covers, cases, or shield holes shall be large enough for mounting screw clearance without perfect case alignment.

5.9.8.3 Opening or removal. Covers, cases, and shields shall be capable of being opened or removed as necessary without taking the equipment apart or removing auxiliary equipment.

5.9.8.4 Interference with controls. When open, covers, cases, and shields shall not obscure or interfere with controls, displays, test points, or connections used in working inside the access or enclosure.

5.9.8.5 Stops and retainers. Covers, cases, and shields shall have stops and retainers to keep them from swinging against or being dropped on fragile equipment or personnel.

5.9.8.6 Locking devices. Covers, cases, and shields shall have locking devices or retaining bars to hold them open if they might otherwise fall shut and cause damage, injury, or inconvenience.

5.9.8.7 Fasteners. Fasteners for covers, cases, and shields shall be selected, applied, and mounted so that they satisfy the preferences, criteria, standardization, and corrosion reduction aspects specified herein.

5.9.8.7.1 Hinges, latches, and catches. Hinges, latches, and catches should be used wherever possible to reduce handling and stowing of covers and cases.

5.9.8.7.2 Spring-loaded fasteners. Where possible, spring-loaded fasteners should be used so their status is readily apparent or the cover itself stays ajar when it is not secured.

5.9.8.8 Labels and markings. Labels and markings on covers and cases shall meet the following criteria:

a. Present instructions on how to open, remove, and position covers and cases, unless the design itself makes operation obvious.

b. Clearly indicate the functions of units behind the enclosure or the functions that are performed through the access (e.g., “Battery,” “Fuel Pump,” or “Oil Here”).

c. Present instructions or procedures that will be visible and properly oriented to maintenance personnel when the cover or case is open.

d. Warn about any dangers or hazards involved in removing the cover, or case, or working within the enclosure.

e. Indicate how units or service equipment are to be oriented or connected to go through the opening (unless this is already obvious).

5.9.9 Cases.

5.9.9.1 Orientation. The proper orientation for mounting an item within its case shall be made obvious by design of the case or use of appropriate labels.

5.9.9.2 Protection from damage. Equipment shall be protected from damage when cases are removed or replaced.

5.9.9.3 Manual support. Cases shall not require manual support to remain in the open position during maintenance.

5.9.9.4 Size. Cases shall be sufficiently larger than the items they cover to facilitate installation and removal with little or no case manipulation.

5.9.9.5 Guides. Guides, tracks, and stops shall be provided as necessary to facilitate handling and prevent damage to equipment or injury to personnel.

5.9.10 Covers.

5.9.10.1 Order of preference. Covers should be used in the following order of preference:

a. Hinged doors, hoods, and caps. Hinged doors, hoods, and caps allow fastest and easiest access with relatively few fasteners, and the cover is supported so the maintainer does not have to handle it. However, these types of covers require swinging space, which may interfere with other operations or components. Where swinging or opening space is limited, double-hinged split doors should be used. Hinges should be placed at the bottom of the door or a prop, catch, or latch should be provided to hold the door open, particularly if the door must be opened in high winds.

b. Sliding doors and caps. Sliding doors or caps are particularly useful where swinging space is limited. Small sliding caps are useful for small accesses that do not require a tight seal. When using sliding doors and caps, they should lock positively, be designed so they will not jam or stick, and be easy to use. Sliding doors and caps should not require tools. Opening or closing them should not interfere with, damage, or make potentially harmful contact with wires or other items.

c. Removable doors, plates, and caps. Removable doors, plates, or caps require little space for opening and, once removed, do not interfere with workspace. However, handling takes time and effort. When using removable covers, tongue-and-slot or similar catches should be used wherever possible for small plates, doors, and caps to minimize the number of fasteners required. If small plates and caps are likely to be misplaced or damaged, they should be secured with retainer chains. If a removable plate must be attached in a certain way, it should be designed so it cannot be attached improperly.

d. Removable panels or sections. Removable panels or sections give access to whole sides of equipment. They discourage non-maintenance personnel from opening the access. They do not require "swinging space," but they can be easily damaged and awkward to handle. When used, panels that must be removed for maintenance should be held with a minimum number of combination-head, captive fasteners. Spring-loaded, quarter-turn fasteners are recommended, and it should be apparent when fasteners have been released. Panels and sections should be designed so one person can carry them. They should be able to be removed and installed with common hand tools, and should have handles to facilitate removal, handling, and replacement. It should not be necessary to disconnect wires or components from a panel before removing it. However, if such items are attached to the panel, the panel should be hinged so wires or components need not be removed.

5.9.10.2 Cover not in place. It shall be obvious when a cover is not in place or is not securely fastened.

5.9.10.3 Instructions. If the method of opening a cover is not obvious from the construction of the cover itself, instructions shall be permanently displayed on the outside of the cover.

5.9.10.3.1 Simple symbols. Instructions shall consist of simple symbols such as arrows or simple words like "push" or "push and turn."

5.9.10.3.2 Contents. Instructions about contents in a box should be located so they can be read when the access cover is open.

5.9.10.4 Ventilation holes. If a cover or shield requires ventilation holes, the holes shall be not larger than 13 mm (0.5 in) in diameter.

5.9.10.5 Hazards. Any component that rotates, oscillates, or carries high voltage shall be spaced back from ventilation holes so personnel cannot accidentally contact the hazard.

5.9.10.6 Orientation. A removable access cover that requires a particular orientation for installation shall be designed to prevent attachment in any other orientation.

5.9.10.7 Fasteners for covers. Fasteners shall give an indication that they are fastened.

5.9.10.8 Opening covers. Access covers shall be equipped with grasp areas or other means for opening them.

5.9.10.8.1 Retained open. Unless access covers or doors are intended to be removable, they should be designed so they can be retained open.

5.9.10.8.2 Accommodate handwear. Covers shall accommodate handwear or other special clothing that may be worn by maintenance personnel.

5.9.10.8.3 Hinged doors. When hinged doors are adjacent, they shall open in opposite directions to maximize accessibility.

5.9.10.8.4 Hinged covers. If covers are hinged, space equal to the sweep volume of the cover should be allowed so the body frame and brackets will not obstruct its opening.

5.9.10.8.5 Hinged caps. Hinged caps should be used over test or service points so they will not interfere with inserting or attaching test or service equipment.

5.9.10.8.6 Stops or retainers. Stops or retainers shall be used as necessary to keep doors from swinging into adjacent controls or fragile components and so they will not spring their hinges.

5.9.10.9 Obstructions. Obstructions (material or structural members) should not block covers or doors so they cannot be opened or removed or restrict the required access through the cover or door opening.

5.9.10.10 Sharp edges. Sharp edges and corners on doors, covers, and other exposed surfaces that might present a safety hazard shall be rounded in accordance with 5.7.6.4.

5.9.10.11 Corrosion protection. In general, covers are preferable to leaving equipment without covers. Even temporary fabric or tarpaulin-style covers offer substantial corrosion protection versus no cover at all. Guidance for such covers can be found in MIL-PRF-20696 and A-A-55308.

5.9.11 Fasteners.

5.9.11.1 Number and diversity. The number and diversity of fasteners used shall be minimized commensurate with stress, bonding, pressurization, shielding, thermal, and safety requirements.

5.9.11.1.1 Distinguish location of fastener. When more than one size or type fastener is used on the same piece of equipment, the design shall permit maintenance personnel to readily distinguish the intended location of each fastener.

5.9.11.1.2 Identical fasteners. Identical fasteners shall not be used where removal of the wrong fastener can result in equipment damage or changes to calibration settings.

5.9.11.1.3 Finger- or hand-operated fasteners. Finger- or hand-operated fasteners should be used when consistent with the requirements specified herein, except where screws with heads flush with the fastening surface are required for CBRNE survivability requirements.

5.9.11.1.4 Non-standard tools. Fasteners shall not require non-standard tools.

5.9.11.2 Hinges, tongue-and-slot catches, and mounting pins. Hinges, tongue-and-slot catches, and mounting pins should be used to minimize the number of fasteners required.

5.9.11.3 Captive fasteners. Captive fasteners shall be used where dropping or losing such items could cause damage to equipment or create a difficult or hazardous removal problem.

5.9.11.4 Frequent removal. Captive fasteners shall be provided for access covers requiring frequent removal.

5.9.11.5 Latches and catches. Latches and catches shall give a clear visual indication that they are engaged.

5.9.11.5.1 Spring action force. The spring action or snap-down force shall not be so strong that it could injure maintenance personnel.

5.9.11.5.2 Inadvertent operation. Latches and catches shall be located and positioned to avoid inadvertent operation.

5.9.11.6 Threaded fasteners.

5.9.11.6.1 Head type fasteners. Head type fasteners shall meet the criteria in 5.9.11.6.1.1 and 5.9.11.6.1.2.

5.9.11.6.1.1 High-torque. External hex or external double-hex wrenching elements should be provided on all machine screws, bolts, or other fasteners requiring more than 14 newton·meters (10 foot·pounds-force) of torque.

a. Internal wrenching fasteners – internal wrenching fasteners may be used when external wrenching fasteners cannot meet the mechanical function or personnel safety requirements or in limited access situations where the fastener is protected from accumulation of foreign material (e.g., ice, snow).

b. Direct tool access – direct tool access shall be provided to allow for torquing without the use of swivel or universal joint extensions.

5.9.11.6.1.2 Low-torque. External hex wrenching head, internal hex wrenching head, combination head (internal hex or straight recess and external hex wrenching head), or star fasteners shall be provided where less than 14 newton·meters (10 foot·pounds-force) torque is required.

a. Internal wrenching fasteners – internal-wrenching fasteners should be used only where a straight or convex smooth surface is required for mechanical function or personnel safety and where the fastener is protected from accumulation of foreign material (e.g., ice, snow).

b. Internal grip fasteners – straight-slot or cross-recess type internal grip fasteners should not be used except as wood fasteners or where these types of fasteners are provided on standard commercial items.

5.9.11.6.2 Common fasteners. Whenever possible, identical screw and bolt heads shall be provided to allow panels and components to be removed with one tool.

5.9.11.6.3 Combination bolt heads. Combination bolt heads, such as slotted hex heads, shall be selected whenever feasible.

5.9.11.6.4 Number of turns. Fasteners for mounting assemblies and subassemblies shall require a minimum number of turns compatible with stress, alignment, positioning, and load considerations.

5.9.11.6.5 Quick-release fasteners. Items requiring removal for daily or more frequently scheduled inspections and servicing should use quick-release fasteners.

5.9.11.6.6 Amount of torque. When machine screws or bolts are required, the number of turns and the amount of torque shall be not more than necessary to provide the required strength.

5.9.11.6.7 Torque labeling. When fastener torquing to meet electromagnetic interference (EMI)/radio-frequency interference (RFI) shielding, thermal conductance, or other constraints is required, an instructional label or placard shall be provided near the fastener.

5.9.11.6.8 Label contents. Labels shall comply with the requirements of 5.4 and specify the required torque value and torquing sequence.

5.9.11.6.9 Left-hand threads. Fasteners with left-hand threads, where required, shall be identified so they are distinguishable from right-hand threaded fasteners.

5.9.11.6.10 Lock washers. Captive washers and lock washers shall be used when loss would present a hazard to equipment or personnel.

5.9.11.6.11 Removal and replacement with one hand or tool. Nuts and bolts that are removed and replaced frequently and that are relatively inaccessible shall be mounted so that they can be removed and replaced with one hand or one tool.

5.9.11.6.12 Attachment. Either the nut or the bolt shall be attached semi-permanently, and they shall not interfere with each other or with other components during release.

5.9.11.6.13 Clearance. Nuts and bolts shall have hand or tool clearance for easy operation.

5.9.11.6.14 Durability. Fasteners that are normally operated by hand shall be durable enough that they can be turned with a wrench.

5.9.11.7 Cotter keys. Cotter keys and pins should fit snugly, but should not have to be driven in or out. Cotter keys should have large heads for easy removal.

5.9.11.8 Safety wire. Safety wire should be used only where self-locking fasteners cannot withstand the expected vibration or stress.

5.9.11.9 Retainer chains. The selection of retainer chains should consider link, sash, or woven-mesh chains; bead-link chain should be avoided because it breaks more easily than other types.

5.9.11.9.1 Attachment. Retainer chains should be attached with screws or bolts, attached strongly and positively, and be disconnected easily when required.

5.9.11.9.2 Eyelets. Eyelets should be provided at both ends of the retainer chain for attachment to the fasteners.

5.9.11.9.3 Length. Retainer chains should not be longer than their function requires.

5.9.11.10 Fastener materials. Corrosion-resistant materials should be chosen when torque and load values allow. Anti-seize compounds should be considered. Non-metallic washers and sleeves will reduce fastener contact on substrate surfaces, minimizing surface coating damage. Strippable coatings may be applied over assembled fasteners to minimize exposure to corrosive environments.

5.9.12 Lubrication.

5.9.12.1 Self-lubricating components. Where feasible, self-lubricating components shall be used.

5.9.12.2 Equipment configuration. Configuration of equipment requiring lubrication shall permit lubrication and, as applicable, checking of lubricant reservoir levels without disassembly.

5.9.12.3 Types of lubricants. The number of types of required lubricants shall be minimized.

5.9.12.4 Lubrication points. Lubrication points should be provided to avoid disassembly of equipment.

5.9.12.5 Accessibility. Lubrication points shall be accessible, clearly labeled, and, where applicable, provided with captive caps or covers.

5.9.12.6 Extended fittings. Extended fittings shall be provided to lubricant ports that are not readily accessible or visible.

5.9.12.7 Number of service points. The number of service points shall be minimized by routing service lines to a centralized servicing location(s).

5.9.12.8 Lubrication indication. A clear indication that the lubrication process is completed shall be provided to ensure proper servicing level.

5.9.12.9 Oil drains. Oil drains, when not permanently piped, shall be provided with a temporary hose attachment for gravity draining into small containers.

5.9.12.10 Improper coupling. Fittings shall be sized to prevent coupling with improper servicing devices.

5.9.12.11 Warning message. Where lubrication is system- or mission-critical, a “low lubrication level” warning message or indicator shall be provided.

5.9.12.12 Labeling.

5.9.12.12.1 Labels. All lubrication storage or service tanks shall be labeled in accordance with 5.4.

5.9.12.12.2 Type of lubricant. Where lubrication is required, the type of lubricant to be used and the frequency of lubrication shall be specified by a label mounted at or near the lube port or grease fitting.

5.9.12.12.3 Lubrication chart. If a lubrication chart is prepared, each fitting shall be labeled to match the chart identification name or number and the label placed immediately adjacent to the fitting.

5.9.13 Lines and cables.

5.9.13.1 Coding.

5.9.13.1.1 Common sheath. Cables containing individually insulated conductors with a common sheath shall be coded every 300 mm (12 in).

TABLE XXXII. Hydraulic and pneumatic coding.

Function	Color	Definition of Function
Intensified pressure	Purple/Violet	Pressure in excess of supply pressure induced by a booster or intensifier.
Supply pressure	Red	Pressure of the power-actuating fluid.
Charging pressure	Intermittent red	Pump-inlet pressure higher than atmospheric pressure.
Reduced pressure	Intermittent red	Auxiliary pressure lower than supply pressure.
Metered flow	Yellow	Fluid at a controlled flow rate (other than pump delivery).
Exhaust	Blue	Return of the power-actuating fluid to reservoir.
Intake	Green	Sub-atmospheric pressure, usually on the intake side of the pump.
Drain	Green	Return of leakage of control-actuating fluid to reservoir.
Inactive	Blank	Fluid within the circuit but not serving a functional purpose during the phase being represented.

5.9.13.2 Cable clamps. Unless wiring ducts or conduits are used, mechanically (not adhesively) mounted cable clamps shall be provided to ensure correct routing of electrical cables within and between items.

5.9.13.2.1 Visibility of clamps. All clamps shall be visible when equipment is installed.

5.9.13.2.2 Spacing. Clamps or plates that mount lines and cables shall have heat-insulating liners and be spaced not more than 610 mm (24 in) apart or as specified (see 6.2).

5.9.13.2.3 Quick release. If cables are removed frequently, clamps or plates should be the quick-release hinged or spring type; hinged clamps are preferable.

5.9.13.2.4 Overhead mounting. For overhead mounting, a spring clamp should be used with a hinged-locking latch over the clamp’s open side.

5.9.13.2.5 Corrosive environments. Clamps subject to corrosive environments shall be manufactured from corrosion-resistant materials, preferably stainless steel, and mounted using a corrosive preventative caulk on metal surfaces to minimize the degradation of the mechanical connection.

5.9.13.3 Length. Cables shall be long enough so that required checking of any functioning item can be accomplished in a convenient place.

5.9.13.3.1 Extension cables. Where installation requirements prevent continuous cabling to the equipment, extension cables shall be provided.

5.9.13.3.2 Checkout of items. Cables shall permit checkout of each functioning item located in drawers or pullout racks without having to remove the item from its installed location.

5.9.13.3.3 Allow two repairs. The length of wires shall be long enough to allow for at least two repairs.

5.9.13.4 Line and cable routing. Line and cable routing shall not obstruct visual or physical access to equipment for operation or maintenance.

5.9.13.4.1 Avoid misuse. Interconnecting cables shall be routed to minimize the possibility of their use as handholds or steps.

5.9.13.4.2 Protective guard. A protective guard shall be placed over the lines and cables where the possibility of using the line or cable as a handhold or step exists.

5.9.13.4.3 Avoid pinching. Lines and cables should be routed so that they are not pinched by doors, lids, and slides.

5.9.13.4.4 Avoid hidden locations. Lines and cables should not be located under floorboards, behind panels, or behind components that are difficult to remove.

5.9.13.4.5 Sharp bends. Lines and cables should be located so they are not bent or unbent sharply when connected or disconnected.

5.9.13.4.6 Avoid heat sources. Line and cable routing should avoid close contact with potential heat sources so they will not be damaged by overheating.

5.9.13.5 Mounting of lines and cables.

5.9.13.5.1 Accessibility. Lines and cables shall be accessible without disassembling or removing other equipment.

5.9.13.5.2 Replacement. Lines and cables shall be removable and completely replaceable if they are damaged.

5.9.13.5.3 Access and clearance. Accesses and clearances shall be provided for removing and replacing lines and cables.

5.9.13.5.4 Rotating parts. Lines and cables shall be mounted such that moving and rotating parts will not snag them.

5.9.13.5.5 Grommets. Lines and cables routed through metal partitions shall be protected by use of insulating grommets.

5.9.13.5.6 Foreign objects. Lines and cables shall be mounted so that foreign objects, such as flying stones, will not damage them.

5.9.13.5.7 Drip loops. Drip loops shall be used prior to cables entering electrical connectors and devices.

5.9.13.5.8 Strippable coatings. Strippable coatings should be applied to conductor terminals to prevent exposure to environmental extremes.

5.9.13.6 Protection of lines and cables.

5.9.13.6.1 Guards. Lines and cables that could be easily damaged should have guards or other protection.

5.9.13.6.2 Protection from fluids. Electrical wiring should be protected from contact with fluids such as grease, oil, fuel, hydraulic fluid, water, or cleaning solvents.

5.9.13.6.3 Moisture. The insulation at the ends of lines and cables should be protected from moisture. Moisture-proof jacketing, which will withstand the required temperature range and mechanical abuse, should be used.

5.9.13.6.4 Protective covers. Protective covers for the line or cable should be provided to prevent damage during periods of non-use.

5.9.13.7 Access. Lines and cables shall be routed to be accessible for inspection and maintenance.

5.9.13.8 Susceptibility to abuse. Lines and cables shall be routed or protected to preclude mechanical damage and abuse, including damage by doors, lids, use as a step or hand hold, or being bent or twisted sharply or repeatedly.

5.9.13.8.1 Protection from mechanical damage. If it is necessary to route lines or cables through holes in metal partitions, the line or cable shall be protected from damage by grommets or equivalent means.

5.9.13.8.2 CBRNE survivability. Where required for CBRNE survivability, lines and cables shall be wrapped and sealed.

5.9.13.9 Identification. Lines and cables shall be labeled to indicate the equipment to which they belong and the connectors with which they mate.

5.9.13.9.1 Unique identification. All receptacle lines and cables shall be uniquely identified with distinct color or number codes.

5.9.13.9.2 Color coding. Color-coded wires shall be color coded over the entire length of the wire.

5.9.13.9.3 Obscured coding. If a wire's color may become obscured, wires may be coded with numbered metal tags.

5.9.13.9.4 Number codes. Number codes shall be repeated every 500 mm (20 in) over the entire length of the wire.

5.9.13.10 Fluid and gas lines.

5.9.13.10.1 Personnel and equipment protection. Fluid lines shall be kept from spraying or draining fluid on personnel or equipment.

5.9.13.10.2 Cutoff valves. Cutoff valves shall be provided at appropriate locations in the system to permit isolation or drainage of the system for maintenance or emergency purposes.

5.9.13.10.3 Mounting and installation. Fluid and gas lines shall be mounted and installed so that rigid lines with fittings do not have to be backed off before they can be disconnected.

5.9.13.10.4 Flexible tubing. Flexible tubing rather than rigid lines shall be used where feasible.

5.9.13.10.5 Prevention of mismating. To avoid the possibility of mismating connectors during service or maintenance, fluid and gas lines shall be coded by arrangement, size, shape, or color.

5.9.13.10.6 Fluid lines. Colored bands shall be used to identify all lines that carry fluids in accordance with ANSI/ASME A13.1 and ISO 14726 for ship and marine technology. Metal tags shall be used where adverse conditions such as grease or mud could obscure colors; otherwise, color coding shall be used.

5.9.13.10.7 Hydraulic and pneumatic diagrams. Hydraulic and pneumatic schematic diagrams shall use a standardized color coding scheme to visualize flow conditions or fluid paths (see table XXXII).

5.9.13.10.8 Fluid and gas connectors. Connectors for pipes, tubing, and hoses shall be located and installed so that it is unnecessary to jack the equipment up to drain it, fill it, or perform other maintenance.

5.9.13.10.9 Gaskets and seals. Gaskets and seals shall be selected and installed so that they can be easily replaced without removing other connector parts or disassembling other equipment.

5.9.13.10.10 Visible gasket or seal. Part of a gasket or seal shall be visible after it is installed as a check that it has been correctly installed after reassembly.

5.9.14 Connectors.

5.9.14.1 Same function. Connectors serving the same or similar functions shall be designed to preclude mismating or misalignment.

5.9.14.2 Use of quick-disconnect plugs. Plugs requiring not more than one turn or other quick-disconnect plugs shall be provided whenever feasible.

5.9.14.3 Keying. Connectors shall be designed, installed, and mounted so that it will be impossible to insert a wrong plug into a receptacle or to insert a plug into the correct receptacle the wrong way.

5.9.14.4 Identification. Electrical plugs and receptacles shall be identified by color, shape, size, or equivalent means to facilitate identification when multiple similar connectors are used in proximity to each other.

5.9.14.4.1 Labels. Labels or codes on connectors and associated items shall be located so that they are visible during maintenance and are visible whether the connector is connected or disconnected.

5.9.14.4.2 Identify connectors. It shall be possible to identify connectors without disconnecting them.

5.9.14.4.3 Consistent position. The position of labels shall be consistent in relation to associated pins, terminals, and receptacles.

5.9.14.5 Alignment. Plugs and receptacles shall be provided with aligning pins, keyways, or equivalent devices to aid in alignment and to preclude inserting in other than the desired position.

5.9.14.5.1 Aligning devices. Aligning devices shall ensure that alignment is obtained before the electrical seals or pins engage.

5.9.14.5.2 Orientation. Plugs and receptacles shall be arranged so that the aligning devices are oriented in the same relative position.

5.9.14.6 Coding. Coding techniques for plugs and receptacles shall provide for position of aligning pins or equivalent devices for proper insertion.

5.9.14.6.1 Color coding. All colors used for coding shall be readily discriminable from one another under operational lighting conditions.

5.9.14.6.1.1 Colored areas. Colored areas shall be protected to the extent possible to keep the color from wearing off, fading, or disappearing.

5.9.14.6.1.2 Permanently applied colors. Whenever possible, permanently applied colors shall be used rather than adhesive tapes or bent-on tapes.

5.9.14.6.1.3 Multiple connectors. If many connectors must be coded and there are not enough easily discriminable colors, matching patterns of colors or stripes shall be used.

5.9.14.6.1.4 Consistent meaning. Colors used to code connectors shall be consistent and have the same meaning throughout the system.

5.9.14.6.2 Shape coding. Connectors shall be coded by using various shapes of matching plugs and receptacles. Different shapes of alignment pins may be used to differentiate connectors and to prevent mismating.

5.9.14.6.3 Pin configurations. Connectors with different numbers and configurations of pins or unique keyway slots may be used so that it is physically impossible to mismate connectors without breaking them.

5.9.14.6.3.1 Selection. To prevent damage from mismating, connectors shall be selected and coded so it is obvious which pairs do or do not match.

5.9.14.6.3.2 Differentiation. When a plug and a receptacle look generally similar but do not mate, additional coding shall be used to differentiate them.

5.9.14.7 Spacing. Connectors shall be spaced far enough apart so that they can be grasped firmly for connecting and disconnecting.

5.9.14.7.1 Space between adjacent connectors. Space between adjacent connectors or between a connector and any adjacent obstructions shall be compatible with the size and shape of the plugs and the type of clothing worn by maintenance personnel (e.g., cold weather handwear, CBRNE gloves, or other mission-required PPE).

5.9.14.7.2 Bare finger operation. For bare finger operation, spacing between adjacent connectors shall be not less than 25 mm (1 in), except where connectors are to be sequentially removed and replaced and 25 mm (1 in) clearance is provided in a swept area of not less than 270 degrees around each connector at the start of its removal and replacement sequence.

5.9.14.7.3 Gloved finger operation. Spacing between adjacent connectors shall be not less than 32 mm (1.25 in) if the connector is to be operated with gloved fingers, 64 mm (2.5 in) if the connector must be gripped firmly, and 75 mm (3 in) if the connector is operated with mittened hands. Spacing may be reduced accordingly where connectors are to be sequentially removed and replaced and the full specified clearance is provided in a swept area of not less than 270 degrees around each connector at the start of its removal and replacement sequence.

5.9.14.7.4 Measuring spacing. Spacing shall be measured from the outermost portion of the connector (i.e., from the backshell, strain relief clamp, dust cover, or EMI/RFI shield).

5.9.14.7.5 High torque. Where high torque is required to tighten or loosen the connector, space shall be provided for use of a connector wrench.

5.9.14.8 Testing and servicing. The rear of plug connectors shall be accessible for testing and servicing, except where precluded by potting, sealing, or other requirements.

5.9.14.9 Drawer modules. Where feasible, removable drawer modules shall be provided with connectors mounted on the back of the drawer to mate with connectors in the cabinet in order to accomplish electrical interconnection between the drawer, other equipment in the rack, and external connectors. Guide pins or equivalent devices shall be provided to aid in connector alignment and mating.

5.9.14.10 Electronic modules. Replacement electronic items (e.g., modules and high-failure-rate components) shall be provided with simple plug-in, rack-and-panel type connectors.

5.9.14.11 Disassembly and adapters. Disassembly of connectors to change pin connections shall be able to be performed without the use of special tools. When adapters are required, they shall be capable of being tightened by hand.

5.9.14.12 Protective covers. If protective covers are required, captive types shall be used.

5.9.14.13 Electrical connectors.

5.9.14.13.1 Multiple contacts. Wherever possible, plugs shall have multiple contacts to reduce the number of plugs and, consequently, the number of maintenance operations.

5.9.14.13.2 "Plug-in" connectors. Connectors shall "plug in" or secure with not more than one complete turn, especially with auxiliary or test equipment.

5.9.14.13.3 Wiring. Wiring shall be routed through the plugs and receptacles so disconnection does not expose "hot" leads.

5.9.14.13.4 Receptacles. Receptacles shall be "hot" and plugs shall be "cold" when disconnected.

5.9.14.13.5 Plugs. Plugs shall be self-locking or use safety catches rather than requiring safety wiring.

5.9.14.13.6 Low insertion force. Plugs should have low insertion forces to minimize the possibility of damaging contact surfaces.

5.9.15 Diagnostics and troubleshooting.

5.9.15.1 Facilitate diagnostics and troubleshooting. All equipment and systems shall be designed to facilitate diagnostics and troubleshooting.

5.9.15.2 Troubleshooting. Troubleshooting shall not require removal of subassemblies from assemblies.

5.9.15.3 Malfunction identification. Equipment design shall facilitate rapid and positive fault detection and isolation of defective items.

5.9.15.4 Automatic fault detection. Wherever possible, equipment shall have an automatic fault detection and isolation capability.

5.9.15.5 Evidence of status. For the appropriate level of line replaceable units (LRUs), components shall provide built-in test (BIT)/built-in test equipment (BITE) or other easily identifiable evidence of their status (e.g., a blown fuse).

5.9.15.6 Test prior to installation. Replacement parts should be tested prior to installation.

5.9.15.7 Error message. To the degree practical, self-test fault and error messages shall be provided.

5.9.16 Failure indications and fuse requirements.

5.9.16.1 Indication of equipment failure.

5.9.16.1.1 Power failure. An indication shall be provided to reveal when a power failure occurs (see 5.2.3.1.7).

5.9.16.1.2 Out-of-tolerance. An indication shall be provided to indicate when an item is not operating within tolerance limits.

5.9.16.1.3 Failure. An indication shall be provided to indicate when an item has failed.

5.9.16.1.4 Automatic self-check. All mission-essential electronic equipment shall incorporate an automatic self-check diagnostic at startup and at the request of maintenance personnel.

5.9.16.1.5 Critical malfunctions. A visual and auditory alarm shall be provided to indicate a malfunction or condition that could cause personnel injury or equipment damage. If an audio alarm would compromise covert operation of the equipment, only a visual signal shall be displayed.

5.9.16.2 Fuses and circuit breakers.

5.9.16.2.1 General. A positive indication shall be provided to indicate that a fuse or circuit breaker has opened a circuit.

5.9.16.2.2 Replacement and resetting. Fuses shall be readily accessible for removal and replacement.

5.9.16.2.2.1 Access to fuses. No other components shall require removal in order to gain access to fuses.

5.9.16.2.2.2 Special tools. No special tools shall be required for fuse replacement unless required by safety considerations.

5.9.16.2.2.3 Resetting circuit breakers. When resetting of circuit breakers is permissible and is required for system operation during a mission, the breakers shall be located within reach of maintenance personnel in their normal operating posture.

5.9.16.2.3 Markings. Equipment served by the fuse or circuit breaker shall be labeled in accordance with 5.4.

5.9.16.2.3.1 Labeling. Labeling of fuses and circuit breakers shall be legible in the anticipated ambient illumination range for maintenance personnel's location.

5.9.16.2.3.2 Fuse ratings. The current rating of fuses shall be permanently marked adjacent to the fuse holder.

5.9.16.2.3.3 Ratings. Fuse ratings shall be indicated either in whole numbers, common fractions (such as ¼), or whole numbers and common fractions (such as 2¼).

5.9.16.2.3.4 Spares. The word SPARE shall be marked adjacent to each spare fuse holder.

5.9.16.2.4 Circuit breaker controls. Toggle bat and legend switch actuated circuit breakers may be used to control electrical power.

5.9.16.2.5 Power switches. Push-pull type circuit breakers shall not be used as power switches.

5.9.16.2.6 Circuit breaker dimensions and separations. Dimensions and separation for toggle bat actuated circuit breakers shall be in accordance with figure 16. Dimensions and separation for legend switch actuated circuit breakers shall be in accordance with figure 17.

5.9.17 Test and service points.

5.9.17.1 Design and location. Test and service points should be designed and located in accordance with the following criteria:

a. According to frequency of use and time requirements.

b. To be clearly distinguishable from one another; where necessary, use color coding and labeling.

c. To offer positive indication by calibration, labeling, or other features of the direction, degree, and effect of adjustments.

d. At a central panel or location or at a series of functionally autonomous panels and locations.

e. With leads, wires, or extended fittings to bring hard-to-reach test and service points to an accessible area.

f. To avoid locating a single test or service point in an isolated position; such points are likely to be overlooked or neglected.

g. To avoid concealment or obstruction by braces, brackets, or other structural items.

5.9.17.2 Adjustment.

5.9.17.2.1 Located close to controls. Test points used for adjustment shall be located sufficiently close to the controls and displays used in the adjustment so that place-to-place movement by maintenance personnel is not required during the adjustment process.

5.9.17.2.2 Accessible. Test points for adjustment shall be physically and visually accessible in the installed condition by maintenance personnel without removing other items.

5.9.17.3 Labeling. All test points shall be permanently labeled with their identification and the within-tolerance range to be measured.

5.9.17.3.1 Identify in maintenance instructions. Each test point shall be labeled to identify it in the maintenance instructions.

5.9.17.3.2 Name of unit. If possible, the name of the unit shall be included in the label.

5.9.17.4 Labels facing maintenance personnel. Test points shall be designed so the test point and its associated labels and controls are facing the maintenance personnel.

5.9.17.5 Ease of access. Test points shall be located on surfaces or behind accesses that may be easily reached or readily operated when the equipment is fully assembled and installed.

5.9.17.6 Minimum clearance. Test points shall be located so that a minimum clearance of 19 mm (0.75 in) is provided when only finger control is required and 75 mm (3.0 in) is provided when a gloved hand must be used.

5.9.17.7 Guards and shields. Test points shall be designed with guards and shields to protect personnel and test and service equipment, particularly if the equipment must be serviced while operating.

5.9.17.8 Isolated position. Locating test points in an isolated position shall be avoided as such points are most likely to be overlooked or neglected.

5.9.17.9 Visual inspection. Test points shall be designed with windows to internal items requiring frequent visual inspections.

5.9.17.10 Tool guides. Test points shall be designed with tool guides and other design features to facilitate operation of test or service points that require blind operation.

5.9.17.11 Functional reach. Test points shall be located within easy functional reach or seeing distance of related or corresponding controls, displays, fittings, and switches.

5.9.17.12 Hazards. Test points shall be located at least 115 mm (4.5 in) away from electrical, mechanical, or other hazards.

5.9.17.13 Templates. Templates or overlays should be provided where they will expedite the use of different test procedures that use the same set of test points.

5.9.17.14 Test routines. Color codes, guides, symbols, and labels should be used to facilitate following logical test routines among the test points.

5.9.17.15 Accessories. Requirements for separate funnels, strainers, adaptors, and other accessories should be avoided. Where practical, these should be built into the system or service equipment so they do not need to be handled separately.

5.9.17.16 Combine test points. Where feasible, test points should be combined into clusters, particularly where similar clusters occur frequently.

5.9.18 Test equipment.

5.9.18.1 Storage. Storage space shall be provided within portable test equipment, its handling case, or lid to contain leads, probes, spares, manuals, and tools, as required.

5.9.18.2 Instructions. Instructions for operating portable test equipment shall be provided on the face of the test equipment, in a lid, in a special compartment, or on an electronic display interface.

5.9.18.2.1 Readability. Instructions shall be directly readable while test equipment is being operated.

5.9.18.2.2 Print size. Instructions shall be printed large enough to be seen in the lowest light level likely to be encountered by maintenance personnel using the test equipment.

5.9.18.2.3 Calibration. Periodic calibration records, including tolerance check values, shall be placarded on the equipment where appropriate.

5.9.18.2.3.1 Calibration reminder. Where applicable, calibration instructions shall include a reminder to calibrate the equipment and calibration procedures.

5.9.18.2.3.2 Go/no-go indication. Test equipment should be equipped with a go/no-go indicator or simple check to determine whether the equipment is malfunctioning or needs calibration.

5.9.18.2.3.3 Electronic display. If the system contains an electronic display, calibration procedures and data shall be available for presentation on the display.

5.9.18.2.4 Set-up procedures. Set-up procedures should be attached to the test equipment.

5.9.18.2.5 Conversion tables. Conversion tables should be provided when needed.

5.9.18.3 Electrical power.

5.9.18.3.1 Electrical source. Test equipment shall be clearly labeled with the type of electrical source to be used.

5.9.18.3.2 Power on indication. An indication that power is on should be included on the test equipment panel.

5.9.18.4 Controls and adjustments. Controls and adjustments should be designed to prevent misalignment caused by vibration, service use, or accidental contact.

5.9.18.5 Portable test equipment.

5.9.18.5.1 Harness or sling. An adjustable harness or sling should be provided to facilitate carrying portable or handheld test equipment.

5.9.18.5.2 Serrated or ridged bottom. The underside of handheld test equipment should be serrated or ridged to prevent it from slipping out of the maintainer's hand.

5.9.18.5.3 Self-powered. Handheld test equipment should be self-powered and not require attachment to an electrical outlet.

5.9.18.5.4 Stands or casters. Stands or casters shall be provided for devices weighing more than 13.6 kg (30 lb).

5.9.18.5.5 Wheels, casters, or hoist-lifting. Wheels, casters, or hoist-lifting shall be provided for devices weighing more than 40.8 kg (90 lb).

5.9.18.5.6 Rounded corners and edges. Portable test equipment shall have rounded corners and edges in accordance with 5.7.6.4.

5.9.18.5.7 Weight.

5.9.18.5.7.1 Portability. The weight of test equipment for portability shall be in accordance with the carrying weight limits of 5.20.4.

5.9.18.5.7.2 Operability. The weight of handheld test equipment shall not exceed 2.3 kg (5 lb), and preferably not exceed 1.4 kg (3 lb).

5.9.19 Tools.

5.9.19.1 Minimize number of tools. Equipment shall be designed to minimize the numbers, types, and complexity of tools required for maintenance.

5.9.19.2 Full range of motion. The design shall provide for effective use of tools through their full range of motion.

5.9.19.3 Common tools. If possible, only those tools normally found in the maintainer's tool kit should be required.

5.9.19.4 Special tools. Special tools shall be used only when common hand tools cannot be used or when they provide significant advantage over common hand tools.

5.9.19.5 Compatible with design. Tools that are compatible with the design of the equipment on which they will be used as well as with the task to be performed should be specified.

5.9.19.6 List of tools. A comprehensive list of tools needed for all maintenance tasks should accompany each equipment system. This should include any special tools necessary to perform the work together with the items requiring their use.

5.9.19.7 Securing tools. Tools required for operational adjustment maintenance should be securely mounted within the equipment in a readily accessible location.

5.9.19.8 Grip span. The grip span for tools should be appropriate for the anticipated tasks to minimize effort and maximize torque.

5.9.19.9 Power tools. The use of speed or power tools, such as ratchets, speed screwdrivers, or power wrenches, should be provided when demanded by torque requirements or space limitations.

5.9.19.10 Dull finish. Tools with a dull finish to prevent reflected glare in areas of high illumination should be used when dictated by operational requirements.

5.9.19.11 Tool handles.

5.9.19.11.1 Gripping surfaces. Tool handles should have serrated gripping surfaces.

5.9.19.11.2 Prevent loss. Tools used where dropping could result in maintenance delay or possible tool loss should be provided with thongs sufficiently long enough to enable the maintainer to place a loop over his or her wrist.

5.9.19.11.3 Heat- or cold-resistant handles. Heat- or cold-resistant handles should be used on tools that are to be used in extreme climates. Metal handles are undesirable for use in cold and hot climates.

5.9.19.12 Toolboxes. Toolboxes should be designed with cut-outs for specific materials and equipment required for task support.

5.9.19.13 Aviation maintenance. In aviation maintenance, the potential for foreign object damage (FOD) should be minimized through equipment selection, supporting equipment that facilitate tracking and location of materials, and associated training and procedures.

5.9.19.14 Fluorescent markings. Fluorescent marking of hand tools should be considered when such equipment will be used in locations where FOD is an issue and illumination may be limited.

5.9.20 Printed circuit boards.

5.9.20.1 Mounting. Printed circuit boards shall be designed and mounted for ease of removal and replacement, considering such factors as finger access, gripping aids, and resistance created by the mounting device.

5.9.20.2 Feedback. Appropriate feedback shall be provided to ensure that maintenance personnel know when the board is securely connected.

5.9.21 Stored energy devices.

5.9.21.1 Release or constrain energy. Devices that operate under stored energy (e.g., springs under compression, shock absorbers operated by pneumatic pressure, pressurized bottles, capacitors) shall be designed so the energy can be safely released or constrained before any maintenance tasks are performed.

5.9.21.2 Apparent to maintainer. The means of release or constraint shall be immediately apparent to maintenance personnel.

5.9.21.3 Inadvertent activation. The means of release or constraint shall be designed so that the means cannot be inadvertently activated once it has been deactivated.

5.9.21.4 Labeling.

5.9.21.4.1 Stored energy devices. All stored energy devices shall be labeled as such.

5.9.21.4.2 Hazard warning. All stored energy devices shall have a DANGER hazard warning sign or label attached to the device.

5.9.21.5 Batteries.

5.9.21.5.1 Installation. Batteries should be installed in locations away from sources of heat and be protected to ensure satisfactory functioning in all anticipated environmental conditions.

5.9.21.5.2 Battery holders. Battery holders should be rugged, have easily operated clamping devices, and not require the use of tools to hold the battery firmly in position.

5.9.21.5.3 Removal and replacement. One person should be capable of removing batteries for servicing and replacing them without having to remove other items of equipment and without using special tools.

5.9.21.5.4 Dust caps. Tethered dust caps should be provided so battery terminals cannot contact metal surfaces during handling, removal, or replacement.

5.9.21.5.5 Battery supports. Battery supports, hold-downs, and areas around the installation that could possibly be affected by dripping or seepage of acids should be protected with acid-proof paints or coatings.

5.9.21.5.6 Battery cases. Battery cases should be drained using acid-proof piping to a container to prevent environmental damage.

5.9.21.5.7 Ventilation. Batteries should be located in well-ventilated areas and have facilities to prevent freezing, when necessary.

5.9.21.5.8 Explosive mixtures. Batteries should not be charged in a poorly ventilated compartment where explosive mixtures may result.

5.9.21.5.9 Electrical fixtures. Only electrical fixtures approved for hazardous locations should be used in battery compartments.

5.9.21.5.10 Quick disconnects. Quick disconnects should be provided on battery leads for power-off maintenance or emergencies.

5.9.21.5.11 Labeling. Labeling should be provided as necessary to identify the battery type, voltage, polarity, and safe rate of charge. All related terminals, connectors, contacts, and leads that are part of the battery circuit should be identified. When practical, a block or pictorial wiring diagram of the battery circuit should also be provided.

5.9.21.5.12 Corrosion prevention. Corrosion preventative greaser should be applied to terminals when installing cables.

5.9.21.5.13 Water resistance. Electrical connectors should be designed to be water resistant and drip loops should be installed to prevent water ingress.

5.9.22 Hydraulic systems.

5.9.22.1 Standardization. Connectors in hydraulic systems shall be of standard design and manipulated with standard tools.

5.9.22.2 Identification. Inlets, outlets, and connecting lines in hydraulic systems shall be identified at least every 450 mm (18 in) and at both ends.

5.9.22.3 Drain cocks. All drain cocks shall be closed when the handle is in the down position.

5.9.22.4 Seals. Seals that are externally visible after they are installed shall be used.

5.9.22.4.1 Protrude beyond coupling. Seals shall not protrude or extrude beyond the coupling.

5.9.22.4.2 Permanent seals. Couplings shall use permanent seals rather than seals that must be removed and replaced.

5.9.22.5 Pressure relief. Hydraulic systems shall be designed to provide for safe release of pressurized lines and reservoirs, capture of released fluids, and safe isolation of non-pressurized systems from pressurized systems.

5.9.22.6 Mechanical stops. The design of hydraulic systems shall provide mechanical stops for valve handles to prevent the valves from opening because of vibration.

5.9.22.7 Self-sealing couplings. Self-sealing couplings shall be provided on hydraulic systems.

5.9.22.8 Automatic bleeding. The design shall provide for automatic bleeding of hydraulic systems whenever possible.

5.9.22.9 Mismating. Hydraulic line connections shall be designed, installed, and mounted such that it will be impossible to connect a line into the wrong fitting or connect a line into the correct fitting the wrong way.

5.10 Workspace and workstation design.

5.10.1 General. These design criteria apply to DoD systems and to DoD personnel and contractors using those systems. Unless otherwise noted herein, the following criteria apply to ground installations and, as determined by the procuring activity, to airborne, ground vehicle, and shipboard installations. Unless otherwise specified (see 6.2), the design of DoD systems, equipment, and facilities shall accommodate the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped males of the target user population and the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped females of the target user population (see 5.8) using dimensions applicable to the task. For univariate accommodation, the central 95 percent of the male target user population and the central 95 percent of the female target user population should be used.

5.10.1.1 Task design. The design shall consider both the appropriate workspace and the workstation assets for personnel to achieve a defined task (see 5.10.3.5).

5.10.1.2 Job design. The designer should consider the necessary task(s) to be accomplished through defining the workstation asset(s) available and the incorporation of those asset(s) within the physical workspace requirements to accomplish job functions.

5.10.1.3 Task definition. The design of fixed, mobile, or temporary workstations shall support the defined tasks (see 5.10.3.5).

5.10.1.4 IT-based design.

5.10.1.4.1 Control space design. In general, the control space is below the space where displays are mounted; displays that are closely associated with controls can be mounted on these surfaces. The workstation or console shall accommodate the physical space requirements of the chosen controls for the tasks.

5.10.1.4.2 Display space design. The display space shall be designed in accordance with 5.2.

5.10.1.4.3 Seated display space design. The seated display space design shall meet the requirements of figure 58 (see 5.10.3.5 and 5.10.3.9).

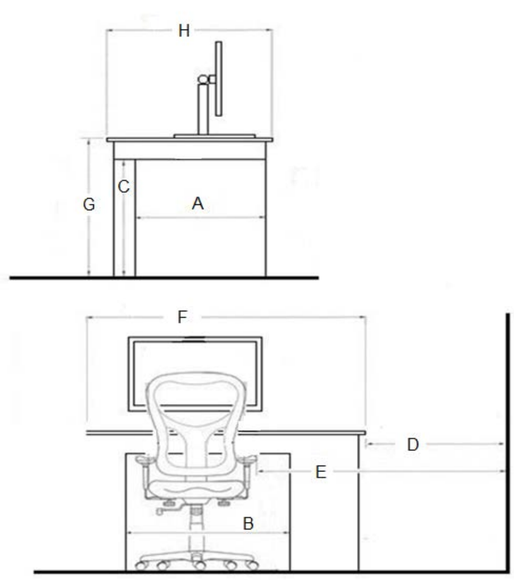


FIGURE 58. Seated workspace dimensions.

Workspace		Minimum Required cm (in)
A	Kneehole depth	45 (18.1)
B	Kneehole width	51 (20.1)
C	Kneehole height (standard office)	63.5 (25.0)
D	Desk to wall	81 (31.9)
E	Armrest to wall	61 (24.0)
F	Lateral work clearance	76 (30.0)
G	Height of work surface	73.5 (28.9)
H	Depth of work surface	--
	Elbow rest alone	10 (3.9)
	Writing surface	30.5 (12.0)

FIGURE 58. Seated workspace dimensions – Continued.

5.10.1.4.4 Workstation monitor placement. Monitor position depends upon and is determined by considering the factors of eye height, monitor size, viewing distance, and viewing angle. Vertically, the top of the monitor should be in line with the user's eye-line to the extent possible. Horizontally, the monitor should be directly in line with the keyboard to the extent possible (see figure 58). For grouping of multiple displays, see 5.17.15.8.

5.10.1.4.5 Workstation keyboard height. The keyboard is dependent on the height of the work surface and chair. The keyboard placement should be low enough so the upper arms can be relaxed at the sides to reduce tension in the shoulder muscles (see figure 58).

5.10.1.4.6 Workstation pointing device placement. The pointing device (e.g., mouse, trackball) should be positioned as close to the user's body as comfortably possible and on the same level as the keyboard (see figure 58).

5.10.1.5 Maintainability. Workspace and workstation design shall be in accordance with 5.9.

5.10.2 Workspace design.

5.10.2.1 Workspace composition. A workspace is comprised of a workstation asset (e.g., a work bench, table, or surface and equipment), and the interaction with the surrounding volume (three-dimensional) space and equipment encompassing the user. Users sometimes have to perform tasks where there is no dedicated workstation because of space limitations. In those situations, the surrounding area becomes the required workspace.

5.10.2.1.1 Task performance. Workspaces shall be provided to allow the user to perform all operational and maintenance tasks while wearing the appropriate clothing (e.g., winter, mission, and PPE) and using the required tools.

5.10.2.1.2 Adjustability. The workspace shall have provisions for adjustability (see 5.8.4.2.5) in order to encourage a neutral posture for each individual user and to facilitate periodic changes in posture.

5.10.2.2 Fixed and mobile workspace. Unless otherwise noted, fixed and mobile workspace design shall include consideration of all postures in accordance with 5.10.2.4.

5.10.2.2.1 Space reserved for controls. Space should be reserved for controls that must be operated frequently or are critical to tasks, placing controls in the optimum space permitting rapid and accurate identification, reaching and operation, and location of visual displays near the controls.

5.10.2.2.2 Space reserved for displays. The workstation or console shall accommodate the physical space requirements of the chosen displays for the tasks.

5.10.2.2.3 Touchscreen technology. For touchscreen technology implementation, display and control design features shall be in accordance with 5.1.3.1.

5.10.2.3 Temporary workspace. The user may conduct temporary tasks and may squat, kneel, or adjust body posture according to a fixed space. Situations where the user must assume an awkward body position shall be minimized.

5.10.2.3.1 Limited workspaces. If users must work in or pass through limited spaces, minimum clearances shall be in accordance with figure 59. These conditions are typically for maintenance-oriented type of tasks and are not recommended for combat tasks for the encumbered user.

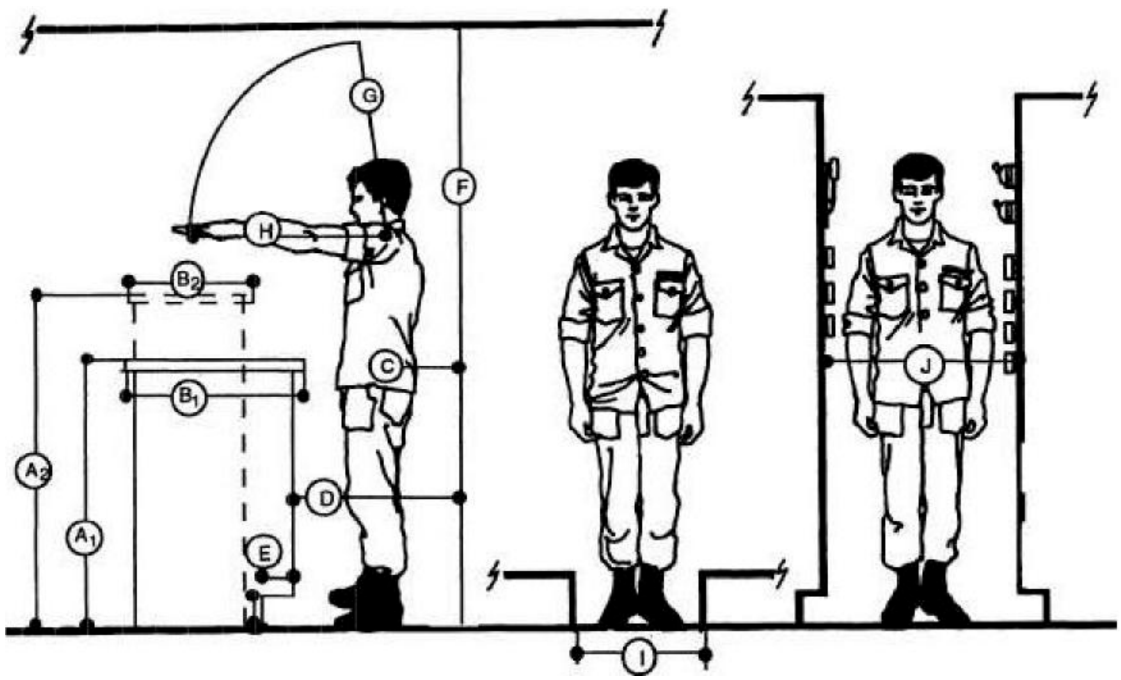


FIGURE 59. Standing workspace dimensions.

Work Benches			
A1	Standard type	Height	0.91 m (2.98 ft) above floor
B1	Standard type	Depth	1 m (3.24 ft)
A2	Podium type	Height	1.04 m (3.4 ft) above floor
B2	Podium type	Depth	0.91 m (2.98 ft)

Required Work Clearances				
		Required Minimum cm (in)	**Required to Accomplish a Task cm (in)**	**Arctic Clothed cm (in)**
C	Passing body depth	33.0 (12.9)	38.0 (14.9)	--
D	Standing space depth	76.0 (29.9)	91.0 (35.8)	--
E	Floor space (height x depth)	14.0 x 14.0 (5.5 x 5.5)	--	--
F	Overhead clearance height	189.5 (74.6)	203.0 (79.9)	--
G	Vertical index fingertip reach height	187.2 (74.3)	--	247.5 (97.5)
H	Functional grip reach	61.0 (24)	--	85.5 (33.6)
I	Walking space width	30.5 (12)	38.0 (14.9)	--
J	Passing body width	56.0 (22)	81.0 (31.8)	--

FIGURE 59. Standing workspace dimensions – Continued.

5.10.2.3.2 Temporary workspace dimensions. Temporary workspaces shall be in accordance with the dimensions on figure 60.

5.10.2.3.3 Minimum area. The general dimensions for the required minimum width and depth allowance shall be 68.5 cm (27 in) width and 91.4 cm (36 in) depth for a given posture. Figure 60 gives the specific postures to be considered in the design of the display and control area.

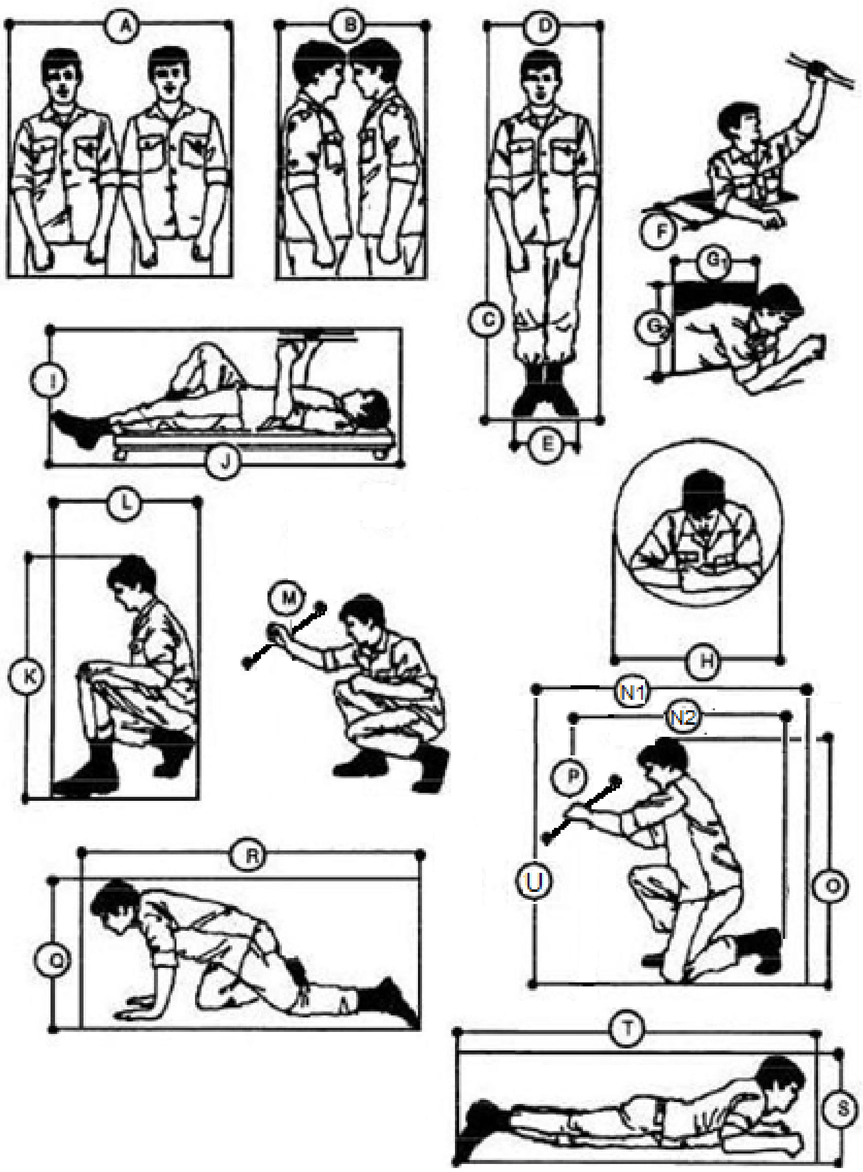


FIGURE 60. Temporary workspace dimensions.

	Required Minimum cm (in)	Required to Accomplish a Task cm (in)	Arctic Clothed cm (in)
A Two person passing abreast	111.7 (44.0)	137.0 (53.9)	153.0 (60.2)
B Two person passing facing	76.0 (29.9)	91.0 (35.8)	91.0 (35.8)
Catwalk Dimensions			
C Height	160.0 (63.0)	186.0 (73.2)	191.0 (75.2)
D Shoulder width	56.0 (22.0)	61.0 (24.0)	81.0 (32.0)
E Walking width	30.5 (12.0)	38.0 (14.9)	38.0 (15.0)
Vertical Entry Hatch			
F1 Square	45.0 (17.7)	56.0 (22.0)	81.0 (32.0)
F2 Round	56.0 (22.0)	61.0 (24.0)	--
Horizontal Entry Hatch			
G1 Shoulder width	53.5 (21.0)	61.0 (24.0)	81.0 (32.0)
G2 Height	38.0 (15.0)	51.0 (20.0)	61.0 (24.0)
H Crawl through pipe (round or square)	63.5 (25.0)	76.0 (29.9)	81.0 (32.0)
Supine Workspace			
I Height	51.0 (20.0)	61.0 (24.0)	66.0 (26)
J Length	186.0 (73.2)	191.0 (75.2)	198.0 (78)
Squatting Workspace			
K Height	122.0 (48.0)	--	129.0 (51.0)
M Width	68.5 (27.0)	91.0 (35.8)	--
L Depth	91.4 (36.0)	115.6 (45.5)	--
Kneeling Workspace			
N Depth	106.0 (41.7) (N2)	122.0 (48.0) (N1)	127.0 (50.0)
O and U Height	68.5 (27.0) (O)	142.0 (55.9) (U)	150.0 (59.0)
P Width	68.5 (27.0)	76.2 (30.0)	--
Kneeling Crawl Space			
Q Height	78.5 (30.9)	91.0 (35.8)	96.5 (38.0)
R Length	150.0 (59.0)	--	176.0 (69.3)
Prone Work or Crawl Space			
S Height	43.0 (16.9)	61.0 (24.0)	61.0 (24.0)
T Length	286.0 (112.6)	--	--

FIGURE 60. Temporary workspace dimensions – Continued.

5.10.2.3.4 Minimum area to accomplish a task. The required width and depth allowance to accomplish a task within the space shall be 76.2 cm (30 in) width and 115.6 cm (45.5 in) depth for a given posture.

5.10.2.3.5 Display type. The type of display selected shall comply with 5.2.2.8.

5.10.2.4 Personnel considerations. In establishing the workspace, consideration shall be given to user body postures required to do the work; the condition of the work being fixed, mobile, or temporary; the environment of the workspace; and the number of personnel required to perform the work.

5.10.2.4.1 Posture. Workspace design shall consider the body postures to include standing, sitting, squatting, and kneeling, among other relevant postures.

5.10.2.4.1.1 Neutral posture. To the maximum extent possible, a workspace shall allow personnel to maintain a neutral posture.

5.10.2.4.1.2 Changing posture. To the maximum extent possible, a workspace shall be designed to allow personnel to change their posture but maintain the ability to remain neutral depending on the posture change. Design of the workspace for adaptability and flexibility provides the ability for frequent changes in posture between standing and sitting or other required postures for accomplishing the task. Maintaining the same posture for long periods of time places the muscles in a constant state of contraction, which can lead to workplace musculoskeletal disorders (WMSDs); therefore, the ability to change posture is recommended to increase health and wellness factors and increase mission readiness.

5.10.2.4.1.3 Forward reach. Jobs requiring the user to lift an object or produce torque (e.g., turning a wrench) shall maintain a neutral posture.

5.10.2.4.2 Kick space. A kick space allows a user to stand or sit close to the front surface of a workstation or console and maintain a neutral posture. All cabinets, workstations, consoles, and work surfaces shall contain a kick space at the base at least 10 cm (4 in) deep and 10 cm (4 in) high to allow for standard footwear. Some oversized boots, such as the Arctic cold-weather boot, may require a larger kick space.

5.10.2.4.2.1 Boot dimensions. Kick space dimensions shall be adjusted from the above criteria to accommodate differences in footwear among the DoD services. Unless otherwise specified (see 6.2), footwear (boots that include the outer sole) shall accommodate the following dimensions for the largest allowable values (e.g., Air Force men's 17 EEEE or women's 11 EE, Army 14 regular). The dimensions account for all standard and special-case scenarios (e.g., CBRNE, extreme cold weather gear) for fielded Air Force and Army boots. For further information regarding non-military use, see ANSI/HFES 100.

a. Boot length: 40 cm (16 in).

b. Boot height: 29.2 cm (11.5 in).

c. Toe height: 11.4 cm (4.5 in).

d. Boot width: 15.2 cm (6 in).

5.10.2.4.2.2 Boots combined with PPE. Boots measuring outside of the above dimensions, such as when combined with PPE, shall be as specified (see 6.2).

5.10.2.5 Standing workspaces. Dimensions for standing workspaces shall be designed as shown on figure 59. Values are provided for the required amount of space for a physical body and for the ability to conduct a task within that physical space. For special or unique considerations, such as for arctic or encumbered soldier conditions, the work clearances should be reviewed for applicability in relation to figure 60 (see 5.8.4.2.3).

5.10.2.6 Sitting workspaces. Sitting workspaces shall be in accordance with figure 58. In general, if space allows for a seat to be used, the user should be provided a seat for extended tasks (longer than 20 minutes).

5.10.2.6.1 Workspace dimensions – height.

5.10.2.6.1.1 Minimum height. The minimum workspace height required to perform work at a task site shall be 150 cm (59 in) for seated operations.

5.10.2.6.1.2 Adjustable seat. The seat design shall provide for adjustability.

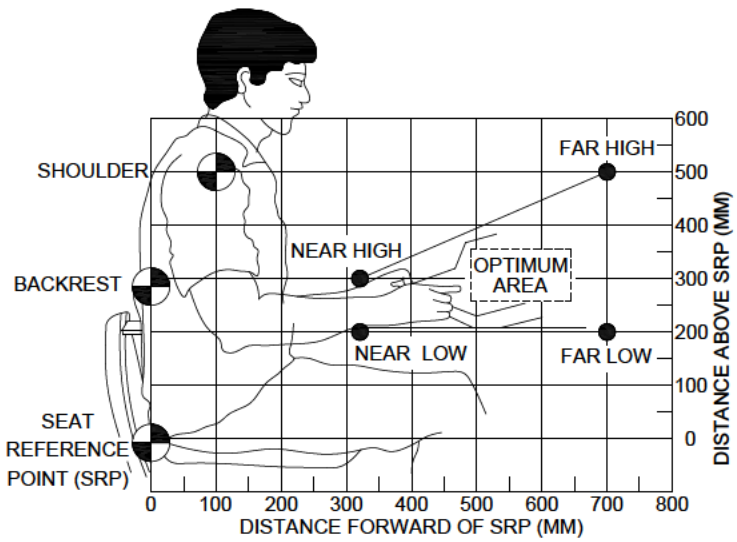
5.10.2.6.2 Workspace dimensions – width.

5.10.2.6.2.1 Minimum width. The workspace width provided to perform work at a task site shall be 83.7 cm (33 in) for seated operations.

5.10.2.6.3 Workspace dimensions – depth.

5.10.2.6.3.1 Minimum depth. The workspace depth provided to perform work at a task site shall be 137 cm (54 in) for seated operations.

5.10.2.6.4 Seated manual control space design. See figure 61 for seated control space design requirements for manual tasks.



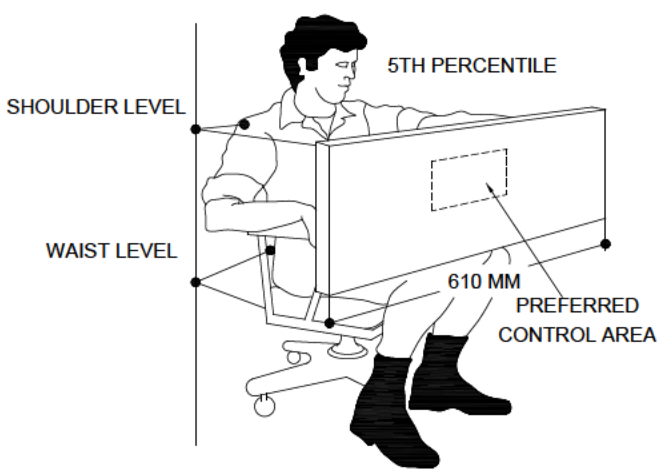


FIGURE 61. Seated manual control space.

5.10.2.6.5 Passing clearance. The lateral distance behind seated workstations is passing clearance as measured from the edge of the work surface (see figure 77).

5.10.2.6.5.1 Chair seat use. The lateral distance behind seated (e.g., bench, chair, stool) workstations (as measured from the edge of the work surface directly in front of the operator) to allow a person to walk behind a seated operator inclusive of a chair or stool shall be a minimum of 122 cm (48 in).

5.10.2.6.5.2 Clear space behind chair. The clear space behind the seated user should be an additional 15.2 cm (6 in) for a total passing clearance depth of 137 cm (53.9 in) as measured from the edge of the work surface.

5.10.2.6.5.3 Stool seat use. A minimum clear passing lane of 127 cm (50 in) shall be provided behind the seated user to allow a person to walk as measured from the edge of the work surface.

5.10.2.6.5.4 Clear space behind stool. The clear space behind the seated user should be an additional 15.2 cm (6 in) for a total passing clearance of 142 cm (56 in) as measured from the edge of the work surface.

5.10.2.7 Kneeling workspaces. Kneeling posture dimensions shall conform to figure 60. If space allows, the user should use a kneeling pad for extended tasks (longer than 20 minutes). The kneeling posture dimensions on figure 60 do not reflect the additional space required for a kneeling pad.

5.10.2.8 Squatting workspaces. Squatting posture dimensions shall conform to figure 60. If space allows, the user should use a seat for extended tasks (longer than 20 minutes).

5.10.2.9 Workspace environment considerations. In establishing the workspace, consideration shall be given to the environments in which the work will be performed. Not all environments should be assumed to have heating, cooling, or other workspace temperature regulation systems installed, or if available, accessible for adjustment. Operations may take place indoors or outdoors and in offices, ships, factories, tents, shelters, warehouses, or mechanical rooms. For design considerations of lighting and illumination, see 5.1.2.1.8, 5.2.1.2, and 5.5.3; for design considerations of heating and cooling, see 5.5.2.1.

5.10.2.9.1 Free floor space. Free floor space of not less than 122 cm (48 in) for the breadth of the workstation or console shall be provided in front of each workstation or console.

5.10.2.9.2 Hazard exposure. If a hazard (e.g., hot surface, electrical contact) exists within the user's reach envelopes, it shall be guarded, removed, or moved beyond the maximum reach of the user.

5.10.2.9.3 Flushing, draining, and venting. Flushing, draining, and venting facilities shall be provided to discharge in a manner that does not place the contents of the pipe onto walking surfaces or into workspaces where personnel could be hit by the discharge or become a hazard.

5.10.2.9.4 Valves. Valves shall be installed in accordance with 5.14.

5.10.2.9.5 Workbench location. Unless the hazard is guarded, workbenches shall not be located within 1 m (3.2 ft) of rotating shafts, hot or cold piping, or any other hazard that a crewmember could come in contact with due to unexpected motion or other circumstance.

5.10.2.9.6 Eliminate interference among crewmembers. The workspace shall be designed to eliminate interference among crewmembers during operation or maintenance to avoid hazardous situations or reduce performance.

5.10.2.9.7 Avoid simultaneous tasks. Multiple simultaneous tasks shall be avoided unless the workspace has been specifically designed to allow such tasks to be performed without interfering with each other.

5.10.2.9.8 Noise control. Noise control for different environments shall be in accordance with 5.5.4 and MIL-STD-1474.

5.10.2.9.9 Guards. Guards shall be provided to minimize exposing the user to dangerous conditions, such as rotating equipment, hot or cold points, exposed electrical wiring, or crushing points. For guard design as it relates to "accidental actuation," see 5.1.1.7, 5.1.4.2.1.7.2, and 5.1.4.2.1.8.6.

5.10.2.9.9.1 Removal of guards. It shall not be possible to remove guards during operation.

5.10.2.9.9.2 Tools. During maintainer tasks, tools shall be required for removal of guards.

5.10.2.9.9.3 Accessibility. Guards shall be accessible from at least two sides (i.e., a guard over a rotating shaft shall be accessible from either side of the shaft).

5.10.2.9.10 Window placement. For ship bridge design considerations, see 5.18.

5.10.2.9.10.1 Standing operations. The lower edge of the window shall be no higher than 1.32 m (52 in) and the upper edge no lower than 1.85 m (74 in) above the floor.

5.10.2.9.10.2 Seated operations. Seated workstations requiring vision through windows shall be designed such that the lower edge of the window is no higher than 100 cm (39 in) above the floor on which the chair sits.

5.10.2.9.10.3 Reflections. Where reflection from window glass could be a problem, the window should be angled from the vertical, top-out, and bottom-in 15 degrees, but in no case shall the angle be less than 8 degrees or more than 25 degrees. Adjustability of the windows shall be considered for meeting the requirement.

5.10.2.9.11 Terrain. Some terrain where mobile or temporary workspaces are required to be used may have uneven surfaces, such as loose ground, gravel, or sand. Design of workspaces shall provide some adjustment means to obtain level and stable work surfaces.

5.10.3 Workstation design. Workstation designs are separated into categories. These categories can be further broken down into subcategories of “standing” and “seated” or a combination (hybrid) of the two. These design requirements for both standing and seated workstations apply to non-IT and IT workstations with specific references being called out for each. As the nature of IT (computer) and seated manufacturing and assembly work is sedentary, these workstations involve prolonged postures without any whole-body movement. This extended sedentary posture can have negative effects on human health. As a general rule, stationary workers should work in a variety of postures to include sitting and standing, which can be accomplished through adjustable workstations, job or shift rotation, and cross-functional training of the user. The categories are as follows:

a. Fixed (i.e., permanently located tasks).

b. Mobile.

c. Short-term or temporary.

5.10.3.1 General design. All general design criteria applies to both fixed and mobile workstations unless specific differences are introduced within the applicable paragraphs.

5.10.3.1.1 Design for the worker. Workstations shall be designed for the worker, not the work.

5.10.3.1.2 Design for required operations. Workstations shall be designed for fixed, mobile, or short-term (i.e., temporary) operations as appropriate for the required tasks.

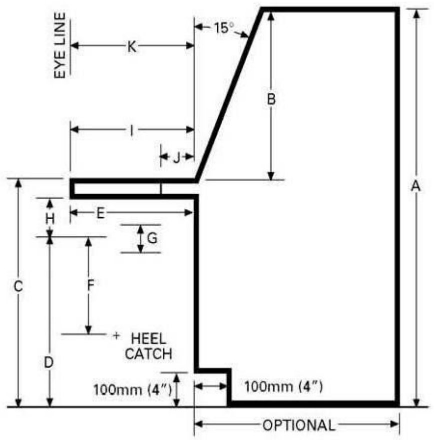
5.10.3.1.3 Adjustable. Workstations shall be as adjustable as possible (i.e., dimensions of chairs, desks, and workbenches). See ANSI/HFES 100 for more information on user postures.

5.10.3.1.4 Display viewing and illumination. Workstations shall consider display distances (see 5.2.2.11.6 and 5.2.2.12.8 for criteria on large screen displays) and illumination levels (see 5.5.3) to accommodate the user.

5.10.3.1.5 Level surface. Workstations shall be placed on floor, deck surfaces, or terrain that is flat or can be leveled to prevent instability and injury.

5.10.3.2 Fixed workstations. Fixed workstations are permanently located without expectation of being relocated and may have a user’s presence for long, sustained periods of time. Workstations may be assembled from individual components or integrated into a unit, cabinet, or console.

5.10.3.2.1 Console selection. A console is a type of fixed workstation. Console workstations (i.e., terminals and instrument panels) consist of integrated input and output devices like a display with keyboard, pointing device, switches, and knobs, all of which assist the user to monitor or control the status of a system. When the workstation design warrants a console configuration, the configuration that will best meet the requirements shall be selected from the five console types represented on figure 62.



Dimension	Description	Measurement
A	Maximum total console height from standing surface.	1/
B	Suggested vertical dimension of panel, including sills.	1/
C	Writing surface: shelf height from standing surface.	1/
D	Seat height from standing surface at midpoint of "G".	1/
E 2/	Minimum knee clearance.	46 cm (18 in)
F 2/ 3/	Foot support to sitting surface.	46 cm (18 in)
G 2/	Seat adjustability.	15 cm (6.0 in)
H 2/	Minimum thigh clearance at midpoint of "G".	19 cm (7.5 in)
I	Writing surface depth including shelf.	40 cm (16 in)
J	Minimum shelf depth.	10 cm (4.0 in)
K	Eye line-to-console front distance.	40 cm (16 in)

FOOTNOTES:

1/ For "A" through "D", see below.

2/ Not applicable to console types 4 and 5 of table below.

3/ Since this dimension must not be exceeded, a heel catch shall be added to the chair if "D" exceeds 40 cm (16 in).

NOTE: A shelf thickness of 2.5 cm (1.0 in) is assumed. For other shelf thicknesses, adjustments shall be made.

FIGURE 62. 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**			
	cm	**in**	**cm**	**in**	**cm**	**in**	**cm**	**in**	**cm**	**in**
1. Sit (with vision over top) [1/]	117	46	52	20.5	65	25.5	43	17	112	44
	134	52.5	52	20.5	81	32	59	23.5	112	44
	144	56.5	52	20.5	91	36	69	27.5	112	44
2. Sit (without vision over top)	131	51.5	66	26	65	25.5	43	17	112	44
	147	58	66	26	81	32	59	23.5	112	44
3. Sit-stand (with standing vision over top)	157	62	66	26	91	36	69	27.5	112	44
	154	60.5	62	24.5	91	36	69	27.5	112	44
4. Stand (with vision over top)	154	60.5	62	24.5	91	36	N/A	N/A	152	60
5. Stand (without vision over top)	183	72	91	36	91	36	N/A	N/A	152	60

NOTE:
[1/] 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”.

FIGURE 62. Standard console dimensions – Continued.

5.10.3.2.2 User population. The console type shall be consistent with the target user population (see 5.8.2.1).

5.10.3.3 Mobile workstations.

5.10.3.3.1 Reconfiguration. Mobile workstations shall have the capability to be relocated or reconfigured within environment boundaries or operational constraints.

5.10.3.3.2 Design considerations. Design considerations that shall be addressed when constructing a mobile workstation include weight, portability, and durability (see 5.10.2.9).

5.10.3.3.3 Design elements. The elements of weight, portability, and durability have a relationship to the overall design considerations for a mobile workstation and shall be evaluated within the context of the system's operational requirements.

5.10.3.3.4 Weight. The weight of a mobile workstation shall be minimized.

5.10.3.3.5 Portability. A mobile workstation shall allow for portability by including features for ease of the system to be dismantled and set up repetitively.

5.10.3.3.6 Durability. A mobile workstation shall be designed for durability to withstand damage by physical impacts during operation, movement, and transportation.

5.10.3.4 Temporary workstations. For requirements related to temporary workspaces, see 5.10.2.3.

5.10.3.5 Workstation configuration design to accommodate posture. Workstation configurations are divided into three categories, which are standing workstations, sitting workstations, and sit-stand workstations. These categories may be employed in fixed, mobile, or temporary conditions. Design considerations shall include the factors that will benefit from the advantages of workstation configurations of posture configurations and conditions that are listed in table XXXIII, in relation to the defined task.

TABLE XXXIII. Advantages of workstation configurations by type.

Sitting Workstations	Standing Workstations	Sit-Stand Workstations
Sitting relieves the stress to the back muscles when standing for a long period of time.	Standing relieves disc pressure and stress caused by the greater curvature of the back that happens when sitting.	Users can sit when the stress to the back legs, hips, back, and neck muscle groups become painful when standing for a long period of time, or stand when the stress caused by the greater curvature of the back that sitting creates becomes painful from sitting.
Sitting relieves the constant state of contraction muscles are in when standing for long periods of time, especially to the legs, hips, and neck muscles.	Users can change postures, to reduce fatigue and boredom; many standing tasks can be done in either a sitting or a standing posture.	Users can change postures to reduce fatigue and boredom.
Sitting uses less energy than standing.	Users can move to see and use components in spaces that would be inaccessible to seated users.	Users can move to see and use components in spaces that would be inaccessible to seated users.

TABLE XXXIII. Advantages of workstation configurations by type – Continued.

Sitting Workstations	Standing Workstations	Sit-Stand Workstations
The performance of fine motor skills is not as good when people stand rather than sit.	User's arms can apply more muscular force and make larger movements when at a standing workstation (see 5.10.3.8.2.6.2.c).	N/A
N/A	Standing saves space; the users can use flat working surfaces without requiring additional knee room.	N/A

5.10.3.5.1 Reach. The location of machinery or equipment to grasp and turn, push, or pull shall be 61 cm (24 in) from the front of the user's body.

5.10.3.5.2 Work surface. The type of task (e.g., manual labor, use of IT) shall be considered when designing a work surface (see 5.10.3.8, 5.10.3.9, and 5.10.3.13).

5.10.3.6 General display design requirements. The placement of traditional (non-touchscreen) displays on the workstation or console for precise and gross monitoring shall meet the criteria in 5.10.3.6.1 through 5.10.3.6.1.5.

5.10.3.6.1 Line of sight requirements.

5.10.3.6.1.1 Touchscreen design. For touchscreen design, see 5.1.3.1.

5.10.3.6.1.2 Primary displays. Frequently-monitored primary displays shall be between the minimum and maximum display mounting heights (figures 69 and 71) and within the optimal visual zone.

5.10.3.6.1.3 Accurate readout. Displays requiring accurate readout shall be located closer to the user's line of sight than displays requiring only gross monitoring.

5.10.3.6.1.4 Display mounting. Displays shall be mounted perpendicular to the line of sight.

5.10.3.6.1.5 Angular deviation. Angular deviation from the line of sight shall not exceed 45 degrees from center, provided accurate instrument reading is not essential and parallax does not detract from readability.

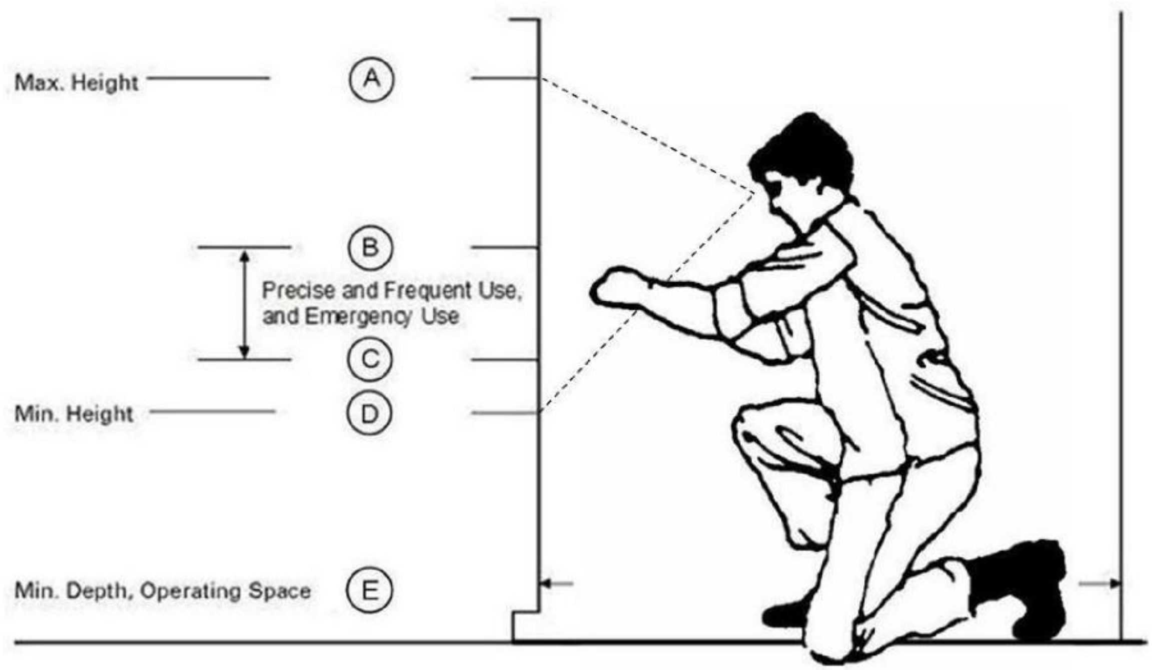
5.10.3.6.2 Uninterrupted time periods. Display(s) that are used for long, uninterrupted periods (longer than 15 minutes) shall be arranged to allow the user to assume the neutral posture (see 5.10.2.1.2 and 5.10.2.4.1.1).

5.10.3.6.3 Head posture. All displays shall be readable from the user's normal head posture, allowing for normal head rotation and for restrictions imposed by helmets or other head gear.

5.10.3.6.4 Display grouping. All displays necessary to support a critical user activity or sequence of activities shall be grouped together.

5.10.3.6.5 Control/display accessibility. If a workstation requires controls or displays, all controls, including foot-operated controls, and displays shall be reachable and readable from the normal work body postures without having to assume awkward or uncomfortable postures.

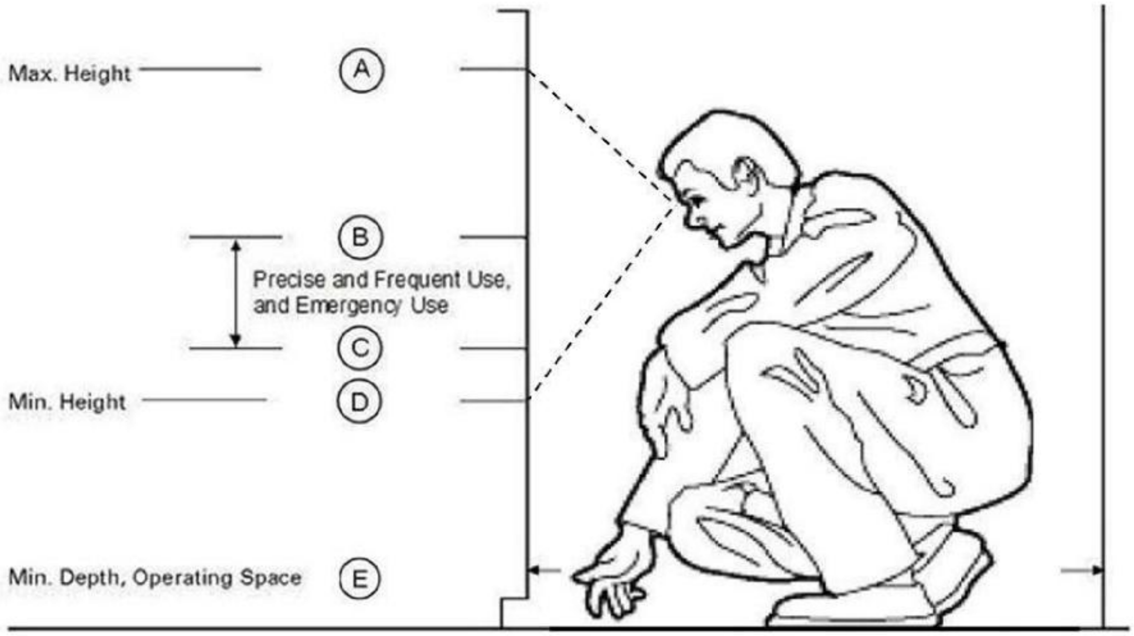
5.10.3.6.5.1 Display mounting height – kneeling. Mounting heights for displays mounted on a vertical surface, such as a bulkhead or panel for use by a kneeling person, shall fall within the range of dimensions A and D (dimensions B and C preferred) of figure 63. Mounting heights for displays that require precise reading, frequent access, or emergency use, shall fall within the range of dimensions B and C of figure 63.



Dimension	Value cm (in)
Maximum height (A)	145 (57)
Maximum height for displays requiring precise reading, frequent access, or emergency use (B)	132 (52)
Minimum height for displays requiring precise reading, frequent access, or emergency use (C)	95 (37)
Minimum height (D)	71 (28)
Minimum depth, operating space (E)	106 (41.7)

FIGURE 63. Display mounting heights for kneeling personnel.

5.10.3.6.5.2 Display mounting height – squatting. Mounting heights for displays mounted on a vertical surface, such as a bulkhead or panel for use by a squatting person, shall fall within the range of dimensions A and D (dimensions B and C preferred) of figure 64. Mounting heights for displays that require precise reading, frequent access, or emergency use shall fall within the range of dimensions B and C of figure 64.



Dimension	Value cm (in)
Maximum height (A)	125 (49)
Maximum height for displays requiring precise reading, frequent access, or emergency use (B)	102 (40)
Minimum height for displays requiring precise reading, frequent access, or emergency use (C)	63.5 (25)
Minimum height (D)	50.8 (20)
Minimum depth, operating space (E)	91.4 (36)

FIGURE 64. Display mounting heights for squatting personnel.

5.10.3.7 General control design requirements. The design shall be in accordance with the applicable requirements of 5.1.2 and figure 62, depending on the type of workstation.

5.10.3.7.1 General requirements.

5.10.3.7.1.1 Primary controls. Primary controls shall be located between shoulder level and waist height.

5.10.3.7.1.2 Simultaneous operation. Controls shall be located so that simultaneous operation of two controls will not necessitate crossing or interchanging hands.

5.10.3.7.1.3 Frequent operation. When controls are operated frequently, they shall be located to the left-front or right-front of the user.

5.10.3.7.1.4 Grouping of frequently-used controls. Frequently-used controls shall be grouped together, unless there are overriding reasons for separating them.

5.10.3.7.1.5 Right-hand operation. Frequently-used controls shall be located for right-hand operation.

5.10.3.7.1.6 Maximum reach. All controls shall be within the maximum reach of the seated user (see figure 61).

5.10.3.7.1.6.1 Placement of frequently-used controls. Frequently-used controls shall be within a radius of 40 cm (15.7 in) from the normal working position.

5.10.3.7.1.6.2 Placement of occasionally-used controls. Occasionally-used controls shall be within a radius of 50 cm (19.6 in) from the normal working position.

5.10.3.7.1.6.3 Placement of infrequently-used controls. Infrequently-used controls shall be within a radius of 70 cm (27.5 in) from the normal working position.

5.10.3.7.1.6.4 Placement for visual access. Controls shall be located where the user can see them to check the control position, regardless of the viewing angle.

5.10.3.7.1.7 Fine adjustments. Controls requiring fine adjustments shall be located closer to the user's line of sight than controls requiring gross positioning.

5.10.3.7.1.8 Control manipulation. When the user must manipulate controls while monitoring the display, the controls shall be placed close to and directly below that display.

5.10.3.7.1.9 Infrequently-used controls. Controls that are used infrequently shall be placed to one side to prevent inadvertent activation.

5.10.3.7.1.10 Occasionally-used controls. Occasionally-used controls may be mounted behind hinged doors or recessed into the panel to reduce distraction and prevent inadvertent operation. If, because of space constraints, controls must be placed where users must locate them without seeing them, the design shall consider the following error tendencies:

a. When controls are above shoulder level, users tend to reach too low.

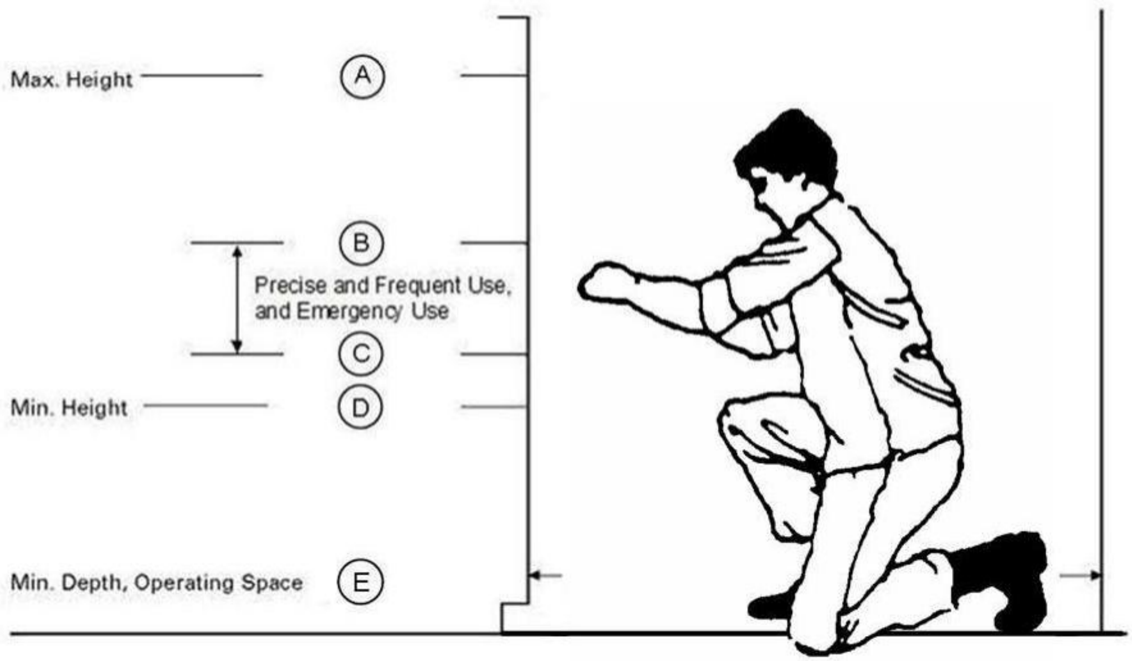
b. When controls are on either side of the user, the user tends to reach too far to the rear.

c. When controls are placed below shoulder level, users tend to reach too high.

5.10.3.7.1.11 Shape coding. When controls need to be placed where users cannot see them, shape coding shall be considered in their design to aid the user in detecting the correct control by touch.

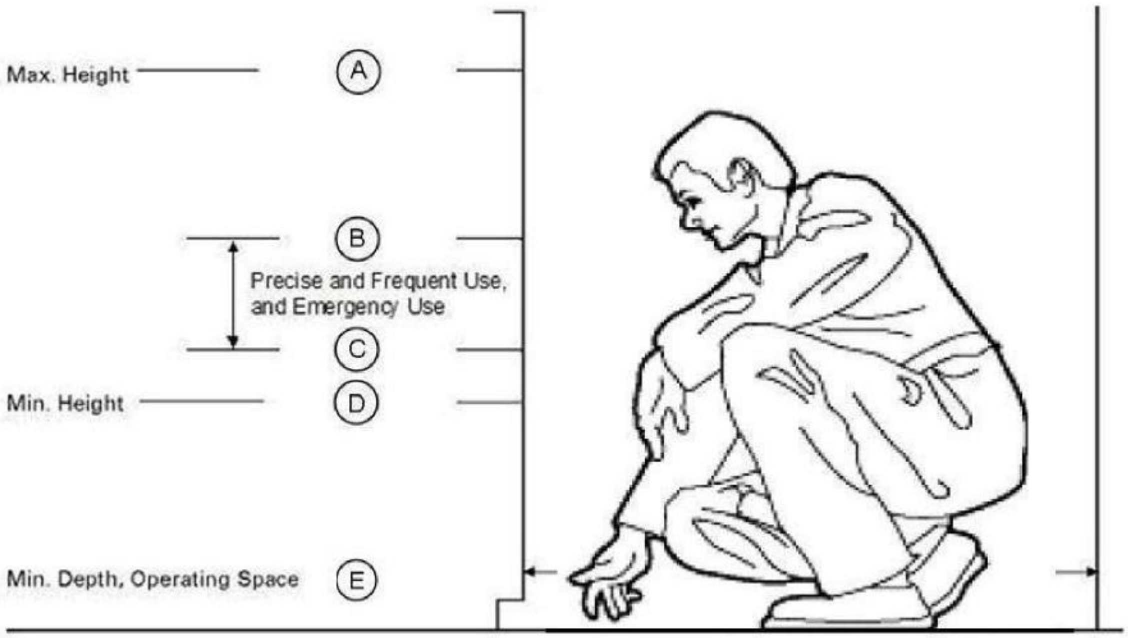
5.10.3.7.2 Control mounting height – kneeling. Mounting heights for the placement of valves or other controls for a kneeling worker to manipulate equipment or machinery at a task site shall fall within the range of dimensions A and D (dimensions B and C preferred) of figure 65. Mounting heights for displays that require precise reading, frequent access, or emergency use shall fall within the range of dimensions B and C of figure 65.

5.10.3.7.3 Control mounting height – squatting. Mounting heights for controls mounted on a vertical surface, such as a bulkhead or panel for use by a person in a squatting posture, shall fall within the range of dimensions A and D (dimensions B and C preferred) of figure 66. Mounting heights for displays that require precise reading, frequent access, or emergency use shall fall within the range of dimensions B and C as shown on figure 66.



Dimension	Value cm (in)
Maximum height (A)	145 (57)
Maximum height for controls requiring precise reading, frequent access, or emergency use (B)	132 (52)
Minimum height for controls requiring precise reading, frequent access, or emergency use (C)	54 (21)
Minimum height (D)	45.7 (18)
Minimum depth, operating space (E)	106 (41.7)

FIGURE 65. Control mounting heights for kneeling personnel.



Dimension	Value cm (in)
Maximum height (A)	125 (49)
Maximum height for controls requiring precise reading, frequent access, or emergency use (B)	81.3 (32)
Minimum height for controls requiring precise reading, frequent access, or emergency use (C)	40 (16)
Minimum height (D)	36 (14)
Minimum depth, operating space (E)	106 (41.7)

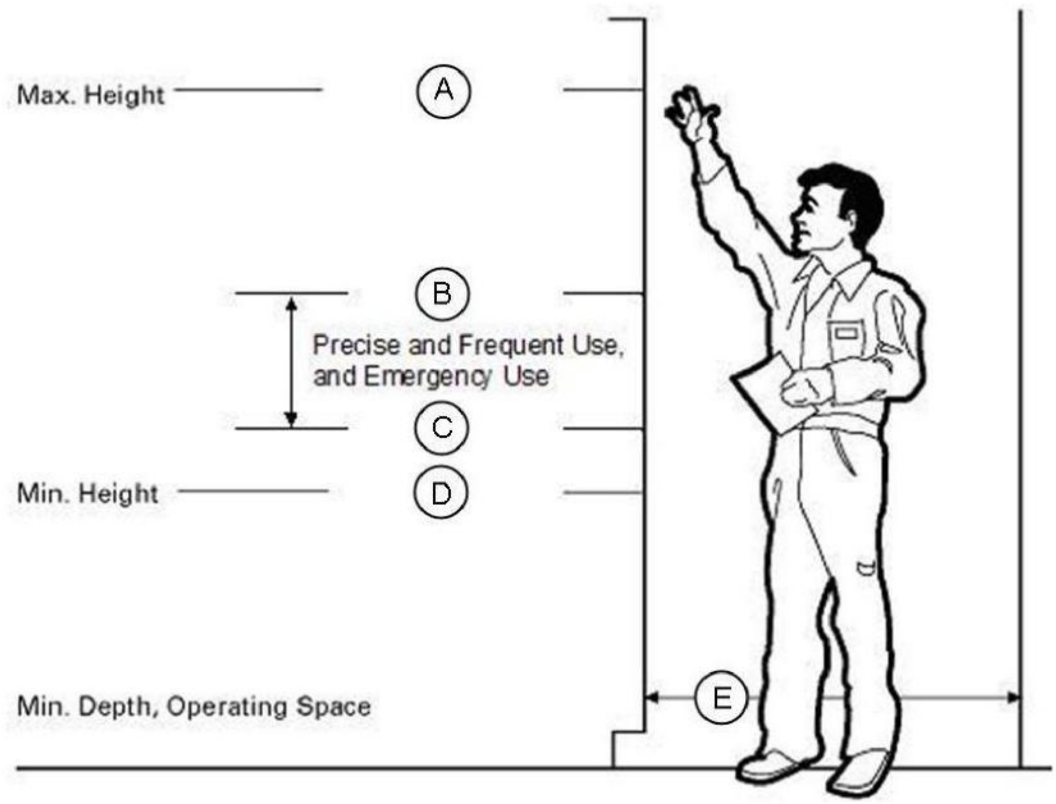
FIGURE 66. Control mounting heights for squatting personnel.

5.10.3.8 Standing workstation design. The type of task (e.g., manual labor, use of IT) shall be considered when designing a standing workstation.

5.10.3.8.1 Standing posture considerations. In the event a workstation design does not accommodate a certain part of the intended user population, a height enhancement device to achieve vertical distance improvements should be considered but shall be designed and engineered to meet the requirements herein.

5.10.3.8.2 Standing workstation control placement.

5.10.3.8.2.1 Control mounting height. Controls mounted on a vertical surface, such as a bulkhead or panel for use by a standing person, shall fall within the range of dimensions A and D (dimensions B and C preferred) of figure 67. Mounting heights for controls that require precise reading, frequent access, or emergency use shall fall within the range of dimensions B and C as shown on figure 67.



Dimension	Value cm (in)
Maximum height (A)	188 (74)
Maximum height for controls requiring precise reading, frequent access, or emergency use (B)	139.7 (55)
Minimum height for controls requiring precise reading, frequent access, or emergency use (C)	86.4 (34)
Minimum height (D)	76 (29.9)
Minimum depth, operating space (E)	76 (29.9)

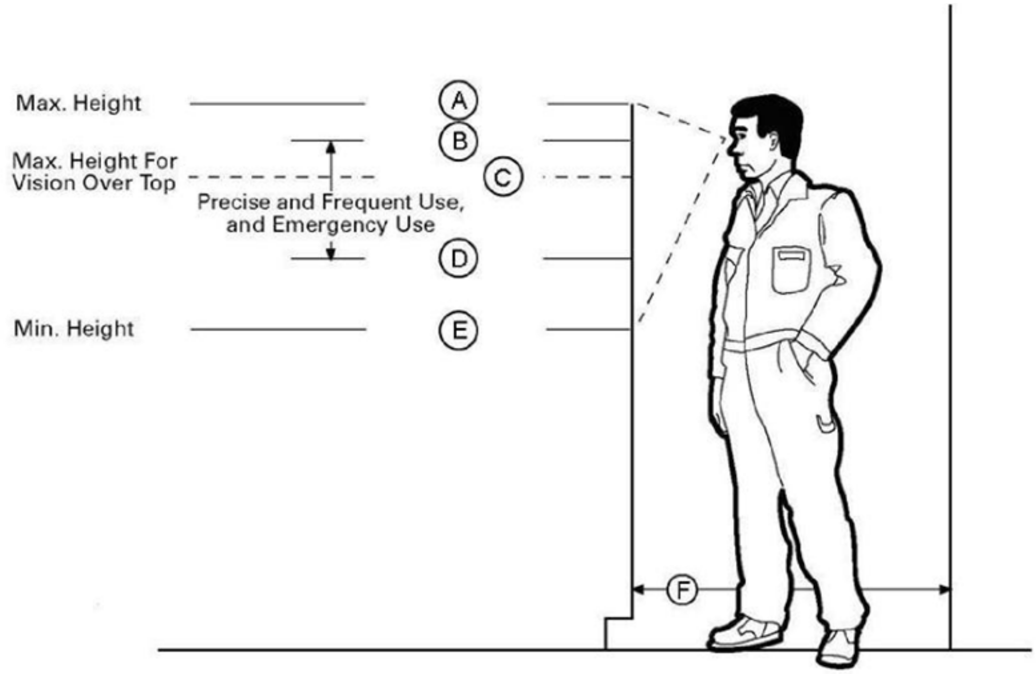
FIGURE 67. Control mounting height.

5.10.3.8.2.2 Standing overhead extended reach. Where overhead extended reach is required for a standing user to operate a control, such as pushing a button, the maximum extended reach (i.e., pushing a button) shall be 191.2 cm (75.3 in). Controls requiring an extended reach should be avoided.

5.10.3.8.2.3 Distance from centerline. Standing overhead extended reach shall be used no farther than 53 cm (21 in) laterally from the centerline.

5.10.3.8.2.4 Standing overhead gripping reach. Where overhead gripping reach is required for a standing user to operate a control, such as grasping a knob or turning a handle, the maximum gripping reach (i.e., grasping a knob or turning a handle) shall be 181 cm (71.2 in).

5.10.3.8.2.5 Standing eye height. For general tasks, the range for standing workstation eye height for display mounting shall fall within the range of dimensions A and E (dimensions B and D preferred) of figure 68. Mounting heights for displays that require precise reading, frequent access, or emergency use shall fall within the range of dimensions B and D as shown on figure 68.



Dimension	Value cm (in)
Maximum height (A)	177.8 (70)
Maximum height for displays requiring precise reading, frequent access, or emergency use (B)	165.1 (65)
Maximum overlook height (C)	143.2 (56.4)
Minimum height for displays requiring precise reading, frequent access, or emergency use (D)	139.7 (55)
Minimum height (E)	104 (41)
Minimum depth, operating space (F)	76 (29.9)

FIGURE 68. Display mounting height.

5.10.3.8.2.6 Standing work surface design.

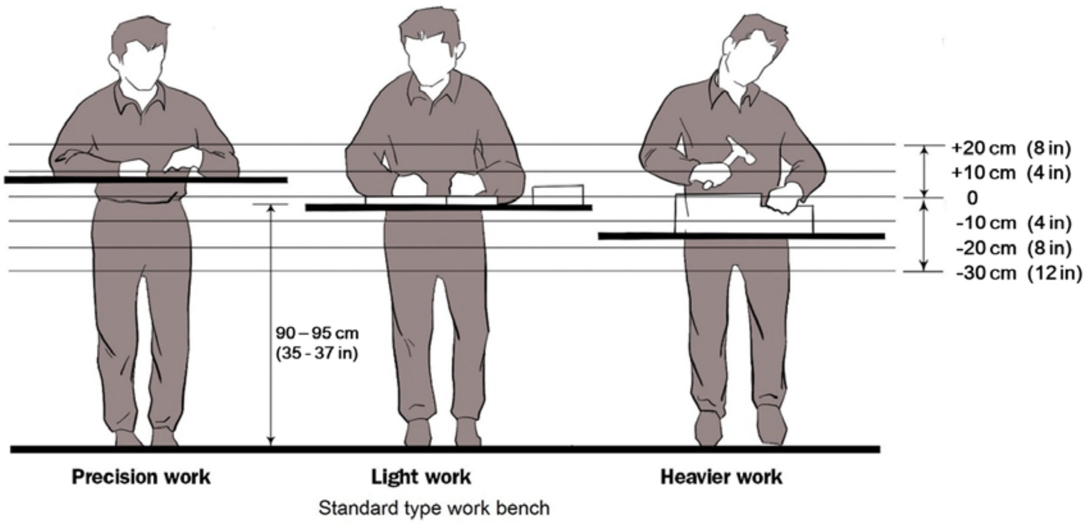
5.10.3.8.2.6.1 Fixed. The height of any fixed work surface shall be designed to fit the specific type of work being performed. The range height of the expected work shall account for the type of work bench as defined on Figure 59, standard type.

5.10.3.8.2.6.2 Adjustability. In accordance with standard type work bench design (figure 59), the height of any adjustable work surface shall be adjusted to fit the individual to the specific type of work being performed as illustrated on figure 69.

a. Delicate, precision work (e.g., drawing) is best performed when the elbow is supported to help reduce static loads in the muscles of the back. Design shall accommodate a range of 95.2 to 123.1 cm (37.5 to 48.5 in).

b. When performing light manual work at a required height of 90 to 95 cm (35.4 to 37.4 in), the workstation shall be no higher than the delicate, precision work height. The worker often needs space for tools, materials, and containers of various kinds.

c. When performing heavier manual work, the workstation shall be no higher than the delicate precision work height. Heavier work that involves much effort and use of the weight of the upper part of the body (e.g., woodworking or heavy assembly work) shall be done at a lower working surface.



NOTE: The level of physical exertion determines the optimum height of a workstation, which includes defining the volume of the type of work to be accomplished and adjusting the top of the work surface appropriately.

FIGURE 69. Work surface height.

5.10.3.8.2.6.3 Fixed-height work surfaces for documents. Unless otherwise specified (see 6.2), fixed height work surfaces to support documents, such as job instruction manuals or worksheets, shall be 90 to 93 cm (35.4 to 36.6 in) above the standing surface.

5.10.3.8.2.6.4 Fixed-height work surfaces for controls. If the work surface is being used for locating certain types of controls, such as a joystick, track ball, and keyboards, it shall be 102 to 107 cm (40.1 to 42.1 in) above the standing surface.

5.10.3.8.2.6.5 Combination work surface and control panel. When combining a horizontal workspace and a control panel, the design shall ensure that users will have a large enough workspace (minimum of 25 cm [9.8 in] deep) and that users will be able to reach the control panel (maximum of 40 cm [15.7 in] deep). For design considerations of controls, see 5.1.

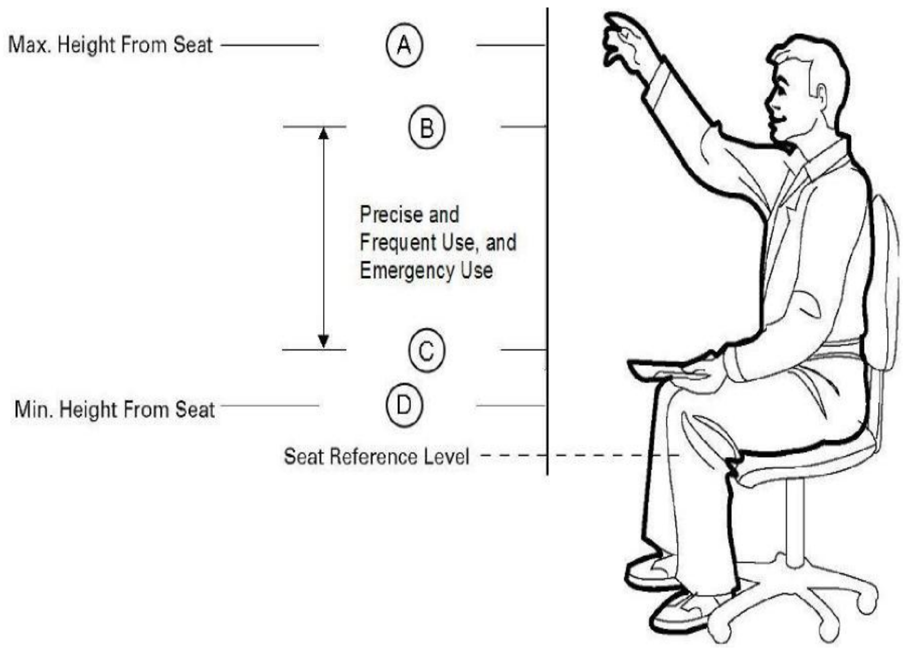
5.10.3.8.3 Standing workstation display placement. Displays mounted on a vertical surface, such as a bulkhead or panel for use by a standing person, shall be mounted as shown on figure 68.

5.10.3.8.4 Equipment racks. For design considerations of equipment racks and corresponding workspace, see 5.9 and figure 67.

5.10.3.9 Sitting workstation design. The type of task (e.g., manual labor, use of IT) shall be considered when designing a sitting workstation.

5.10.3.9.1 Sitting posture considerations.

5.10.3.9.1.1 Control mounting height. Controls mounted on a vertical surface, such as a bulkhead or panel for use by a seated person, shall fall within the range of dimensions A and D (dimensions B and C preferred) of figure 70. Mounting heights for controls that require precise reading, frequent access, or emergency use shall fall within the range of dimensions B and C as shown on figure 70.



Dimension	Value – cm (in) (above seat reference level)
Maximum height (A)	106.7 (42)
Maximum height for controls requiring precise reading, frequent access, or emergency use (B)	86 (32)
Minimum height for controls requiring precise reading, frequent access, or emergency use (C)	20.3 (8)
Minimum height (D)	15 (6)
NOTE: All values require adding in the seat reference level to arrive at a total height from the floor.	

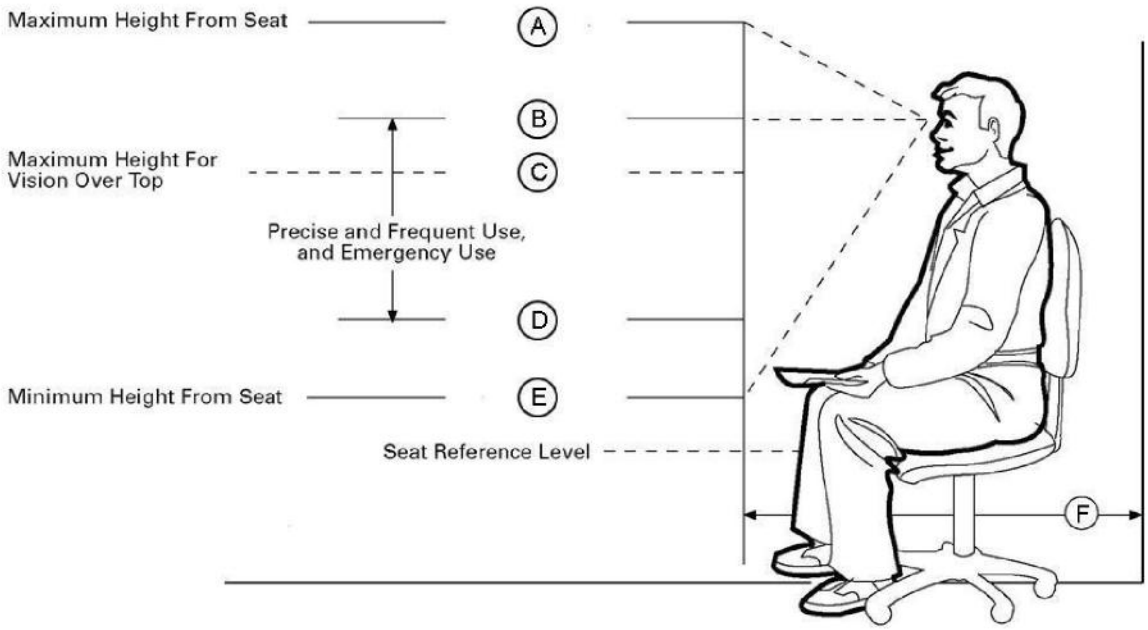
FIGURE 70. Control mounting heights for seated personnel.

5.10.3.9.1.2 Sitting overhead extended reach. Where overhead extended reach is required for a seated user to operate a control (i.e., pushing a button), the maximum extended reach shall be 117 cm (46 in) above the seated surface. Controls requiring an extended reach should be avoided.

5.10.3.9.1.3 Sitting overhead gripping reach. Where overhead gripping reach is required for a seated user to operate a control (i.e., grasping a knob or turning a handle), the maximum gripping reach shall be 106.7 cm (42 in) above the seated surface.

5.10.3.9.1.4 Sitting eye height. For general tasks, the range for sitting workstation eye height, measured from the top of the seat pan surface, should be 68.6 to 87.5 cm (27 to 34.45 in).

5.10.3.9.1.5 Sitting display mounting height. Mounting heights for displays mounted on a vertical surface, such as a bulkhead or panel for use by a sitting person, shall fall within the range of dimensions A and E (dimensions B and D preferred) of figure 71. Mounting heights for displays that require precise reading, frequent access, or emergency use shall fall within the range of dimensions B and D of figure 71.



Dimension	Value - cm (in) (above seat reference level)
Maximum height (A)	111.8 (44)
Maximum height for displays requiring precise reading, frequent access, or emergency use (B)	90 (35)
Maximum height for vision over the top (C)	68.6 (27)
Minimum height for displays requiring precise reading, frequent access, or emergency use (D)	35.6 (14)
Minimum height (E)	15.2 (6)
NOTE: All values require adding in the seat reference level to arrive at a total height from the floor.	

FIGURE 71. Display mounting heights for seated personnel.

5.10.3.9.2 Sitting work surface design. Desktops, tabletops, and work benches are all considered work surfaces relating to manual work and not requiring the use of IT.

5.10.3.9.2.1 Work surface width and depth. A lateral workspace not less than 76 cm (30 in) wide and 40 cm (16 in) deep shall be provided.

5.10.3.9.2.2 Work surface height. Unless otherwise specified (see 6.2), work benches, desktops, and writing tables shall be 74 to 79 cm (29 to 31 in) above the floor.

5.10.3.9.2.3 Writing surfaces. Writing surfaces shall be not less than 40 cm (16 in) deep and 61 cm (24 in) wide.

5.10.3.9.2.4 Sitting at tables. For single or multiple persons sitting at tables (adjoining or separate table spaces), the dimensions shown on figure 72 shall be provided.

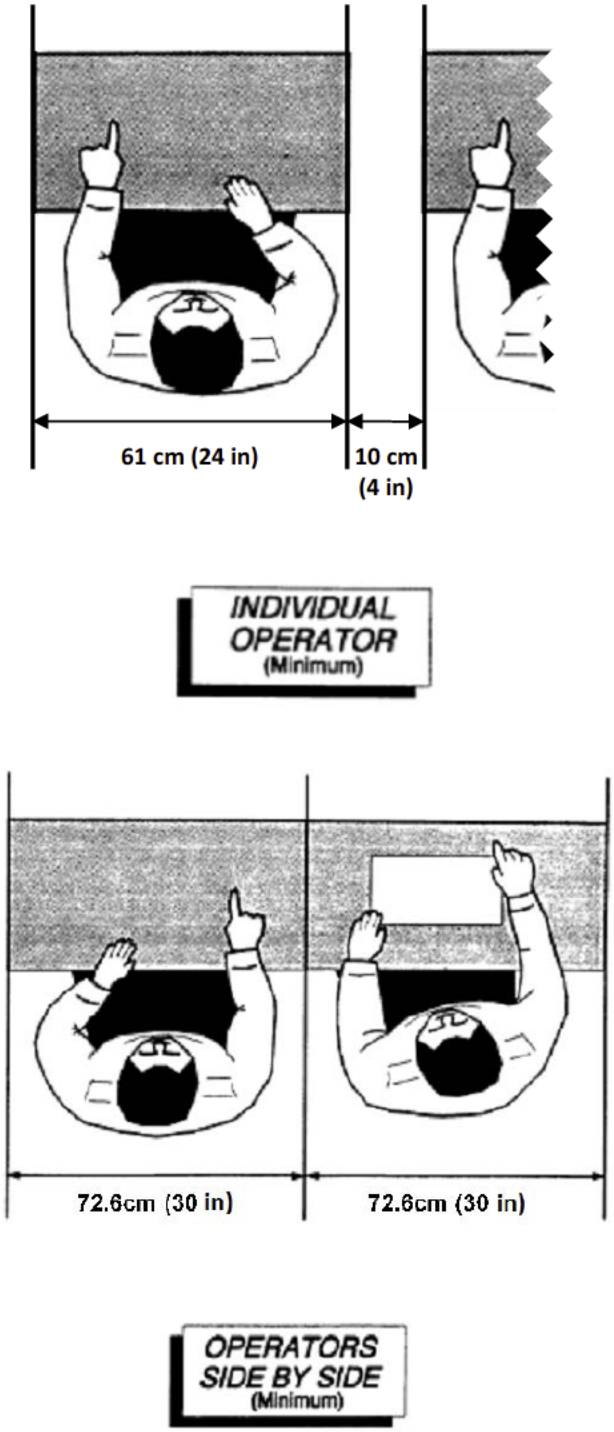


FIGURE 72. Dimensions for single or multiple personnel at a table or other duty station not requiring a desk.

5.10.3.9.2.5 Lower leg clearance. Knee and foot room not less than 64 cm (25 in) high, 51 cm (20 in) wide, and 46 cm (18 in) deep shall be provided beneath work surfaces; however, if a fixed footrest or a foot-operated control is provided, the height dimension shall be increased accordingly.

5.10.3.9.3 Sitting workstation display placement.

5.10.3.9.3.1 Vertical surface. Mounting heights for displays on a vertical flat surface, such as a panel or bulkhead for use by a seated person, shall be as shown on figure 71.

5.10.3.9.3.2 Horizontal arrangement.

5.10.3.9.3.2.1 Single display. For a single display workstation or console, a display that must be read precisely and frequently shall be located no farther than 53 cm (21 in) laterally from the centerline.

5.10.3.9.3.2.2 Multiple displays. Displays that are used frequently or must be read precisely should be placed as close to the centerline as possible, preferably within the optimal visual zone, regardless of the number of displays. For multiple-display wraparound consoles (see figure 75 for an illustration), displays that are used less frequently or do not need to be read precisely can be placed further away from the centerline on the angled segments.

5.10.3.10 Warning notifications. See 5.7.2 and 5.7.3 for design characteristics of visual warning notifications. Visual warnings may be installed on walls or surrounding spaces of the workspace. For seated tasks, workstations or consoles requiring horizontal vision over the top to view critical visual warning displays on walls or spaces around the perimeter beyond the workstation or console shall be mounted not less than 57 cm (22.5 in) above the sitting surface.

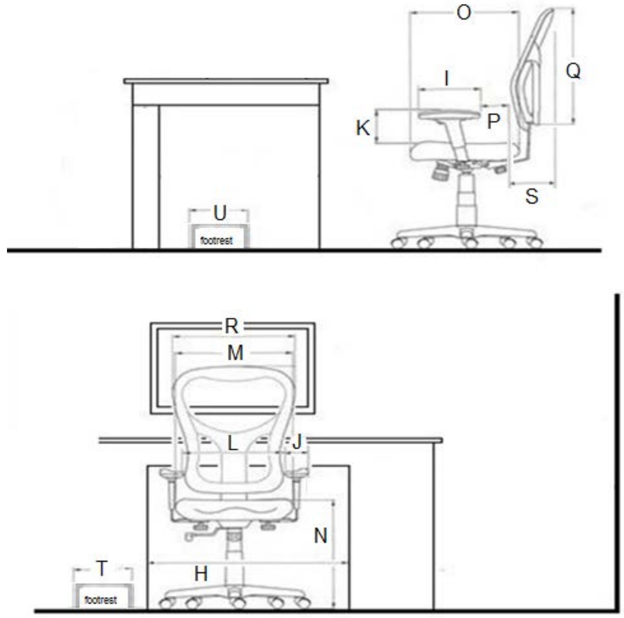
5.10.3.11 Control placement – seated user. Controls mounted on a vertical surface and used in normal equipment operation shall be located 20 to 86 cm (8 to 34 in) above the sitting surface.

5.10.3.11.1 Frequent operation. Controls that require frequent operation shall be located 20 to 74 cm (8 to 29 in) above the sitting surface. In the case of foot-operated controls (e.g., pedals), see 5.1.4.2.1.2 and 5.1.4.2.2.2.

5.10.3.11.2 Control mounting heights. Mounting heights for controls mounted on a vertical surface to be used by a seated user shall be as shown on figure 70.

5.10.3.12 General seating design. Work seating shall provide a supporting framework for the body relative to the activities that must be carried out.

5.10.3.12.1 Perform mission functions. Seating shall allow the user population to perform their mission functions without degradation of their performance capability in alertness, cognition, strength, or dexterity, and without significant or lasting pain or injury (see figure 73).



			Minimum cm (in)	Maximum cm (in)
Chair				
Armrests	I	Length	20 (8)	--
	J	Width	5 (1.96)	--
	K	Height 1/ 3/	19 (7.4)	--
	L	Separation	46 (18.1)	--
Seat pan	M	Width	38 (14.9)	--
	N	Height 1/	46 (18.1)	--
	O	Depth 1/ 2/	--	40 (15.7)
Backrest	P	Space 1/	15 (5.9)	--
	Q	Height 1/ 3/	38 (14.9)	--
	R	Width	30 (11.8)	--
	S	Lumbar support 4/	--	--
Footrests	T	Width	18 (7.1)	N/A
	U	Depth	not less than 30 (12)	N/A
	--	Height	1/	N/A

FIGURE 73. Seated dimensions.

			Minimum cm (in)	Maximum cm (in)
Office Design				
--	--	Keyboard height 1/	See figure 58.	--
--	--	Pointing device height 1/	Level with keyboard	±2.5 (1)
--	--	Monitor height 1/	See figure 58.	--

NOTES:

1/ Adjustability shall be designated by the procuring activity.

2/ To avoid pinch points or injury, it is critical that the seat pan depth shall be fitted to the individual user.

3/ Dimension is from the bottom of the armrest to above the compressed sitting surface (seat pan).

4/ Adjustability shall be provided.

FIGURE 73. Seated dimensions – Continued.

5.10.3.12.2 Benches or chairs. Benches or chairs to be used with sit-down (i.e., temporarily or permanently seated) workstations or consoles shall be operationally compatible with the workstation or console configuration.

5.10.3.12.3 Unstable forms of seating. Unstable forms of seating (e.g., ball-type chairs) or standing (e.g., balance boards, rocker boards, wobble boards, or stability trainers) shall not be used.

5.10.3.12.4 Adjustable. The chair shall be as adjustable as possible within the values provided on figures 58, 73, and 74. See ANSI/HFES 100 for more information.

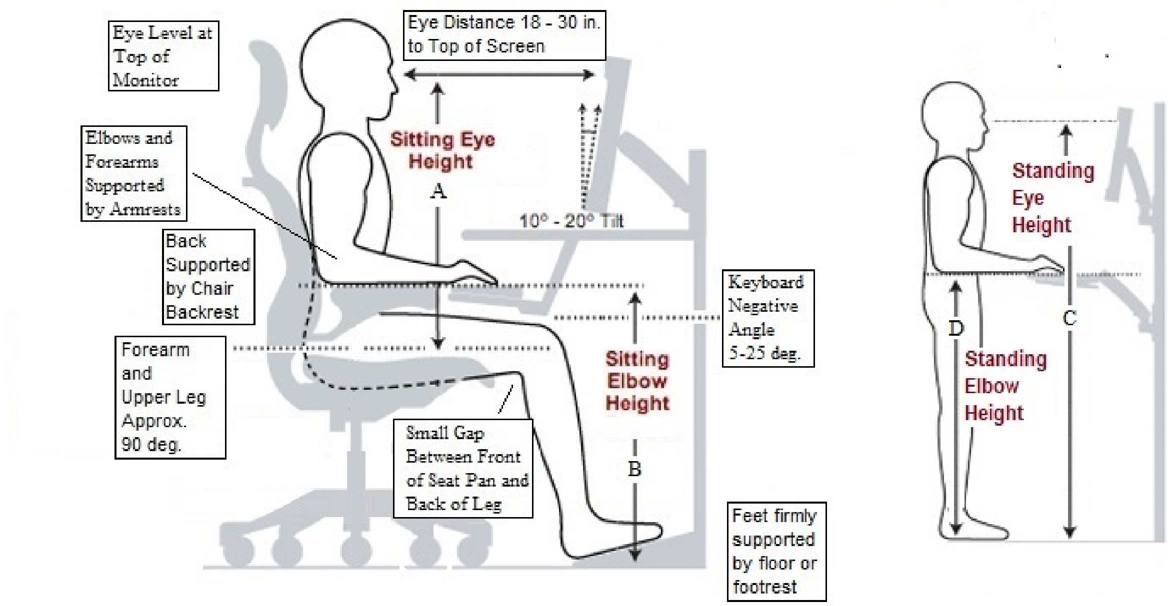


FIGURE 74. Sit-stand workstation design.

Distance "A"	The range for seated eye height measured from the top of the seat pan surface: 68.6 cm (27 in) to 87.5 cm (34.5 in).
Distance "B"	The range for sitting elbow height: 53.2 cm (21 in) to 65.7 cm (26 in).
Distance "C"	The range for standing eye height: 143.2 cm (55 in) to 182.7 cm (70 in)
Distance "D"	The range for standing elbow height: 95.2 cm (36 in) to 123.1 cm (47 in).
Shoulder	58.5 cm (23 in)
Elbows	63.5 cm (25 in)

FIGURE 74. Sit-stand workstation design – Continued.

5.10.3.12.5 Seat pan height and vertical adjustment. If the seat height is taller than what allows the user to have their feet firmly supported by the floor, height enhancement adjustments or accessories shall be provided to allow the user to have their feet firmly supported. For vehicle design considerations, see 5.6.

5.10.3.12.6 Seat pan depth. The seat pan depth should be fitted for the individual user. Too short a seat pan for a taller user will result in discomfort; too long a seat pan for a shorter user will result in long-term back injury, as the user will not be able to use the backrest for support.

5.10.3.12.7 Seat pan. The seat pan for workstation or console chairs shall have a 0- to 7-degree adjustable tilt rearward.

5.10.3.12.8 Backrest angle. A supporting backrest that reclines 100 to 115 degrees shall be provided for workstation or console chairs.

5.10.3.12.9 Backrest support. The backrest for workstation or console chairs should engage the lumbar and thoracic regions of the back using an adjustable backrest support to support the torso.

5.10.3.12.10 Cushioning and upholstery. Where applicable, both the backrest and seat shall be cushioned with at least 2.5 cm (1 in) of compressible material.

5.10.3.12.10.1 Durable. Upholstery shall be durable, non-slip, and porous.

5.10.3.12.10.2 Cushioning of chairs. Chairs shall be cushioned whenever users must remain seated for longer than 1 hour. Good seat cushions have the following characteristics:

a. Have a flat, firm shape but with enough softness to deform.

b. Have resilient material under the cushion to absorb low-frequency vibrations. See 5.5.5.1.5 for more information about design characteristics for vibration and shock in vehicle seating.

c. Support body weight, primarily around the two bony points of the pelvis.

d. Be shaped to follow the inward curve of the lower back and provide support for it to relieve strain on the back muscles.

e. Avoid applying pressure under the thighs or the back of the calf.

f. Use perforated or ventilated material to prevent "hotness" or "sweatiness".

g. Allow the sitter to shift postures. Larger backrests are better because more support space gives greater opportunity for changing postures.

5.10.3.12.11 Armrests. Unless otherwise specified (see 6.2), armrests shall be provided and designed in accordance with figure 73.

5.10.3.12.11.1 Modified or retractable armrests. Modified or retractable armrests shall be provided for adjustability and, when necessary, to maintain compatibility with an associated workstation, surface, or console.

5.10.3.12.11.2 Distance between armrests. The distance between armrests shall be not less than 46 cm (18 in).

5.10.3.12.11.3 Adjustable armrests. The armrests shall be adjustable over the range necessary to approximate the height of the work surface.

5.10.3.12.12 Seat base. Non-swivel chairs shall have at least four supporting legs.

5.10.3.12.12.1 Swivel chairs. Swivel chairs shall have five supporting legs in accordance with figure 73.

5.10.3.12.12.2 Diameter. The diameter of the seat base of swivel type chairs shall be at least 46 cm (18 in).

5.10.3.12.13 Footrests. Footrest height shall be designed so the user will have his or her feet firmly supported in accordance with figure 73.

5.10.3.12.13.1 Non-skid surfaces. Footrests shall contain non-skid surfaces.

5.10.3.12.13.2 Integration. Footrests may be integrated into the chair or console seating or may be an independent entity. When integrated, design considerations shall allow for the footrest to be easily stowed or moved aside to accommodate user preference.

5.10.3.12.13.3 Design. Footrests should be designed in accordance with figure 73.

5.10.3.12.13.4 Footrest inclination. The user's foot and lower-leg angle shall be adjustable from 60 to 90 degrees (in increments of 5 to 10 degrees) through the full range of motion of the chair or seat.

5.10.3.12.14 Stowable seats. If there is not enough space to include a permanent seat, a stowable "swing-away" seat should be considered.

5.10.3.13 Sit-stand workstation design. The type of task (e.g., manual labor, use of IT) shall be considered when designing a sit-stand workstation.

5.10.3.13.1 Dimensions. Where the user will work from both standing and seated postures at a single workstation, cabinet, or console, dimensions shall be in accordance with figure 62.

5.10.3.13.2 Fixed workstation. Where the worker is planned to be at a fixed workstation for an extended period of time (i.e., in an office), adherence to these requirements maintains mission readiness and is linked by research to promote health and reduce injury costs. The workstation shall provide a sit-stand design as the primary design choice unless the environment does not accommodate the option or the choice creates a safety concern. In addition to IT workstation design, frequent posture changes help prevent work-related musculoskeletal disorders. Best practice dictates that IT users should work in a variety of postures to include sitting and standing over the course of the work shift and job rotation.

5.10.3.13.3 Console design. Unless otherwise required herein, criteria relating to sit-stand workstation design shall also apply to console design.

5.10.3.13.4 Sit-stand posture considerations. Dimensions of consoles and the units and racks that constitute user workstations shall be in accordance with figure 62. The configurations represented on figure 62 may not be applicable to all design situations. Operational requirements may require unique design solutions.

5.10.3.13.4.1 Standard configurations. Because of the benefits and economies inherent in a standard console, designs shall conform to standard configurations rather than special designs.

5.10.3.13.4.2 Accommodations. As applicable, the selected console design shall accommodate the required visibility over the top of the console, user mobility, panel space (as in columns B and D of figure 74), and volume in the space below the writing surface.

5.10.3.13.4.2.1 Sitting. When sitting at a workstation, seating shall be adjustable to allow the user to maintain a neutral posture (see 5.10.2.4.1). For best practices, see Army Public Health Center (APHC) Fact Sheet 88-009-0311.

5.10.3.13.4.2.2 Standing. Whenever possible, the workstation shall be designed so users can do routine frequent or short-term jobs while standing and incorporate adjustability where appropriate (see 5.10.2.5, 5.10.3.1, APHC Fact Sheets 88-024-0318 and 88-024-0711, and APHC webpage "Sit/Stand Set-up").

5.10.3.13.4.2.3 Stool seating. Stools may be used for temporary seating, especially where the user frequently moves from a sitting to standing posture. Stool heights shall range from 71 to 81 cm (28 to 32 in) measured from the floor to the top of the seat.

5.10.3.13.4.3 Overhead reaches.

5.10.3.13.4.3.1 Overhead extended reach. Overhead extended reach distance shall be considered in workstation design for a sitting and standing user to operate a control without gripping, such as pushing a button.

5.10.3.13.4.3.2 Extended reach control range. Controls to be operated by an extended reach shall be placed between the values for a sitting posture (minimum) and a standing posture (maximum) of figures 70 and 67, respectively.

5.10.3.13.4.3.3 Overhead gripping reach. Overhead gripping reach distance shall be considered in workstation design for a sitting and standing user to operate a control, such as grasping a knob or turning a handle.

5.10.3.13.4.3.4 Gripping reach control range. Controls to be operated by a gripping reach shall be placed between the values for a sitting posture (minimum) and a standing posture (maximum) of figures 70 and 67, respectively.

5.10.3.13.5 Sit-stand work surface design. The height of any work surface shall be adjusted to fit the individual to the specific type of work being performed, as illustrated on figures 67, 69, and 70.

5.10.3.14 Special-purpose console design.

5.10.3.14.1 Primary display surface. The primary visual surface on workstations or consoles shall be reserved for displays that are used frequently or are critical to successful operation. Special cases where controls and displays are combined or where control and display compatibility is important (even though the displays are of secondary importance) may warrant placing them on this surface.

5.10.3.14.2 Secondary display surface. The secondary display surfaces should be located above or to the side of the primary display surfaces. These surfaces should be used for displays that are used infrequently during mission operations (e.g., setup, adjustment, or operationally non-critical functions).

5.10.3.14.3 Horizontal wraparound.

5.10.3.14.3.1 Panel width. When requirements for panel space for a single seated user exceed a panel width of 112 cm (44 in), a flat-surface, segmented, wraparound console shall be provided to place all controls within reach. See figure 75 for an example.

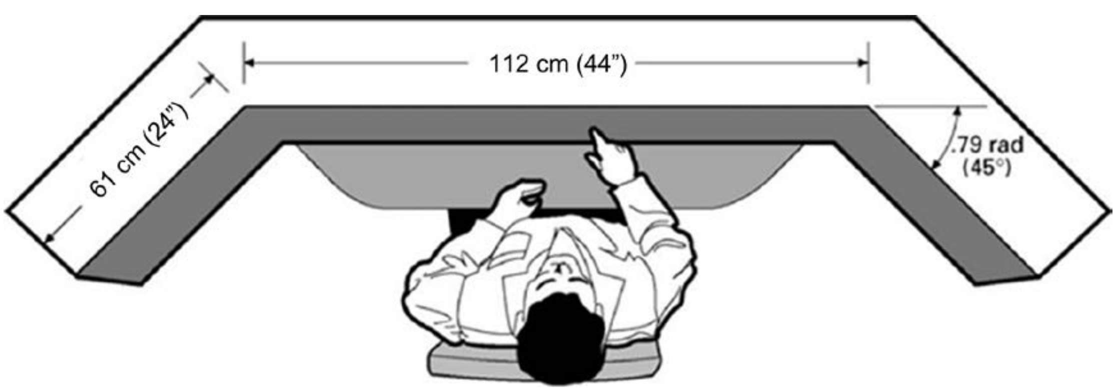


FIGURE 75. Wraparound seated console.

5.10.3.14.3.2 Panel angle. The left and right segments shall be angled from the frontal plane of the central segment such that they can be reached without moving the torso.

5.10.3.14.3.3 Viewing angle. The total required left-to-right viewing angle shall be not more than 190 degrees and be reduced, if possible, through appropriate control-display layout.

5.10.3.14.3.4 Dimensions. For fixed seating, the width of the central segment shall be not more than 112 cm (44 in). The width of the left and right segments should not exceed 61 cm (24 in).

5.10.3.14.3.5 Dimensions (no vision over top). The width of the central segment should be not more than 86 cm (34 in) for fixed seating where vision over the top is not required (i.e., console height exceeds the seat height by more than 69 cm [27 in]).

5.10.3.14.4 Stacked segments.

5.10.3.14.4.1 Display mounting height. The display mounting height for vertical or stacked console segments (see figure 76 for an example) shall meet the criteria in 5.10.3.14.4.2 through 5.10.3.14.4.5.

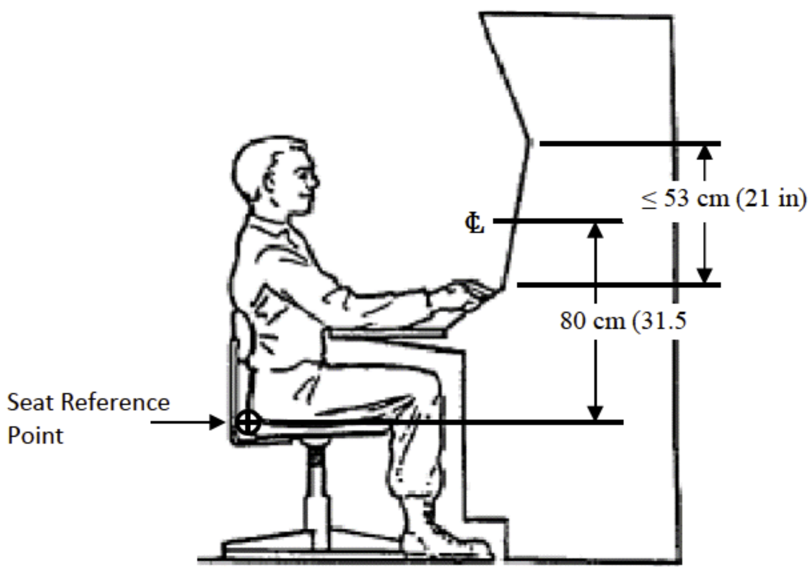


FIGURE 76. Example of vertical stacked segments.

5.10.3.14.4.2 Panel surface division. The surfaces of the panels shall be perpendicular to the user's line of sight with little or no head movement.

5.10.3.14.4.3 User's line of sight. Where direct forward vision over the top of the console is not required by a seated user and when lateral space is limited, the panel may be divided into two or three vertical or stacked segments.

5.10.3.14.4.4 Center segment. The center of the central segment (or lower segment when only two segments are used) should be 80 cm (31.5 in) above the seat reference point.

5.10.3.14.4.5 Height of central segment. The height of the central segment shall be not more than 53 cm (21 in).

5.11 Physical environment design. Physical environment and associated equipment design shall systematically incorporate the influence of tasks, performance capabilities, physical dimensions, and viewing angles for operator and maintainer personnel.

5.11.1 Equipment and workstation layout.

5.11.1.1 Traffic areas. Traffic area and traffic flow design should be based on the following criteria:

a. Consideration of task-based activities in and around workstations.

b. Location of workstations and traffic areas so that they interfere minimally with each other.

c. Consideration of the necessary movements of equipment in the work and traffic areas.

d. Consideration of normal traffic conditions, worst cases, and emergency conditions.

e. Consideration of means by which to avoid collisions and to maximize traffic efficiency.

5.11.1.2 Layout to minimize traffic and congestion. Equipment and workstations shall be located to minimize congestion in workflow or personnel movement and to minimize interference with, and from, personnel traffic areas.

5.11.1.3 Equipment grouping by maintenance needs. Equipment and components maintained by the same person should be grouped together to minimize moving from place to place while monitoring or working on the equipment.

5.11.1.4 Visual inspection. Components that require frequent visual inspection of check points, adjustment points, cable-end connections, and labels should be located in positions that can be seen easily.

5.11.1.5 Equipment arrangement for multiple workers. When two or more people need to be located within a workspace, the equipment shall be arranged so that equipment can be shared, communications requirements can be minimized, face-to-face communications are facilitated, and mutual interference is minimized.

5.11.1.6 Layout for safety. All equipment and components shall be located to minimize the possibility of equipment damage, personnel injury, or inadvertent actuation.

5.11.1.7 Criticality. The most critical units (based on functions and tasks) shall be located to be the most accessible.

5.11.1.8 Frequency. Where criticality is not a factor, units of equipment expected to require more total use (either more frequent or longer durations of use) shall be more accessible.

5.11.1.9 Floor space for work and passage. Floor space shall be planned and designed to ensure compliance with the following criteria:

a. Floor space for work areas and for aisle space do not interfere with each other by occupying the same space.

b. Material and equipment handling tasks, including necessary turning space, are used in sizing work and aisle spaces.

c. The work and aisle space can be kept clean and in good repair.

d. Storage space for material and equipment does not interfere with work or passage.

e. Floor work and aisle space are free of protruding nails, splinters, holes, loose boards, or other loose materials.

f. Permanent aisles and passageways are appropriately marked.

g. Covers and guardrails are provided to protect personnel from the hazards of open pits, tanks, vats, and ditches.

h. Floor loading limits are conspicuously displayed to prevent structural overloading.

i. Sufficient floor space around electrical utilization equipment.

j. Free floor space of at least 1.2 m (48 in) is provided in front of each equipment rack and cabinet.

5.11.1.10 Spacing between racks and cabinets. The minimum space between rows of cabinets containing drawers shall be 200 mm (8 in) greater than the depth of the deepest drawer.

5.11.1.11 Lateral workspace. 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 lb), allow for 460 mm (18 in) on one side and 100 mm (4 in) on the other.

b. For racks having drawers or removable items weighing more than 20 kg (44 lb), allow for 460 mm (18 in) on each side (two person access – one on each side).

5.11.1.12 Rear access space. When a maintainer is to have access to the back of an entire rack or panel-mounted unit, the unit shall be installed with sufficient clearance to permit the maintainer to perform all required maintenance tasks, including the removal of the rear panel(s).

5.11.1.13 Maintenance separation. Workplaces, controls, and displays that are associated with maintenance activities should be separate from operational workplaces, controls, and displays. Controls and displays that are used solely by the maintainer should not be visible to operational personnel, but should be readily accessible when needed by maintenance personnel.

5.11.2 Workspace features designed into equipment.

5.11.2.1 Protection against potential hazards. Protection shall be provided against any potential hazards that might exist while personnel are performing their tasks.

5.11.2.2 Guarding hazardous conditions. If a hazardous condition, such as exposed high-voltage conductors, exists behind an access, the physical barrier over the access shall be equipped with an interlock that will de-energize the hazardous equipment when the barrier is open or removed. Both the presence of the hazard and the fact that an interlock exists shall be noted on the equipment case or cover so that it remains visible when the access is open.

5.11.2.3 Non-skid surfaces. Top surfaces of equipment shall be reinforced and provided with non-skid surfaces whenever they are used as work platforms.

5.11.2.4 Features to assist personnel. Auxiliary hooks, holders, lights, outlets, non-skid treads, expanded metal flooring, or abrasive coating on surfaces used for walking, climbing, or footholds shall be provided at the workplace, as appropriate, to assist personnel in performing their jobs.

5.11.2.5 Access to items and components. Access shall be provided to all points, items, units, and components that require testing, servicing, adjusting, removing, replacing, and repairing.

5.11.2.6 Access openings. Access openings shall be large enough to accommodate hands, arms, and tools, as well as provide full visual access to the task area. The type, size, shape, and location of accesses (see 5.9) shall be based on a thorough understanding of the considerations listed below:

a. Operational location, setting, and environment of the unit.

b. Frequency of use.

c. Maintenance tasks performed in the access cavity and the difficulty of the tasks being performed.

d. Time required to perform maintenance functions.

e. Types of tools and accessories required.

f. Workspace required.

g. Type of clothing likely to be worn by personnel.

h. Necessary access reach.

i. Visual requirements and the intricacy of the tasks.

j. Packaging of items and elements behind the access.

k. Mounting of items, units, and elements behind the access.

l. Hazards in using the access.

m. Size, shape, weight, and clearance requirements for logical combinations of human appendages, tools, and units that will enter the access.

5.11.2.7 General access. Physical access designs shall meet the criteria in 5.11.2.7.1 through 5.11.2.7.5.

5.11.2.7.1 Physical space. Unless otherwise specified (see 6.2), physical space shall be designed into and within the equipment and systems so that sufficient accessibility and accommodation for all required operational and maintenance activities is provided for at least the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped males of the target user population and the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped females of the target user population.

5.11.2.7.2 Body postures. Where operational or maintenance tasks require the assumption of various body postures, the access opening and the physical space requirements for these body postures shall be provided in accordance with 5.10.

5.11.2.7.3 Maintenance from above and outside. Whenever possible, equipment design shall permit maintenance from above or outside, rather than from underneath or inside components.

5.11.2.7.4 Space. Space of 0.4 square meters (4 square feet) per person minimum shall be provided for personnel and their clothing, including required PPE, tools, and equipment as well as free space for the movements and activities required to perform their tasks.

5.11.2.7.5 Working space. When maintenance requires removing large internal parts, the working space provided shall accommodate the person(s) performing the task, the physical size of the removed component, and any area needed to lay down the component, tools, or equipment.

5.11.2.8 Arm and hand access. Arm and hand access designs shall meet the criteria in 5.11.2.8.1 through 5.11.2.8.6.

5.11.2.8.1 Location and size. Openings provided for access shall be located and sized to permit the required adjustment or handling.

5.11.2.8.2 Viewing. Openings shall provide a view of the item being manipulated.

5.11.2.8.3 Reach access dimensions. The dimensions of access openings shall be in accordance with 5.10.

5.11.2.8.4 Clearance for hand. Space allowance shall be made for the clearance of the maintainer’s hand, applicable hand wear, and clothing.

5.11.2.8.5 Access shape. Access shape shall provide clearance for the equipment (including its protuberances, attachments, and handles), appropriate body parts, and tools.

5.11.2.8.6 Access opening dimensions. Access openings shall be large enough for the maintainer to use tools and test equipment within the access cavity.

5.11.2.9 Visual access. Openings shall provide visual access that is large enough to view all required information at the normal operating or maintenance position.

5.11.2.10 Visual inspection. Items requiring visual inspection (e.g., hydraulic reservoirs, gauges) shall be located so personnel can see them without removing panels or other components.

5.11.2.11 Visual access only. Where only visual access is required, the following shall be adhered to in order of precedence:

a. Opening with no cover, except where this might degrade system performance.

b. Transparent window if dirt, moisture, or other foreign materials might otherwise create a problem.

c. Break-resistant glass window if physical wear, heat, or contact with solvents would otherwise cause optical deterioration.

5.11.3 Design of corridors.

5.11.3.1 Corridors.

5.11.3.1.1 Corridor width. Corridor widths shall be designed for the peak traffic load expected, for traffic directions, and for the number of entrances and exits in the area.

5.11.3.1.2 Corridor dimensions. To allow personnel to move with tolerable restrictions, corridors shall meet the dimensions given on figure 77. See 5.11.7.4 for OSHA implications when a corridor is designated as part of an emergency exit.

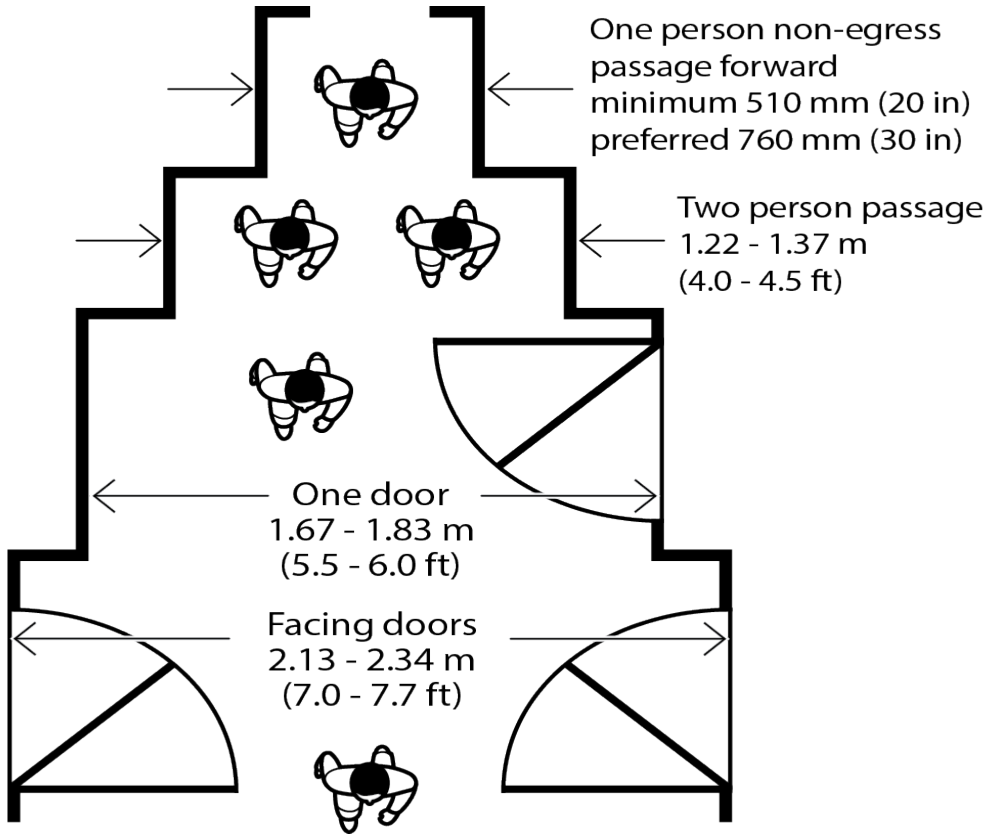


FIGURE 77. Corridor dimensions.

5.11.3.1.3 Added clearance. Clearance should be allowed for personnel wearing bulky clothing and carrying equipment. A person can move through a corridor 510 mm (20 in) wide with some difficulty; however, a corridor intended for one person to travel comfortably even while wearing bulky clothes should be at least 760 mm (30 in) wide. The dimensions of equipment to be carried or transported may add width to these values.

5.11.3.2 Wheelchair accessible routes.

5.11.3.2.1 Width. The minimum clear width of an accessible route for a single wheelchair shall be 915 mm (36 in) except at doors, which shall be 815 mm (32 in) (see figure 78).

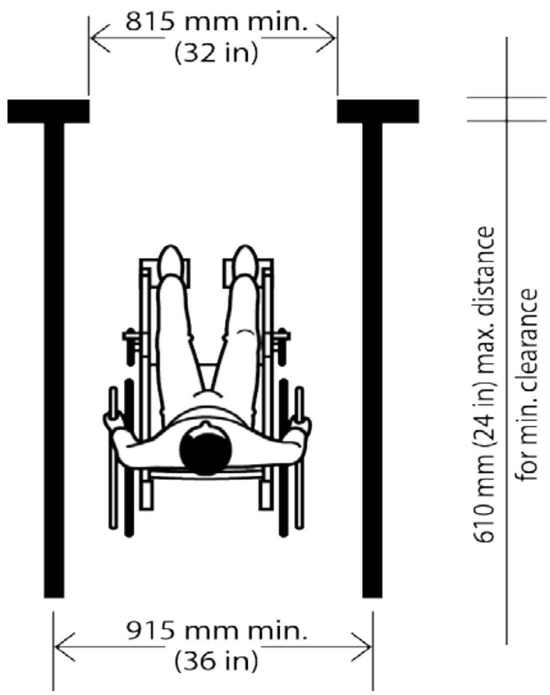


FIGURE 78. Minimum clearance for a single wheelchair.

5.11.3.2.2 Width for wheelchair passing. The minimum width for two wheelchairs to pass shall be 1,525 mm (60 in) (see figure 79).

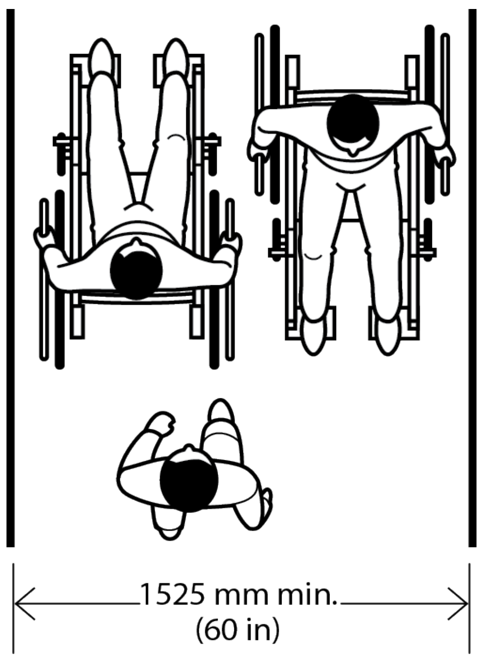


FIGURE 79. Minimum clear width for two wheelchairs.

5.11.3.2.3 Passing space. If an accessible route has less than 1,525 mm (60 in) clear width, then passing spaces at least 1,525 by 1,525 mm (60 by 60 in) shall be located at reasonable intervals not to exceed 61 m (200 ft).

5.11.3.2.4 Minimum accessible routes. At least one accessible route within the boundary of the site shall be provided from public transportation stops, accessible parking, accessible passenger unloading zones, and public streets or sidewalks to the accessible building entrance they serve.

5.11.3.2.5 Exclusion of stairs, steps, and escalators. An accessible route shall not include stairs, steps, or escalators.

5.11.3.2.6 Exit for emergencies. Accessible routes serving any accessible space or element shall also serve as a means of exit for emergencies or connect to an accessible area of rescue assistance.

5.11.3.2.7 Connecting routes to other areas. At least one accessible route shall connect accessible buildings, facilities, elements, and spaces that are on the same site.

5.11.3.2.8 Connecting entrances to other areas. At least one accessible route shall connect accessible building or facility entrances with all accessible spaces within the building or facility.

5.11.3.2.9 Obstacles. If a person in a wheelchair must make a turn around an obstruction, the minimum clear width of the accessible route shall be as shown on figures 80 and 81.

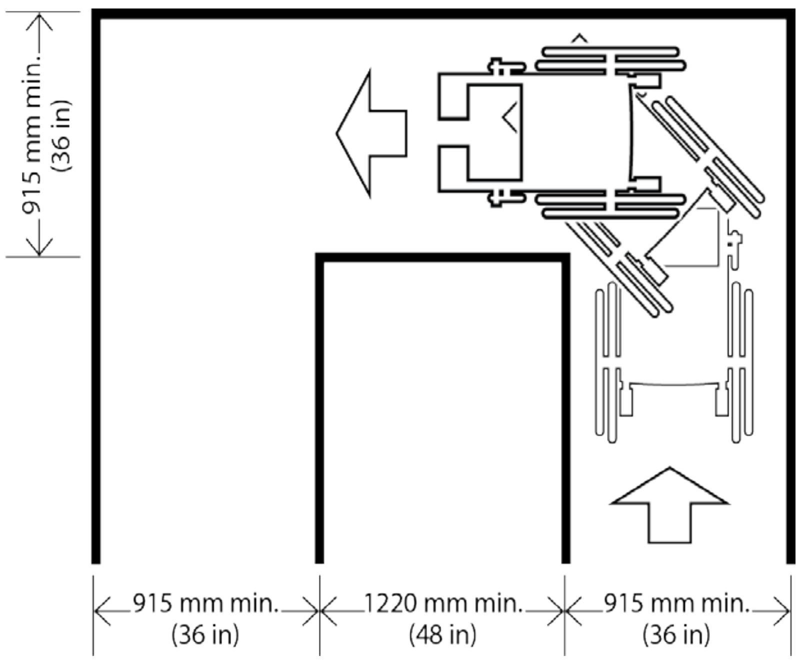


FIGURE 80. Accessible route with a 90-degree turn.

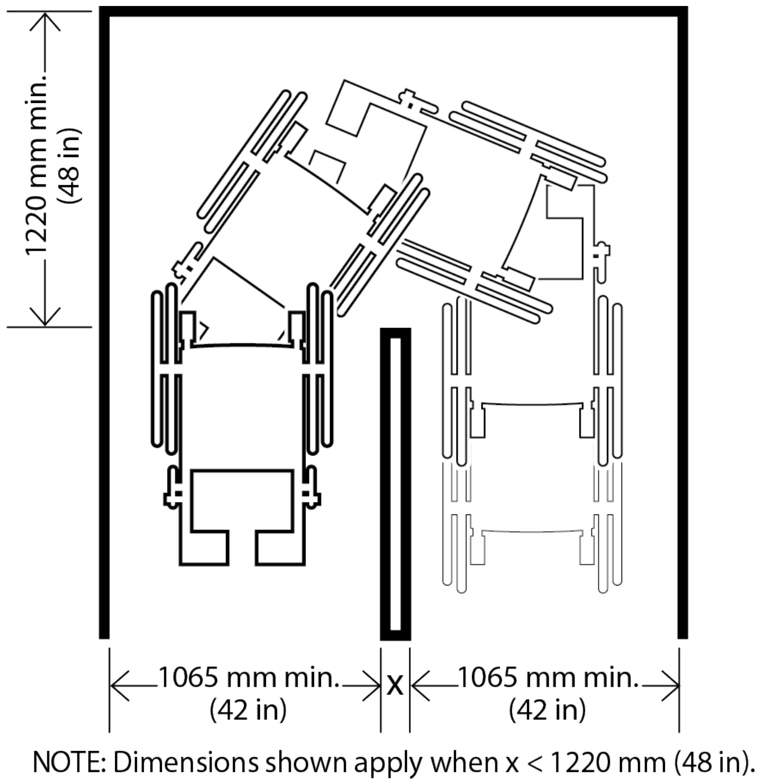


FIGURE 81. Accessible route with turns around an obstruction.

5.11.3.2.10 Protruding objects. Protruding objects shall not reduce the clear width of an accessible route or a maneuvering space.

5.11.3.2.11 Changes in level.

5.11.3.2.11.1 Changes up to 6 mm. Changes in level up to 6 mm (0.25 in) may be vertical and without edge treatment.

5.11.3.2.11.2 Changes from 6 to 13 mm. Changes in level from 6 to 13 mm (0.25 to 0.5 in) shall be beveled with a slope no greater than 1:2.

5.11.3.2.11.3 Changes greater than 13 mm. Changes in level greater than 13 mm (0.5 in) shall be accomplished by means of a ramp.

5.11.3.2.12 Carpeted surfaces. Carpet pile height shall be a maximum of 13 mm (0.5 in).

5.11.3.2.12.1 Secured attachment. Carpeted surfaces shall be securely attached with either a firm pad or no pad underneath.

5.11.3.2.12.2 Exposed edges. Exposed edges shall be fastened securely to the floor surface and have trim along the entire length of the exposed edge.

5.11.3.2.13 Slope. An accessible route with a running slope greater than 1:20 is considered to be a ramp and shall comply with 5.11.8.2.

5.11.3.2.14 Maximum slope. Nowhere shall the cross slope of an accessible route exceed 1:50.

5.11.3.2.15 Clear width of doors. Doorways shall have a minimum clear opening of 815 mm (32 in) with the door open 90 degrees, measured between the face of the door and the opposite doorstop.

5.11.4 Floors and walkway surfaces.

5.11.4.1 Floors. Floors shall be stable, firm, and slip resistant.

5.11.4.2 Walkway surfaces. Walkway surfaces shall be stable, planar, flush, and even to the maximum extent possible.

5.11.4.3 Non-skid walkway surfaces. Surface treatments to walkway surfaces shall meet the criteria in 5.11.4.3.1 and 5.11.4.3.2.

5.11.4.3.1 Handling pathways. Walkway surfaces used for ammunition handling or movement of stores shall be provided with non-skid surfaces on all areas where personnel are expected to walk or stand to work.

5.11.4.3.2 Wet surfaces. Walkway surfaces that are reasonably anticipated to be exposed to water, condensation, or other liquids shall be provided with non-skid surfaces on all areas where personnel are expected to walk or stand to work.

5.11.5 Catwalks, tunnels, and crawl spaces. Catwalks, tunnels, and crawl spaces are specialized facility features used to accommodate unique space or environmental limitations that preclude normal corridors or walkways.

5.11.5.1 Accommodate operations. Catwalks, tunnels, and crawl spaces shall be designed to ensure personnel safety (see 5.7.7.2), accommodate operations performed therein, and accommodate personnel clothing and equipment.

5.11.5.2 Minimum catwalk width. The minimum catwalk floor width shall be 460 mm (18 in) to accommodate walking one foot in front of the other and carrying tools or equipment.

5.11.5.3 Air ventilation.

5.11.5.3.1 Enclosed spaces. Enclosed catwalks, tunnels, and crawl spaces shall have air ventilation to sustain their maximum permissible personnel numbers for an indefinite period.

5.11.5.3.2 Temperature and air quality. Both temperature and air quality shall be considered when determining the appropriate air ventilation design.

5.11.5.4 Movement or work without mechanical aid. When tunnels or crawl spaces require bending, stooping, or crawling, these areas shall accommodate the multivariate largest 99 percent of the male target user population and the multivariate largest 99 percent of the female target user population to accomplish the movement and, where applicable, work without the assistance of mechanical aids.

5.11.6 Platforms, elevators, and inclinators.

5.11.6.1 Platforms. Platforms should be used where personnel must be raised to the working distance of equipment.

5.11.6.1.1 Guardrails. Guardrails shall be provided in accordance with 5.11.6.3.

5.11.6.1.2 Minimum dimensions. Platforms shall measure at least 610 mm (24 in) wide by 910 mm (36 in) long.

5.11.6.1.3 Hands-free work area. Platform design shall permit both of the user's hands to be free for work.

5.11.6.1.4 Gaps with equipment. Platform design shall not have gaps greater than 150 mm (6 in) between the equipment and the platform; the preferred gap is within 50 mm (2 in).

5.11.6.1.5 Protect equipment surface. Contact plates, cushions, bumpers, or pads shall be used, as necessary, to protect the equipment surfaces.

5.11.6.1.6 Platform strength. The platform shall have the strength to hold the worker(s) in addition to the heaviest tools and equipment expected plus a safety factor consistent with design practice for the structural materials. Use 113.4 kg (250 lb) per person to estimate personnel weight.

5.11.6.1.7 Test equipment support. When test equipment will be used, the design shall provide support for test equipment at the appropriate height for its use.

5.11.6.1.8 Open metal grating for exterior platforms and work area surfaces. Exterior platforms and similar work areas shall be constructed of open metal grating.

5.11.6.1.9 Alternative surfaces for platforms and work area surfaces. Where grating is impractical, and for interior platforms and work passageways, floor surfaces shall be treated with non-skid material.

5.11.6.2 Portable platforms.

5.11.6.2.1 Portable platforms. Portable platforms should be lightweight and fully collapsible.

5.11.6.2.2 Platform wheels and brakes. Any platform on wheels shall have brakes and wheel locks.

5.11.6.3 Platform guardrails, toeholds, guard screens, and handholds.

5.11.6.3.1 Open sides of personnel platforms. All open sides of personnel platforms shall be equipped with guardrails that have at least two rails (an intermediate rail and top rail).

5.11.6.3.2 Guardrail dimensions. Guardrail dimensions shall be as follows:

a. Top rail height shall be not less than 1.1 m (42 in).

b. Distance between the platform edge and the centerline of the railing shall be not greater than 65 mm (2.5 in).

c. Rail diameter is between 37 mm (1.5 in) and 75 mm (3 in).

5.11.6.3.3 Toe board or guard screen. The height of a toe board or guard screen shall be not less than 150 mm (6 in). The guard screen is used to prevent a person who falls onto the platform from falling off the platform. It can also prevent most tools, parts, and equipment from falling off the platform. Toe boards are intended to prevent tools, parts, and equipment from falling as well as to prevent the worker's foot from slipping off the edge of the platform.

5.11.6.3.4 Handholds. Handholds shall be furnished where needed to assist in climbing onto a platform or as aids in performing the intended maintenance tasks from the platform.

5.11.6.3.5 Handholds and guardrails for adverse conditions or motion. Handholds and guardrails shall be provided where personnel must stabilize themselves because of high winds, ice, fog, or other hazards and when working in moving vehicles.

5.11.6.4 Elevators, inclinators, and hydraulically-operated work platforms.

5.11.6.4.1 Safety features. Where elevators, inclinators, or hydraulic work platforms are needed, the following operating safety features shall be included:

a. Maximum load signs located where they can be easily seen.

b. Guards used to prevent accidental operations of the lift.

c. An easily reachable capability for manually lowering the platform or elevator provided when feasible.

d. Floor surface treatment in accordance with the treatment of open platforms in 5.11.6.1.9.

5.11.6.4.2 Designed-in safety features. The following features shall be provided as a part of the design:

a. Limit stops to prevent injury to personnel and damage to equipment.

b. Automatic fail-safe brake or other self-locking device in case of lift mechanism failure.

5.11.7 Entrances and exits.

5.11.7.1 General.

5.11.7.1.1 Means of exit continuity. The exit path shall not be interrupted by any building element other than an exit component (e.g., a ramp).

5.11.7.1.2 Entrances for enclosed work areas. Enclosed work areas should have conventional entrances and exits for routine access and to permit unrestricted flow for all anticipated traffic and movement of equipment.

5.11.7.1.3 Access to controls and displays. Conventional entrances and exits for enclosed work areas should be located so that personnel who are entering or leaving will not inadvertently operate or block access to controls or displays, or otherwise interfere with ongoing work in the area.

5.11.7.1.4 Illumination level. The illumination level of an exit shall be not less than 11 lux (1 foot-candle) at the walking surface.

5.11.7.2 Doorways and hinged doors.

5.11.7.2.1 General door dimensions. Hinged doors shall have at least the dimensions shown on figure 82.

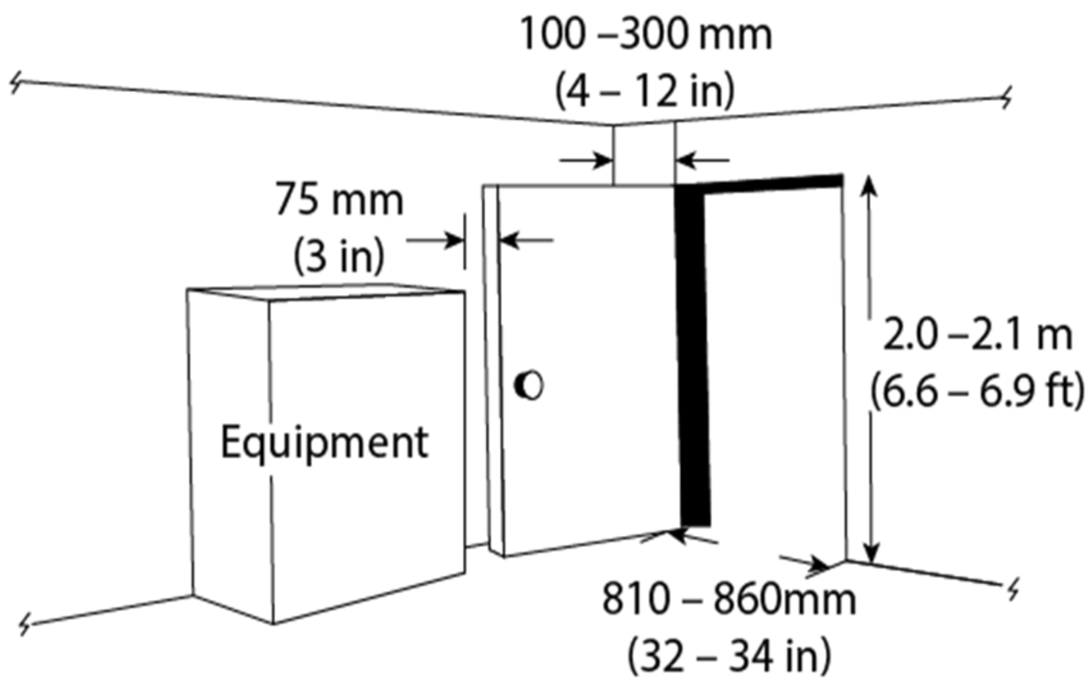


FIGURE 82. General door dimensions.

5.11.7.2.2 Doors used in exit routes. Side-hinged doors shall be used in exit routes.

5.11.7.2.3 Perpendicular wall door clearances. When a door opens inward next to a perpendicular wall, a clearance shall be provided of at least 100 mm (4 in) between the door at the hinge and the plane of the wall (see figure 83).

	Light Clothing		Bulky Clothing	
Minimum Opening Sizes	**A**	**B**	**A**	**B**
Top and bottom access	330 mm (13 in)	580 mm (23 in)	410 mm (16 in)	690 mm (27 in)
Side access	660 mm (26 in)	760 mm (30 in)	740 mm (29 in)	860 mm (34 in)
NOTE: Dimensions are based on male data.				

FIGURE 83. Whole body access dimensions.

5.11.7.2.4 Equipment or furniture door clearances. Equipment or furniture shall not be positioned within 75 mm (3 in) of the swing path of a door that opens inward (see figure 82).

5.11.7.2.5 Door opening direction.

5.11.7.2.5.1 Normal density traffic. When the normal traffic density and the exiting personnel traffic in emergency conditions are expected to be low, hinged doors shall open inward rather than outward into a corridor. Opening inward will help prevent injury to personnel using the corridor.

5.11.7.2.5.2 High-density traffic. When exiting traffic volume is expected to be high, the door shall have a see-through window and open outward to aid exiting in an emergency.

5.11.7.3 Alternative door types.

5.11.7.3.1 Sliding and folding doors. When horizontal-, vertical-sliding, or folding doors are used to allow large pieces of equipment or vehicles to pass through, alternative personnel exits should be available.

5.11.7.3.1.1 Large doors. Because large doors may jam, an additional hinged door should be provided for personnel entrance and exit.

5.11.7.3.1.2 Sliding or folding doors as exits. If horizontal-, vertical- sliding, or folding doors are the only exits available for personnel to exit the building, a hinged door built into the sliding or folding door should be provided.

5.11.7.3.2 Swinging doors. Swinging doors should be used in pairs (one for each direction of traffic) with the hinges attached to a center post that separates the doors.

5.11.7.3.3 Visual access on swinging doors. Swinging doors should have openings or windows for visual access to oncoming traffic.

5.11.7.3.4 Spring mechanisms on swinging doors. A spring mechanism should be used when the door size or weight prevents manual opening and closing. Avoid spring closure mechanisms with a lightweight door because this closing arrangement can be hazardous.

5.11.7.3.5 Revolving doors. Revolving doors can be hazardous and should not be used.

5.11.7.3.6 Floor-to-ceiling glass doors or windows. Where floor-to-ceiling doors or windows are used, the glass area shall be patterned or labeled so that users do not mistake it for an unobstructed passageway.

5.11.7.4 Emergency doors.

5.11.7.4.1 Space for exit. Emergency exits shall allow enough space for rapid exit of all occupants, including any who must carry essential equipment or wear bulky clothing without danger of personnel injury or damage to the equipment being carried. 29 CFR 1910.36, 29 CFR 1910.37, and the National Fire Protection Association codes specify the design requirements for "ways of exit" from buildings and facilities. Design requirements for any unobstructed way of exit are functions of the nature of the building construction and contents, the maximum occupancy capacities of its components, and the arrangement of designated ways of exit.

5.11.7.4.2 Emergency door and exit design and construction. Emergency doors and exits shall be designed and constructed using the following criteria:

a. Simple to operate.
b. Readily accessible.
c. Clearly designated.
d. Unobstructed.
e. Simple to locate and operate in the dark.
f. Capable of being opened in 3 seconds or less.
g. Require from 44 to 133 newtons (10 to 30 pounds-force) of operating force to open.
h. Permit exit by one person in 5 seconds or less.
i. Do not, in themselves or in their operation, constitute a safety hazard.

5.11.7.4.3 Ceiling areas along a means of exit. Ceiling areas along a means of exit (including exterior escape paths) shall be at least 2.29 m (7.5 ft) above the floor.

5.11.7.4.4 Protrusions. Protrusions along a means of exit shall be not lower than 2.04 m (6.7 ft) above the floor.

5.11.7.4.5 Unobstructed travel to exit. A designated means of emergency exit shall have a minimum of 460 mm (18 in) of unobstructed way-of-exit travel from any point in a structure to an exterior safe public way.

5.11.7.5 Hatches.

5.11.7.5.1 Flush with surfaces. Where structural considerations permit, hatches shall be flush with the floor or wall surfaces.

5.11.7.5.2 Hatch opening motion. Hatches shall open with a single motion of the hand or foot.

5.11.7.5.3 Hatch operating forces with a handle. When a handle is used, the operating force shall not exceed 90 newtons (20 pounds-force).

5.11.7.5.4 Overhead hatches. Overhead hatches shall require an operating force of less than 220 newtons (50 pounds-force) for opening and closing.

5.11.7.5.5 Dimensions.

5.11.7.5.5.1 Clearance dimensions. Clearance dimensions for the hatch and passage sizes shall be based on the multivariate central 98 percent of the male target user population and the multivariate central 98 percent of the female target user population using dimensions applicable to the hatch and passage sizes. The dimensions shall accommodate suitably clothed and equipped personnel together with any equipment they are expected to carry. Clearance dimensions influence the size for access, accommodation, and egress by the largest people in the user population.

5.11.7.5.5.2 Limiting dimensions. Limiting dimensions for hatch location and operability shall be based upon the multivariate central 98 percent of the male target user population and multivariate central 98 percent of the female target user population. Limiting dimensions permit the smaller people in the user population to manipulate latches, handles, or accesses.

5.11.7.5.6 Emergency escape hatches. Emergency escape hatches shall accommodate the equipment and clothing that escaping personnel will be carrying and wearing, be clear of all external obstructions, and be located to avoid external hazards.

5.11.7.5.6.1 Emergency escape hatch dimensions. The minimum and preferred dimensions for special emergency escape hatches shall adhere to the following criteria:

a. Rectangular: minimum 405 by 610 mm (16 by 24 in), preferred 510 by 710 mm (20 by 30 in).

b. Square: minimum 460 mm (18 in), preferred 560 mm (22 in).

5.11.7.5.6.2 Overhead hatches. If emergency hatches must be placed overhead, they shall require no more than 220 newtons (50 pounds-force) of force to operate.

5.11.7.5.6.3 Accommodation. Emergency escape hatches shall be operable by a suitably equipped and clothed user with fifth percentile arm and hand strength of the expected user population.

5.11.7.5.6.4 Rescue requirements. Where the rescue of personnel may be required, hatch openings shall be large enough to accommodate two suitably clothed rescuers.

5.11.7.5.7 Rectangular hatch minimums. When rectangular hatches are used, they shall meet the minimal whole body access dimensions of figure 83.

5.11.7.6 Whole body access.

5.11.7.6.1 Whole body access dimensions. Dimensions for whole body access shall meet or exceed those shown on figure 83.

5.11.7.6.2 Whole body access with a step down. Where there is a need to step down through an access and the step distance exceeds 690 mm (27 in), footrests or steps shall be provided.

5.11.8 Ramps, stairs, and ladders.

5.11.8.1 General.

5.11.8.1.1 Selection of safest structure. The structure that gives the safest and most efficient passage shall be selected.

5.11.8.1.2 Selection based on angle. The selection of ramps, stairs, stair-ladders, or fixed ladders for specific applications shall be based on the angle of ascent required and the critical criteria levels in table XXXIV.

TABLE XXXIV. Type of structure in relation to angle of ascent.

Type	Angle of Ascent (Degrees)	Preferred Angle of Ascent (Degrees)
Vertical ladders	75 to 90	90
Inclined stairs	50 to 75	Not recommended
Stairs	30 to 50	38
Ramps for personnel	7 to 15	7 to 8
Ramps for material handling	4 to 7	4

5.11.8.1.3 Carrying heavy loads by hand. The following shall be followed when selecting structures over which heavy equipment or tools must be hand carried by personnel:

a. Stairs and steps should not be used where personnel must carry bulky loads or loads in excess of 13 kg (29 lbs); ramps, elevators, or equivalent means should be provided.

b. Ladders shall not be used when personnel must carry equipment because both hands should be free to grasp and climb ladders.

5.11.8.1.4 Material characteristics. Ramps, stairs, and ladders shall be constructed of materials that are lightweight, nonconductive, splinter-proof, waterproof, weatherproof, humidity-resistant, and resistant to chemical action. If applicable, environmental conditions shall be taken into account during the design phase, including inclement weather (e.g., snow, ice, mud, sand, and wind). If de-icing is applicable, ramps, stairs, and ladders shall be designed to be tolerant of hot water or steam de-icing.

5.11.8.1.5 Carrying strength of the structures. Ramps, stairs, and ladders shall be designed to withstand the total weight of the largest combination of personnel and carried equipment likely to be on them at one time. Multiply these estimates by a safety factor appropriate to the materials used. Use 113.4 kg (250 lb) per person to estimate personnel weight.

5.11.8.1.6 Non-skid floor surfaces. Ramps, stairs, and ladders shall be provided with non-skid surfaces on all areas where personnel are expected to walk or stand to work.

5.11.8.1.7 Warning labels and signs. Ramps, stairs, and ladders shall have labels or symbols that warn against any hazards associated with their use (e.g., low overhead obstructions, possible shock, and load limits).

5.11.8.1.7.1 Ladder warning labels. Ladder warnings labels shall comply with ANSI/ASC A14.

5.11.8.1.7.2 Ramp and stair warning labels. Ramps and stair warning labels shall comply with ANSI Z535.2.

5.11.8.1.8 Handrails. Ramps, stairs, and ladders shall be equipped with a handrail on each side.

5.11.8.1.9 Guardrails. Where personnel could fall into an open area under a catwalk, balcony, parapet, ramp, stair, or ladder handrail, an intermediate level guardrail shall be provided.

5.11.8.1.10 Proper illumination. Ramps, stairs, and ladders shall be provided with appropriate illumination (see 5.5.3 for illumination criteria).

5.11.8.1.11 Combined vehicular or cart and personnel traffic. Stairs should be provided for personnel when vehicles and pedestrians share a ramp and the angle of ramp inclination exceeds 7 degrees. Figure 84 illustrates a ramp and stairs combination with a pedestrian area on the right side.

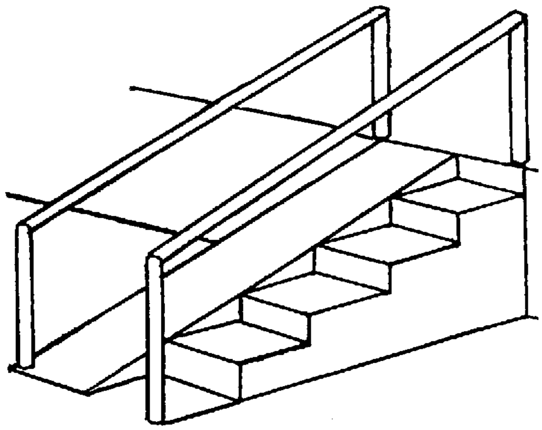


FIGURE 84. Combined ramp and stairs.

5.11.8.1.12 Personnel traffic area placement. Personnel traffic areas should be either to one side of the vehicle area or on both sides with the vehicle area in the middle.

5.11.8.1.13 Separation of vehicular and personnel traffic areas. Vehicular traffic and walking traffic should be clearly separated by markings and handrails.

5.11.8.2 Ramps.

5.11.8.2.1 Ramp cleats. Where environmental conditions require cleating of ramps, cleats should be spaced 360 mm (14 in) apart and run from handrail to handrail at right angles to traffic. Cleating of ramps facilitates footing for walking and rolling equipment on inclines.

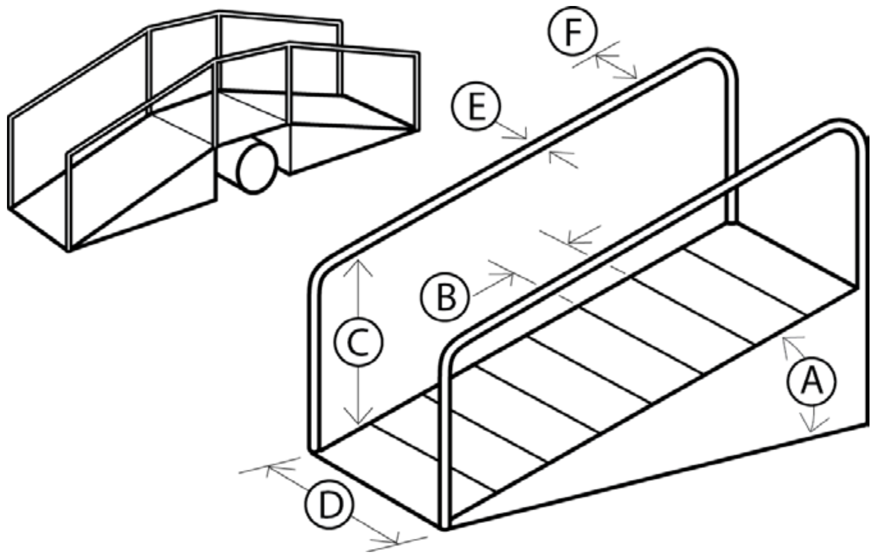
5.11.8.2.2 Ramp landings. Ramps shall have level landings at the top and bottom of each ramp and each ramp run.

5.11.8.2.2.1 Width. The landing shall be at least as wide as the ramp run leading to it.

5.11.8.2.2.2 Length. The landing length shall be not less than 1.53 m (60 in).

5.11.8.2.2.3 Change of directions. If a ramp changes direction at a landing, the landing size shall be not less than 1.53 by 1.53 m (60 by 60 in).

5.11.8.2.3 Dimensions. Ramp dimensions shall conform to the values on figure 85.



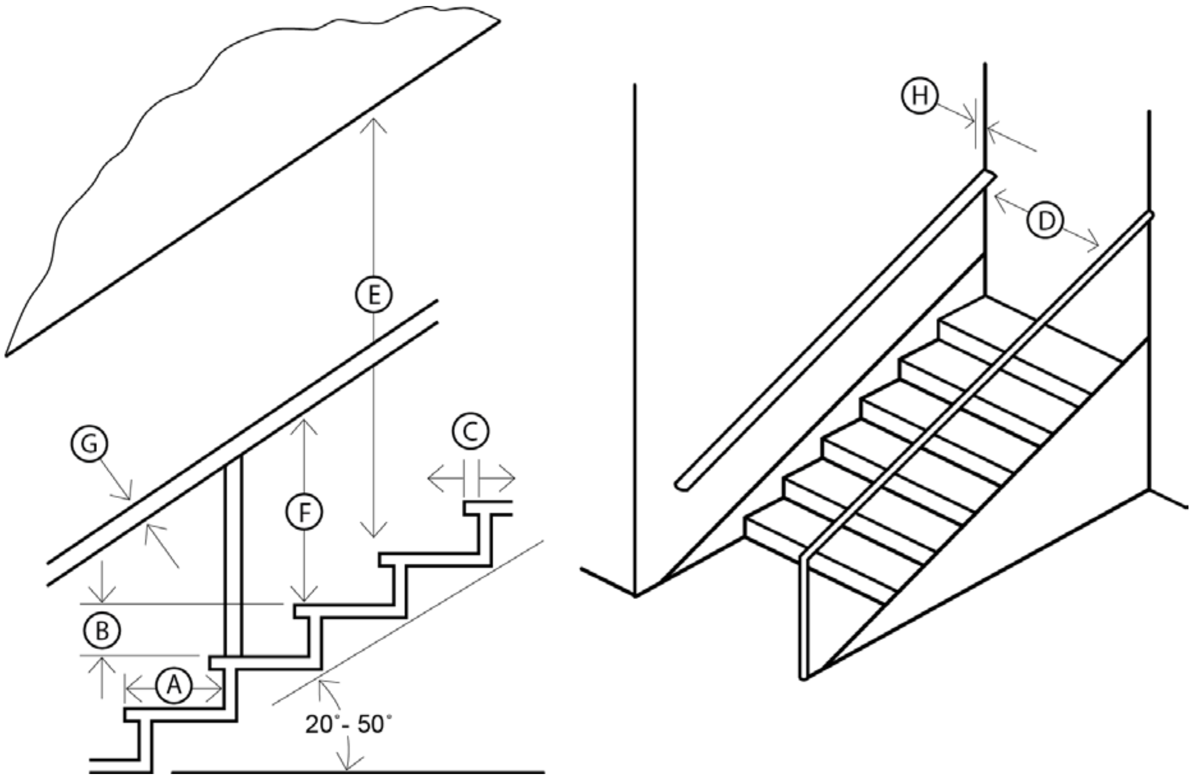
Dimension	Minimum	Maximum	Preferred
A: Angle of rise	--	20°	7 to 15°
B: Distance between cleats	230 mm (9 in)	410 mm (16 in)	360 mm (14 in)
C: Height of handrails	950 mm (36 in)	1,070 mm (42 in)	1,070 mm (42 in)
D: Width	950 mm (36 in)	--	--
E: Diameter of handrail	40 mm (1.5 in)	80 mm (3 in)	40 mm (1.5 in)
F: Clearance around handrail	80 mm (3 in)	--	80 mm (3 in)

FIGURE 85. Ramp dimensions.

5.11.8.2.4 Ramps for pushing or pulling equipment on carts. When ramps are used to push or pull carts, the design shall stay within human strength capabilities when establishing the ascent of inclination.

5.11.8.3 Stairs.

5.11.8.3.1 Dimensions for stairs. Stair dimensions shall be within the values shown on figure 86.



Dimension	Minimum	Maximum	Preferred
A: Tread depth (including nosing)	280 mm (11 in)	300 mm (12 in)	280 to 300 mm (11 to 12 in)
B: Riser height	130 mm (5 in)	200 mm (8 in)	170 to 180 mm (6.5 to 7 in)
C: Depth of nosing (where applicable)	19 mm (0.75 in)	38 mm (1.5 in)	25 mm (1.0 in)
D: Width (handrail-to-handrail)			
One-way stairs	760 mm (30 in)	--	910 mm (36 in)
Two-way stairs	1,220 mm (48 in)	--	1,300 mm (51 in)
E: Minimum overhead clearance	1,930 mm (76 in)	k	1,980 mm (78 in)
F: Height of handrail	860 mm (34 in)	940 mm (37 in)	--
G: Diameter of handrail	40 mm (1.5 in)	80 mm (3 in)	40 mm (1.5 in)
H: Rail clearance from wall	80 mm (3 in)	--	80 mm (3 in)

FIGURE 86. Stair dimensions.

5.11.8.3.2 Landings. There should be a landing for each floor level; other landings are recommended for each 10 to 12 treads.

5.11.8.3.3 Riser uniformity. Riser heights and the height to landings shall be uniform.

5.11.8.3.4 Stair lengths. Long flights of stairs should be avoided.

5.11.8.3.5 Slip resistance. Skid-proof stair and step treads shall be provided.

5.11.8.3.6 Non-skid coating. Where conditions warrant special precaution, surfaces shall be treated with a non-skid coating.

5.11.8.3.7 Open tread and protection beneath. Where practical, treads should be open with metal screens or kick plates fastened to the underside to avoid injuries from dropped articles.

5.11.8.3.8 Stair design for load carrying. When people are going to carry loads of more than 9 kg (20 lb) or where stairs are more than two stories high, deep treads of 300 mm (12 in) and low risers of 125 mm (5 in) should be used.

5.11.8.3.9 Spiral stairways. Spiral stairways shall not be permitted except for special limited usage and secondary access situations where it is not practical to provide a conventional stairway.

5.11.8.3.9.1 Tread depth. Spiral stairways shall provide a clear tread depth of at least 190 mm (7.5 in) at a point 305 mm (12 in) from the narrow edge.

5.11.8.3.9.2 Risers. The risers shall be high enough to provide a minimum headroom of 1,981 mm (78 in).

5.11.8.3.9.3 Riser height. Riser height shall be not more than 241 mm (9.5 in).

5.11.8.3.9.4 Clear width. The minimum stairway clear width at and below the handrail shall be 660 mm (26 in).

5.11.8.4 Stair ladders. Stair ladders are intended for one person at a time either ascending or descending.

5.11.8.4.1 Dimensions for stair ladders. Stair ladder dimensions shall be in accordance with the values on figure 87.

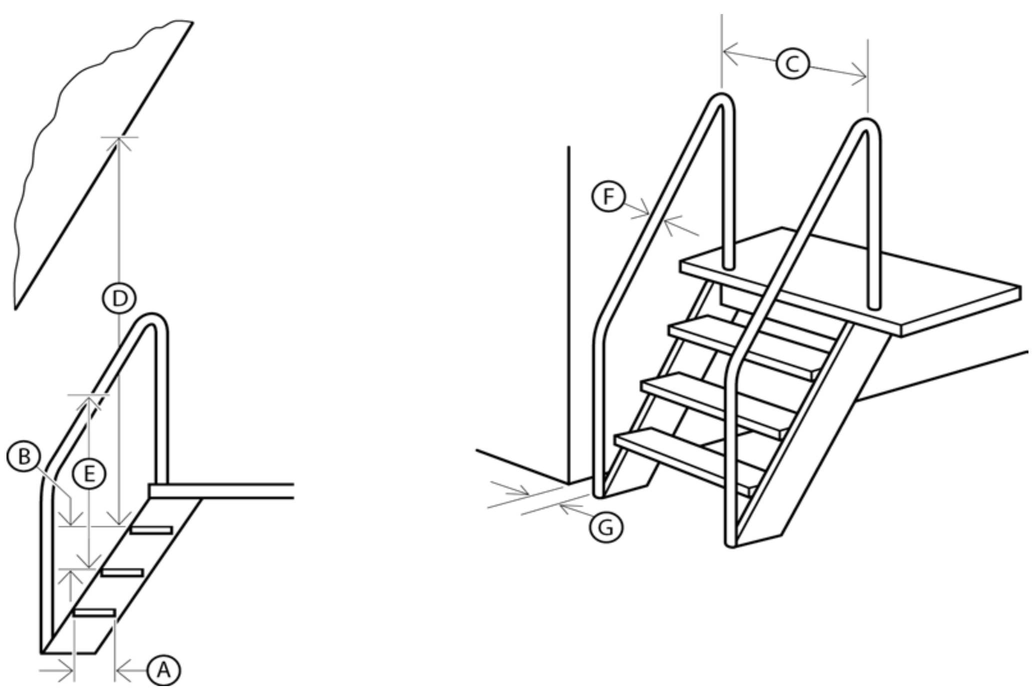


FIGURE 87. Stair ladder dimensions.

Dimension	Minimum	Maximum	Preferred
A: Tread depth range			
For 50° rise	150 mm (6 in)	250 mm (10 in)	215 mm (8.5 in)
For 75° rise (open ladder only)	75 mm (3 in)	140 mm (5.5 in)	100 mm (4 in)
B: Riser height	180 mm (7 in)	300 mm (12 in)	230 mm (9 in)
C: Width (handrail-to-handrail)	530 mm (21 in)	610 mm (24 in)	560 mm (22 in)
D: Overhead clearance 1/	1,730 mm (68 in)	--	1,930 mm (78 in)
E: Height of handrail (from leading edge of tread)	860 mm (34 in)	940 mm (37 in)	890 mm (35 in)
F: Handrail diameter	32 mm (1.1 in)	75 mm (3 in)	38 mm (1.5 in)
G: Rail clearance from wall	50 mm (2 in)	--	75 mm (3 in)

NOTE:

1/ Whenever distance D is less than 1,880 mm (74 in), the overhead obstruction shall be painted with yellow and black stripes.

FIGURE 87. Stair ladder dimensions – Continued.

5.11.8.4.2 Two-way traffic with stair ladders. When simultaneous two-way traffic is desired, separate up and down ladders should be provided located side by side with double center handrails and a minimum separation of 150 mm (6 in) (200 mm [8 in] preferred separation) between these rails.

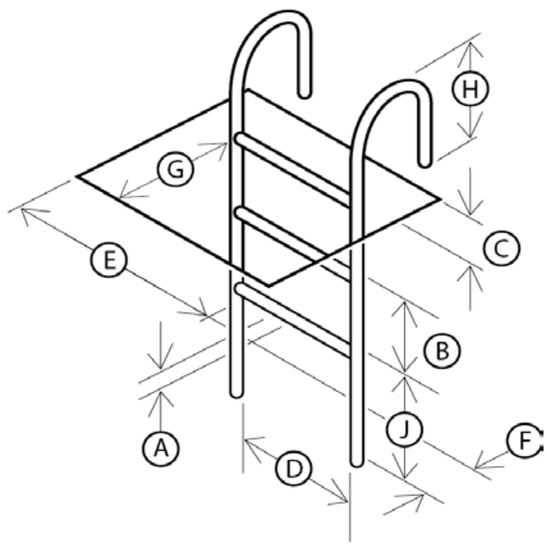
5.11.8.4.3 Open treads and protection. Treads should be open (without riser boards) and have screens or kick plates fastened to the underside to prevent injury to personnel or damage to equipment if objects are dropped.

5.11.8.4.4 Exterior stair ladders. The surface of treads on exterior stair ladders should be constructed of open grating material or be treated with non-skid material.

5.11.8.5 Ladders.

5.11.8.5.1 Fixed ladders.

5.11.8.5.1.1 Dimensions for fixed ladders. Fixed ladder dimensions shall be in accordance with the values on figure 88.



Dimension	Minimum	Maximum	Preferred
A: Rung thickness			
Wood	32 mm (1.1 in)	38 mm (1.5 in)	35 mm (1.4 in)
Protected metal	19 mm (0.8 in)	38 mm (1.5 in)	35 mm (1.4 in)
Corrosive metal	25 mm (1 in)	38 mm (1.5 in)	35 mm (1.4 in)
B: Rung spacing	230 mm (9 in)	300 mm (12 in)	300 mm (12 in)
C: Height, rung to landing	150 mm (6 in)	380 mm (15 in)	380 mm (15 in)
D: Width between stringers	400 mm (16 in)	400 mm (16 in)	400 mm (16 in)
E: Climbing clearance width	610 mm (24 in)	--	760 mm (30 in)
Clearance depth	--	--	--
F: In back of ladder	200 mm (8 in)	--	200 mm (8 in)
G: On climbing side (range)	Minimum of 910 mm (36 in) for 75°, to 760 mm (30 in) for 90°		
H: Height of stringer above landing	1,067 mm (42 in)	--	1,067 mm (42 in)
J: Height from lower elevation to bottom rung	--	180 mm (15 in)	--

FIGURE 88. Dimensions for fixed ladders.

5.11.8.5.1.2 Top rung at access or exit level. The top step or rung of a ladder shall be level with the top of the access or exit level or landing platform served by the ladder.

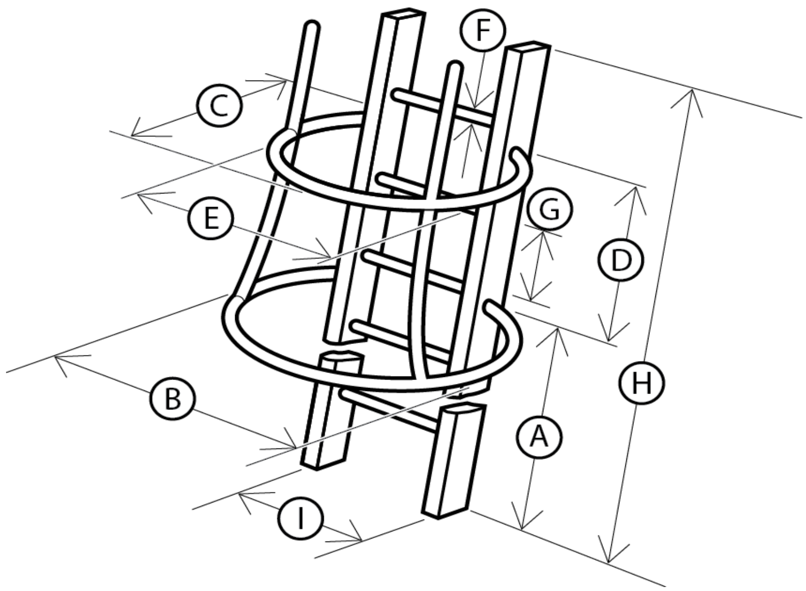
5.11.8.5.1.3 Landing platforms. Landing platforms shall be provided when the stepping distance from the centerline of a ladder rung to the nearest edge of a structure or equipment is greater than 300 mm (12 in).

5.11.8.5.1.4 Step-across distance. The minimum step-across distance between a ladder and a landing platform shall be 64 mm (2.5 in).

5.11.8.5.1.5 Landings and entrances with guardrails. When fixed ladders are used between several floors, the landings and entrances should have guardrails, especially if the ladder well is open.

5.11.8.5.1.6 Cages and safety devices. OSHA-compliant hands free ladder safety devices or cages complying with figure 89 shall be provided for fixed ladders over 6.1 m (20 ft) long.

5.11.8.5.1.7 Rung ladders. Rung ladders are acceptable for occasional traffic, but they shall not be used for frequent passage. For rung ladder dimensions, see figure 89.



Dimension	Preferred
A: Height of cage from base of ladder	2.1 m (6.8 ft)
B: Flare at bottom of cage	800 mm (32 in)
C: Depth of cage from center of ladder	710 mm (28 in)
D: Maximum distance between cage ribs	460 mm (18 in)
E: Width of cage	680 mm (27 in)
F: Rung diameter	35 mm (1.38 in)
G: Rung spacing	300 mm (12 in)
H: Maximum ladder length	
Single ladders	9.1 m (30 ft)
Two-section metal ladders	14.6 m (48 ft)
Two-section wood ladders	18.3 m (60 ft)
I: Minimum width between side rails 1/	
Metal ladders	300 mm (12 in)
Wood ladders up to 3 m (10 ft) long	290 mm (11.4 in)

NOTE:
1/ Add 6 mm (0.25 in) for each additional 610 mm (24 in) in length.

FIGURE 89. Ladder cage and rung ladder dimensions.

5.11.8.5.1.8 Obstruction-free cages. The inside of fixed ladder cages shall be free of all obstructions.

5.11.8.5.1.9 Rungs versus level steps. Rungs provide better hand holds than steps, but when handrails are provided on both sides of the ladder, level steps that are 75 to 100 mm (3 to 4 in) wide should be used.

5.11.8.5.1.10 Non-skid surfaces on rungs. All rungs should have non-skid surfaces.

5.11.8.5.1.11 Tread and tread rise. Tread rise should be open in the rear.

5.11.8.5.2 Portable ladders.

5.11.8.5.2.1 Use. The use of portable ladders should be restricted to emergency functions, infrequent maintenance tasks, or situations where fixed ladders are impractical.

5.11.8.5.2.2 Portable stepladders. 29 CFR 1910.25, 29 CFR 1910.26, 29 CFR 1910.27, 29 CFR 1910.28, and 29 CFR 1910.29 provide guidance for the design, use, and maintenance of wood and metal portable stepladders as well as additional guidance for the design and use of a variety of ladders and scaffolding.

5.11.8.5.2.3 Dimensions for portable stepladders. Portable stepladder dimensions shall be within the minimum and maximum values on figure 90.

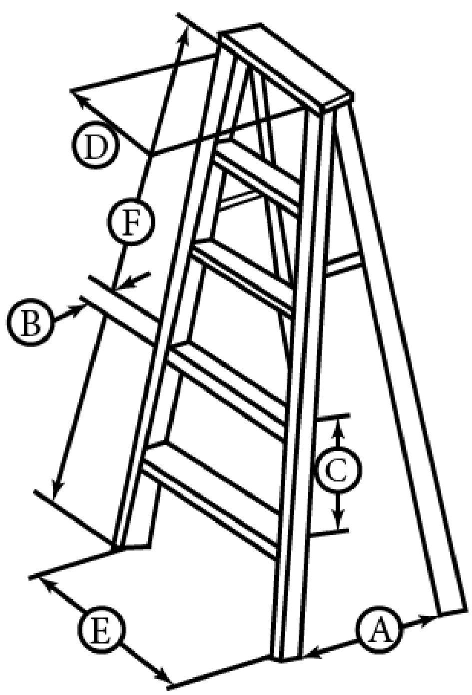


FIGURE 90. Portable stepladder dimensions.

Dimension	Minimum	Maximum	Preferred
A: Spread between side rails	From top to bottom, increase a minimum of 30 mm (1.25 in) per 300 mm (12 in) of side rail length	--	--
B: Tread width	80 mm (3 in)	--	80 to 100 mm (3 to 4 in)
C: Step spacing	230 mm (9 in)	300 mm (12 in)	--
D: Width between side rails at top step	300 mm (12 in)	--	--
E: Width at bottom	Add 30 mm (1.25 in) per foot of length	--	--
F: Length of ladder	--	6.1 m (20 ft)	--

FIGURE 90. Portable stepladder dimensions – Continued.

5.11.8.5.2.4 Lifting ladders. Where one person is to lift ladders and store them by hand, ladder weights shall not exceed 9 kg (20 lb) for a lift distance of 1.8 m (6 ft) or 11.3 kg (25 lb) for a lift distance of 1.5 m (5 ft).

5.11.8.5.2.5 Weather implications for portable ladders. Ladders should be provided with rubber-cleated pivoted feet for use in nonfreezing weather and steel cleats for use in ice and snow.

5.11.9 Surface colors.

5.11.9.1 Army. Unless otherwise specified (see 6.2), surface colors should use the guidance of MIL-HDBK-1473.

5.11.9.2 Navy. Surface colors shall be as specified (see 6.2).

5.11.9.3 Air Force. Surface colors shall be selected from SAE AMS-STD-595 as follows:

a. Console, rack, and cabinet exteriors: 24300 Green

b. Panels: 26492 Gray

c. Non-critical functional grouping pads: 26622 Gray

d. Emergency or critical grouping pads: 21136 Red

e. Interior walls and ceilings: 27875 White

f. Interiors of uninhabited compartments where maintenance is performed: 26622 Gray

g. Standard commercial equipment: existing color. If, however, such equipment becomes an integral part of an assembly, the color shall be identical to or compatible with that of the assembly.

h. Anodized or conductive surface: not painted.

i. Lettering: background color/lettering color:

(1) 24300 Green/17875 White

(2) 26492 Gray/17038 Black

(3) 27875 White/17038 Black

(4) 26231 Gray/17875 White

(5) 21136 Red/17875 White

(6) Anodized or non-painted: 17038 Black or 17875 White, whichever provides better contrast.

(7) Commercial equipment: contrasting color.

5.12 Virtual environments, remotely handled systems, automated systems, telepresence, teleoperations, and telemedicine.

5.12.1 Virtual environments (VE).

5.12.1.1 Task performance. The VE shall replicate natural environments to the degree that tasks can be performed at the same level that would occur in the natural environment, replicating at a fidelity consistent with the tasks being performed.

5.12.1.2 Mental model. Information presented should be consistent with the users' expectations and mental model.

5.12.1.3 VE workstation design.

5.12.1.3.1 Physical barriers. VE workstations shall have physical barriers that prevent persons working in a VE from wandering into hazards or becoming entangled in or unexpectedly constrained by cabling associated with the system.

5.12.1.3.2 Surfaces.

5.12.1.3.2.1 Floors and walkways. Floors and walkways shall be flat and level to accommodate moving or walking users and support personnel.

5.12.1.3.2.2 Ramps and steps. Ramps, steps, and changes in path grade should be minimized. Any such workstation elements should be present in the VE to allow users to navigate them appropriately.

5.12.1.3.3 Cabling. Tethering and cabling should be eliminated as much as possible in order to minimize entanglement and tripping hazards and to limit the extra weight a user must carry or wear in VE devices. Wireless technologies should be considered as an alternative mechanism for system communications when practical.

5.12.1.3.4 Exclusion zone. An equipment-, personnel-, and obstruction-free exclusion zone not less than 1 m (39 in) beyond each edge of the interactive area shall be provided for all immersive VE applications when the operator is not seated or constrained.

5.12.1.3.5 Environment.

5.12.1.3.5.1 Air quality. Efforts shall be made to minimize contaminants that degrade air quality.

5.12.1.3.5.2 Temperature. VE environmental temperature shall be cool and constant (with respect to user's preference) and fans and ventilation shall provide air movement. Cool temperatures and air movement can limit discomfort associated with the warmth and sweating that can be caused by VE sickness.

5.12.1.4 VE (simulator) sickness. Primary causes appear to be due to sensory/perceptual cue conflicts, especially conflicts involving motion including moving images and physical motion. Moving visual fields can cause significant discomfort in 50 to 100 percent of normal healthy observers who are physically stationary, and after-effects can linger for extensive periods of time following exposure. Delays between physical motion and visual displays of motion can be particularly problematic.

5.12.1.4.1 Latency limits. Latency limits shall meet the criteria in 5.12.1.4.1.1 and 5.12.1.4.1.2.

5.12.1.4.1.1 System. System transport delays between user input and system output (display or platform) should not exceed 100 milliseconds (preferred range: 20 to 50 milliseconds) roundtrip (user input, system execution, and display of system execution). System delays as small as 50 milliseconds can negatively impact user performance in critical applications, while longer delays can induce serious behavioral oscillations and manual over-correction loops.

5.12.1.4.1.2 Helmet-mounted displays (HMDs). For displays with head-mounted imagery, delays as brief as 80 milliseconds to respond to a head movement with an updated view have been shown to negatively impact task performance and are likely to affect user sickness and discomfort. Latencies shall be not longer than 150 milliseconds (50 milliseconds preferred) without an evaluation in a representative environment by the user. For HMDs with large fields of view, important precision applications need latencies to be as low as 20 milliseconds or better; the latency shall be not longer than 20 milliseconds. HMD end-to-end system latencies of 5 milliseconds or less are completely imperceptible to a user.

5.12.1.4.2 Frequency range. Flicker or bright light pulsing should be avoided for frequencies in the range of 1 to 30 hertz, as these may cause photic seizures for sensitive individuals and may induce discomfort for others. Using display refresh rates of 100 hertz or greater is also recommended, if possible, for similar reasons.

5.12.1.4.3 Head-mounted display update rate. For head-mounted displays, the scene update rate shall be at least 60 hertz.

5.12.1.4.4 Update rate for critical applications. For critical applications involving fast-moving stimuli or rapid motions, total latency shall not be greater than 20 milliseconds and update rates should be at least 100 hertz.

5.12.1.4.5 Terminal position. Simulations shall always end with the user and visual field geometry positioned as they started.

5.12.1.4.6 Psychological fidelity. Simulations and scenarios to be conducted within simulations shall provide the user with the same psychological fidelity as the target domain. This may include similarity in the types of tasks, decisions, vulnerabilities, workload, and stress as the target domain.

5.12.2 Design of equipment for remote handling (teleoperative control).

5.12.2.1 Characteristics of systems to be handled remotely.

5.12.2.1.1 Alignment. Self-alignment devices shall be provided for components that must be joined remotely.

5.12.2.1.2 Disconnect. Quick-disconnect devices shall be provided for items that must be disconnected remotely.

5.12.2.1.3 Fasteners. Fasteners shall be captive and readily replaceable by remote handling techniques.

5.12.2.1.4 Lock and latching mechanisms. Each lock or latching mechanism shall be operable from a single point, have a positive catch, and provide a clear visual indication of the latch position.

5.12.2.1.5 Body-referenced interfaces latencies. The human interfaces to robotic systems employing body-referenced interfaces shall have latencies below 50 milliseconds.

5.12.2.1.6 Design-function alignment. The design and appearance of the robotic system should be aligned to the intended use of the system such that the appearance should not be mismatched with user expectations.

5.12.2.2 Feedback. Feedback shall be provided to the user from remote work areas of the remote-handling system.

5.12.2.2.1 Environmental transparency. The system should provide real-time information regarding its state in the environment. The system should signal when the environment is degraded such that it will reduce the effectiveness of the system.

5.12.2.2.2 Projective transparency. The system should provide the user with projective information about its future state within the environment. Examples might include projecting geographic locations, time to task completion, temporal and geographic limits of remaining battery life or fuel, and projected task barriers.

5.12.2.2.3 Remote surveillance. For remote surveillance systems, the display shall update no later than 200 milliseconds from user command.

5.12.2.2.4 Automation features and transfer of control.

5.12.2.2.4.1 Automated features. When using automated features, the system should provide the user with awareness of which system features are currently automated and which are manual control or some combination thereof.

5.12.2.2.4.2 Transfer of control. When the system plans to engage in a transfer of control, it should communicate that intent to the user with enough time for the user to perceive the action and to react as desired prior to the system transferring control. This communication could come in the form of audio, visual, or tactile cues. This is true for the case of relinquishing control back to the user or in assuming control from the user.

5.12.2.3 Warnings. Warning indicators (i.e., visual, auditory, or tactile) shall be presented wherever the system health or operational parameters are approaching critical limits. Alerts should also be considered to indicate trends exceeding normal parameters or expected values.

5.12.2.4 Manipulators.

5.12.2.4.1 Safety. Power manipulators shall be provided with positive stops to prevent accidents.

5.12.2.4.2 Characteristics. For tasks requiring manipulative dexterity and load capacities of less than 10 kg (22 lb), manipulators with the following characteristics shall be provided:

a. Position control (i.e., zero-order control in which the user's control output directly determines the machine output).

b. Mutual force reflection between control and effector.

c. Appropriate number of degrees of freedom in motion and force control. The degrees of freedom (DOF) for operator motion control and force control should be matched to the task. For example, a six-DOF telemanipulator task should provide the user with six degrees of control (three for translation, three for rotation). Some tasks may require additional DOF for control, such as gripping.

5.12.2.4.3 Power assist. For tasks involving gross positioning of loads equal to or heavier than 10 kg (22 lb), electrically or hydraulically powered manipulators with rate control (not position control) shall be provided (i.e., the user's control output shall directly determine the rate of change of the machine output).

5.12.2.5 Viewing equipment.

5.12.2.5.1 General. A viewing system that gives the user of a remote manipulator enough information with respect to the parameters of the task (display compatibility) shall be provided. For instance, a three-DOF positional spatial task should provide a display for the three spatial coordinates of the telemanipulator or object being manipulated.

5.12.2.5.2 Direct viewing. When permitted by shielding requirements, provision shall be made for the user to view the work directly through shielding windows. When practical, direct viewing shall be used over indirect viewing.

5.12.2.5.3 Viewing angle. In order to avoid spatial perceptual distortions caused by image refraction, requirements for direct viewing of objects near the viewing window or off-axis from the direct line of sight from the window shall be avoided.

5.12.2.5.4 Indirect viewing. Indirect viewing systems (e.g., closed circuit television systems, periscopes, microscopes) shall be provided to supplement or replace direct viewing where required by specific remote-handling situations.

5.12.2.5.5 Lettering. Letters, numbers, and important details that must be viewed on an electronic display shall be a minimum 12-point sans-serif font at the highest contrast practical. The 12-point font is assuming standard visual display reading distance of approximately 70 cm (28 in). If the display is further, then scale as appropriate to maintain visual angle.

5.12.2.5.6 Surfaces. Glazed or reflecting surfaces shall be avoided.

5.12.2.5.7 Stereo viewing. Stereo viewing designs should meet the following criteria:

a. Stereo-pair images going to each eye should be precisely matched in terms of luminance, color gamut, image size fields-of-view, resolution, magnification, and vertical alignment. This image matching will avoid binocular rivalry and subsequent monocular suppression.

b. For similar reasons to above, interocular channel cross-talk should be avoided so that each eye sees only one image (the image intended for each eye). Double-imaging, ghosting, or cross-talk blur should be reduced so as to be completely imperceptible to a viewer.

c. Stereo camera configurations should utilize parallel configurations instead of convergent or “toed-in” configurations to minimize vertical image disparities and spatial imaging distortions. If “toe-in” is unavoidable, optical or digital image rectification may be necessary.

d. The amount of depth in front of and behind the stereoscopic display shall be limited to ±0.75 diopters to minimize focus-fixation mismatch.

e. Extensive rapid changes in depth (into or away from the plane of the display screen) should be avoided.

f. Viewing times for stereoscopic displays should be limited either if stereo pairs do not meet criteria in 5.2.2.14 or the degree of depth exceeds ±0.75 diopter in front of or behind the display.

g. Refer to 5.2.2.14 for additional information and display characteristics.

5.12.2.6 Illumination.

5.12.2.6.1 Reflected light. Unless otherwise specified (see 6.2), reflected light from remote work areas, as measured at the user’s workstation (in direct viewing), shall be in accordance with the requirements of 5.5.3.12.

5.12.2.6.2 Threshold viewing. Monochromatic lighting shall be provided when viewing conditions are near threshold, when high magnification powers are required, or when the user is required to view the workspace at high angles of incidence through refractive materials.

5.12.2.6.3 Ambient lighting. Ambient room lighting should be reduced to minimize reflections from window (for direct view) or display surfaces (for indirect view) of telerobotic control scenes. Some persistent low-level ambient lighting is recommended for safety purposes (rapid room egress).

5.12.2.6.4 Illumination changes. Sudden changes in room illumination should be avoided during teleoperation, particularly if the viewer is dark-adapted within a space with low light level.

5.12.3 Automated systems.

5.12.3.1 Rationale for automation.

5.12.3.1.1 Provision. Automated systems shall be provided when users cannot reliably, safely, or effectively perform assigned tasks or mission and to keep the user workload at a manageable level.

5.12.3.1.2 Human support. Automated systems shall provide support for human performance in terms of enhancing information processing, enabling faster response times, achieving more accurate process controls, keeping user workload manageable, and increasing overall mission capabilities and effectiveness.

5.12.3.1.2.1 Performance improvement. Functions shall be automated only if they improve user or system performance, user safety, or user workload.

5.12.3.1.2.2 User focused. Automation shall be used to support the user where appropriate (human-centered automation) and not implemented simply because the technology is available (technology-centered automation).

5.12.3.1.2.3 Task difficulty. An automated task shall be less difficult to perform than the manual task it replaces, unless there is a documented system performance requirement that mandates the automation chosen.

5.12.3.2 General requirements.

5.12.3.2.1 User in command. Automated systems shall not remove the user from the command role.

5.12.3.2.2 User involvement. To maintain engagement and situation awareness, users shall be given an active role through relevant and meaningful tasks in the operation of a system regardless of the level of automation being employed.

5.12.3.2.3 Situation awareness. The system shall provide the user situation awareness regarding system state (e.g., position, location), capability (e.g., health, readiness), and, where possible, a projection of system status in a timely manner.

5.12.3.2.3.1 System state parameters. The system shall provide the user with system state parameters that are appropriate to the user's current role and task.

5.12.3.2.3.2 Current situation. The system shall provide the user with its current situation within both functional and mission contexts as appropriate to the user's current role and task.

5.12.3.2.3.3 Future system states. The system should provide the user with likely future system states based on the current situation.

5.12.3.2.4 Predictability. Automated systems shall behave predictably so that the user knows the purpose of the automation and how the operation will be affected by that automation.

5.12.3.2.5 Consistency. The way that automated systems interact with their users shall reflect a high degree of consistency within and between systems.

5.12.3.2.6 Intuitive. Automated systems and associated information displays should be easy to understand, learn, use, and should meet user expectations.

5.12.3.2.7 Input and setup. Automated systems shall provide a way to check automation setup and to check information used as input for the automated system.

5.12.3.2.8 Information. The system shall provide the user information from the perspective of the system hardware and software.

5.12.3.2.9 Multiple systems. Multiple systems designs shall meet the criteria in 5.12.3.2.9.1 and 5.12.3.2.9.2.

5.12.3.2.9.1 Controls and displays. Controls and displays shall be standardized across the different platforms that the same users are expected to control, including users who may be reassigned to or from other platforms.

5.12.3.2.9.2 Terminology. Terminology shall be standardized across the different platforms that the same users are expected to control, including users who may be reassigned to or from other platforms.

5.12.3.2.10 Off-nominal situations.

5.12.3.2.10.1 Recovery. Automation shall maintain sufficient user engagement to allow the user to safely recover during emergencies or operate the system manually if the automation fails.

5.12.3.2.10.2 Limitation. Automated systems shall be designed to avoid mission degradation, system damage, or injury to personnel.

5.12.3.2.10.3 Override capability. The user shall be provided the ability to override, shut down, or neutralize the automated system.

5.12.3.2.10.4 Skills maintenance. The system should provide a means for the user to practice critical skills as determined through analysis (e.g., task, functional, or workload).

5.12.3.3 Function allocation.

5.12.3.3.1 User task. Tasks that are performed in an unpredictable environment requiring flexibility and adaptability should be allocated to the user.

5.12.3.3.2 High-risk actions or decisions. For system tasks associated with greater uncertainty and risk, automation shall not proceed beyond the level of recommending a preferred decision or action alternative as specified (see 6.2).

5.12.3.3.3 Changing roles and responsibilities. The automated system should provide a means for changing the allocation of roles and responsibilities among human and other system components.

5.12.3.3.4 Analysis. Automated systems may be provided when a function allocation analysis indicates that the system hardware and software can accomplish the mission or tasks better than a human.

5.12.3.3.4.1 Allocation of function. Allocation of a function to human or system hardware and software should be made based on the following considerations:

a. An assessment of relative capabilities of humans and system hardware and software.

b. Command authority requirements.

c. Operational effectiveness.

e. Demands to reduce manpower.

f. Technology maturity.

g. Safety implications.

5.12.3.3.4.2 Default allocation. A default function allocation should be implemented wherein every function is assigned exclusively to the human (manual), the system hardware and software (automated), or shared between them (semi-automated).

5.12.3.3.4.3 Dynamic function allocation. When dynamic function allocation is employed during system operation, the reallocation of tasks shall be readily apparent to the user in a way that does not reduce system performance or user situation awareness.

5.12.3.3.4.4 Functions allocated to automation. For functions allocated to automation, the role of the human should be explicitly defined to be that of a manager, monitor, decision maker, system integrator, or backup performer.

5.12.3.3.5 Allocation.

5.12.3.3.5.1 Function allocation. Function allocation shall be determined in terms of well-defined roles for the operator and automation in the performance of each system function.

5.12.3.3.5.2 System functions. System functions should be allocated between the operator and automation to optimize operator engagement in system operations.

5.12.3.3.5.3 Low workload periods. During low workload periods of system operation, the automation should offer the opportunity for the operator to assume manual control of certain functions to support situation awareness, cognitive engagement, and maintenance of manual skills (e.g., flying, sailing, driving).

5.12.3.3.5.4 Considerations. Function allocation to automation should be considered with the following goals in mind to reduce the following:

a. The amount of information to be processed by the operator.

b. The complexity of the information processing.

c. The number of decisions or options to be handled.

d. The complexity of actions, interactions, and communication required.

e. The task accuracy requirements on the part of the operator.

f. The amount of specialized knowledge or skills required of the operator.

g. The level of operator stress due to task complexity or time pressure.

h. The incidence of human error.

5.12.3.4 Interface.

5.12.3.4.1 Relationship with user task. The relationships among displays, controls, decision aids, information structure, and user tasks should be clear to the user.

5.12.3.4.2 Clear roles and responsibilities. The automated system shall clearly indicate whether the user or system hardware and software is supposed to perform a particular task at a specific time.

5.12.3.4.2.1 Changes of state. The interface shall provide clear indication of all changes to the state and level of automation, particularly when a system failure causes mode reversion, or the operator makes a mode change.

5.12.3.4.2.2 Appropriate to level and mode of control. The information elements appropriate to the level and mode of control shall be made salient to the operator as function allocation and level of automation changes.

5.12.3.4.2.3 Return to manual control. When the automation determines that the operator should return to manual control, the system should provide clear indications of the appropriate information and control actions required.

5.12.3.4.3 Continuous feedback. The system should provide an appropriate level of feedback for systems control, status, and outputs under normal operations as well as situations of system malfunction.

5.12.3.4.4 System response. Automated system responses to user commands shall be brief and unambiguous. System responses shall be in accordance with 5.1.2.1.6.

5.12.3.4.5 Visualize consequences of decisions. The automated system should provide information to the user to visualize the expected outcome of a decision, whether made by the user or the automated system.

5.12.3.4.6 Consistency. The behavior of automated systems and interfaces should be consistent with the expectations and understandings of users.

5.12.3.4.7 Organization. Automation interfaces should be organized to match user expectations, task processes, and system capabilities.

5.12.3.4.8 Data space. Interfaces and navigation aids shall provide information to enable the user to know where they are in the data space.

5.12.3.4.9 Representations. Spatial representations of information should be used instead of verbal or textual displays in high workload situations.

5.12.3.4.10 Timeliness. Dynamic information (information that changes over time) shall be presented in real time and on demand to ensure accurate and timely decision making.

5.12.3.4.11 Error checking. Displays and data entry devices should provide a means to cross-check the accuracy of data entered manually.

5.12.3.4.12 Automation modes. Mode designs shall meet the criteria in 5.12.3.4.12.1 through 5.12.3.4.12.7.

5.12.3.4.12.1 Identification. When control, display, or automation functions change in different modes of operation, the system shall provide the user a clear indication of the change and current mode, function identification, and status.

5.12.3.4.12.2 Accessibility. Frequently used modes should be more accessible than infrequently used modes.

5.12.3.4.12.3 Number of modes. The number of different modes for a given system should be minimized.

5.12.3.4.12.4 Switching. The user shall be able to easily switch between modes.

5.12.3.4.12.5 Consistent. Features and functions that are common between display modes shall be consistent.

5.12.3.4.12.6 Alerts. The automated system should alert the user when a particular mode may be potentially hazardous.

5.12.3.4.12.7 Inadvertent activation. The automated system should safeguard against the inadvertent activation of a potentially unsafe mode.

5.12.3.4.13 Monitoring functions. The system should be designed so that users are involved in active control and monitoring of the automated systems and the functionality of its hardware and software, including the display of status and trend information, as needed.

5.12.3.4.13.1 Changing data. Changing data that must be monitored by the users should be displayed in a graphic format.

5.12.3.4.13.2 Limited time. The system should not be designed to require users to perform purely monitoring tasks for longer than 20 minutes at a time.

5.12.3.4.13.3 Multiple displays. When users must monitor multiple displays, notification of important events should occur in the same single physical display in order to promote effective centralized monitoring performance. Important events should occur in the same location within and across displays in order to promote effective monitoring performance.

5.12.3.4.13.4 Monitoring indication. Automated systems that are without incident for long periods of time should provide some type of indication that the automation is still monitoring the system.

5.12.3.4.13.5 User interactions. Automated systems should be able to monitor user interactions and to warn of user errors.

5.12.3.4.13.6 Manual control. Intermittent periods of manual control should be used during extended periods of task automation to improve monitoring of the automation.

5.12.3.4.14 Control functions. Control automation shall meet the criteria in 5.12.3.4.14.1 through 5.12.3.4.14.6.

5.12.3.4.14.1 User control. When automated control actions are performed, the automated tasks should be easily understood by users and similar to user control actions.

5.12.3.4.14.2 Safety or degraded system performance. Control automation should not be able to jeopardize safety or degrade system performance.

5.12.3.4.14.3 Range of control. An automated system should provide the user with an appropriate range of control options that are flexible enough to accommodate the full range of operating conditions for which it was certified.

5.12.3.4.14.4 Feedback. To promote successful situation awareness of the automated system, the user shall be given immediate feedback to command and control orders. System responses shall be in accordance with 5.1.2.1.6.

5.12.3.4.14.5 Flexible. Control automation should be flexible enough to allow for different user styles and responses without imposing new tasks on users or affecting automation performance.

5.12.3.4.14.6 Override. When a user might need to operate in out-of-tolerance conditions, a deliberate overriding action should be provided.

5.12.3.4.15 Automated system information.

5.12.3.4.15.1 Incomplete data. The automated system shall provide a means to indicate to the user that data are incomplete, missing, unreliable, or invalid or that the system is relying on backup data. When the information is graphically displayed, color coding should be used to provide the user the status of the information.

5.12.3.4.15.2 Accurate status. Information presented to the user shall accurately reflect system and environment status in such manner that the user rapidly recognizes, easily understands, and easily projects system outcomes in relation to system and user goals.

5.12.3.4.15.3 Information presentation. Both the content of the information made available through automation and the ways in which it is presented should be consistent with the task priorities.

5.12.3.4.15.4 Cueing important information. When information must be updated quickly, the most important information should be cued to ensure it will be the first to be processed by the user.

5.12.3.4.15.5 Highlight changed data. Data changes that occur following automatic display update should be temporarily highlighted.

5.12.3.4.15.6 Store and prioritize information. Long lists of information and tasks should be stored and prioritized by the automated aid to minimize the number of decision alternatives and reduce the visual processing load of human users.

5.12.3.4.15.7 Information history. Provisions should be made to display historical information that allows the user to display and review changes to critical information.

5.12.3.4.16 Decision aiding. The system should provide sufficient information for the user to properly operate the system.

5.12.3.4.16.1 When to use. Decision aids should be designed to aid the user in effectively operating the system in the following situations or as otherwise specified (see 6.2):

a. For managing system complexity, such as combining multiple cues or criteria, allocating resources, managing detailed information, performing computations, and selecting and deciding among alternatives.

b. For assisting users in coping with information overload by assisting the user in retrieving, retaining, representing, or manipulating large amounts of information.

c. For focusing the user's attention.

d. For assisting the user in accomplishing time-consuming activities more quickly.

e. When limited data results in uncertainty.

f. For overcoming human limitations that are associated with uncertainty; the emotional components of decision making, finite-memory capacity, and systematic and cognitive biases.

5.12.3.4.16.2 When to avoid. Decision aids should not be used in the following situations unless specified (see 6.2):

a. When solutions are obvious.

b. When one alternative clearly dominates all other options.

c. When there is insufficient time to act upon a decision.

d. When the user is not authorized to make decisions.

e. For cognitive tasks in which humans excel, including generalization and adapting to novel situations.

5.12.3.4.16.3 Determine decision aid use. Users should be able to determine when and how the decision aid should be used.

5.12.3.4.16.4 Terms and criteria. Decision aids shall use terminology and criteria appropriate to the target user group.

5.12.3.4.16.5 Response options. Decision aids should reduce the number of response options.

5.12.3.4.16.6 Assist user decisions. Decision aids should assist, rather than replace, human decision makers by providing data for making judgments rather than commands that the user must execute.

5.12.3.4.16.7 Mental models. The support provided by decision aids shall be consistent with user cognitive strategies and expectations (mental models).

5.12.3.4.16.8 Task interruption. Use of decision aids shall not require ongoing user tasks to be cancelled.

5.12.3.4.16.9 Minimize query of user. Decision aids should minimize query of the users for information.

5.12.3.4.16.10 Minimize data entry. Decision aids should minimize user data entry requirements.

5.12.3.4.16.11 Planning strategy. Decision aids should be capable of planning a strategy to address a problem or guide a complex process.

5.12.3.4.16.12 Accept user direction. Decision aids should accept direction from the users on which problem solving strategy to employ when alternative strategies are available.

5.12.3.4.16.13 Prioritize alternatives. When more than one alternative is available, the decision aid shall provide the alternatives in a recommended prioritization scheme based on mission and task priorities.

5.12.3.4.16.14 Decision aid limit. Decision aids should alert the user when a problem or situation is beyond the aid's capability.

5.12.3.4.16.15 Flexibility. Decision aids should be flexible in the types and sequencing of user inputs accepted.

5.12.3.4.16.16 Estimate uncertainty. Decision aids should estimate and indicate the certainty of analysis and provide the rationale for the estimate.

5.12.3.4.16.17 Decision data and information accessibility. Procedural information, derived or processed information, and the data from which it is derived should be visible or accessible for decision verification.

5.12.3.4.16.18 Decision logging. The system shall log decision aid data including screen displays, procedural information, rules and facts, data employed, hypotheses tested, and summary information. This capability should be user configurable to log all, some, or none of the above data.

5.12.3.4.16.19 Decision explanation detail. When the system provides explanations to the user, it should supply a short explanation initially with the ability to make available more detail at the user's request, including access to process information or an explanation for the rules, knowledge basis, and solutions used by the decision aid.

5.12.3.4.16.20 Clear explanations to user. When the system provides explanations to the user, the explanations shall use terms familiar to the user and maintain consistency with the immediate task.

5.12.3.4.16.21 Repeated information. Decision aids should avoid repeating information that is already available.

5.12.3.4.16.22 Alert to newly available information. Decision aids shall alert the user to changes in the status of important system information, such as when critical information becomes available during decision aid utilization.

5.12.3.4.16.23 Patterns. Decision aids should automatically notify the user of meaningful patterns or events, such as when they predict a future problem.

5.12.3.4.16.24 Prediction. Decision aids should provide estimates of future data or system states based on probability data, historical data, and current conditions.

5.12.3.4.17 Frames of reference. The human interfaces should be designed to enable quick and accurate coordination of or shifting between multiple frames of reference as needed for system operation.

5.12.3.4.18 Spatial disorientation. The human interface should minimize spatial disorientation resulting from differing spatial frames of reference between the automated system and the user.

5.12.3.5 Fault management. Design for fault management shall meet the criteria in 5.12.3.5.1 through 5.12.3.5.9.

5.12.3.5.1 Failure recovery. If the automation of one or more components on which the automation depends fails, automated systems shall allow for manual control and preservation of safe operations.

5.12.3.5.2 Failure indication. The system shall indicate automation failures to the user. If a simple indication of automation failure could result in user confusion in selecting an appropriate response, the system should also display the correct action(s) that the user should take.

5.12.3.5.3 Early warning. Early warning notification of pending automation failure or performance decrements shall be presented to the user in sufficient time for the user to successfully adjust to the task.

5.12.3.5.4 Potential failure. The user shall be informed of automation performance decrements, potential failures, and malfunctions.

5.12.3.5.5 Alerts. The user shall be provided unambiguous visual and auditory alerts when the system health or operational parameters are approaching critical limits. Haptic alerts may be provided in addition to visual and auditory alerts as long as they do not degrade the performance of the primary alerting action.

5.12.3.5.6 Causes of alerts. The origin, conditions, and causes of one or more alerts, cautions, or warnings shall be presented in the primary field of view in easily understood human-readable text or graphics.

5.12.3.5.7 Automate diagnostic aids. Fault isolation, inspection, and checkout tasks shall be automated.

5.12.3.5.8 Automatic self-checking components. All essential electronic computer and peripheral components that are part of a system shall incorporate an automatic self-check diagnostic test of software and hardware, both at power up and at the request of the user, to ensure they are functioning properly.

5.12.3.5.9 Diagnostic information. The user shall be provided with sufficient information and controls to diagnose automated warning system operation.

5.12.3.6 Weapon automation.

5.12.3.6.1 Autonomous weapon systems.

5.12.3.6.1.1 Select and engage targets. Upon activation, autonomous weapon systems shall select and engage targets without further human input.

5.12.3.6.1.2 Deactivate autonomous system. The design shall include a means for superior authority to deactivate the autonomous system.

5.12.3.6.1.3 Interface to autonomous system. As determined by the procuring activity (see 6.2), an interface to the autonomous weapon system shall be provided to allow superior authority to monitor and review the activity of the system.

5.12.3.6.2 Human-supervised autonomous weapon systems.

5.12.3.6.2.1 Characteristics. Upon activation by an operator in a supervisory role, the human-supervised autonomous weapon system shall possess the same characteristics as an autonomous weapon system.

5.12.3.6.2.2 Monitor system performance. The design shall provide the ability to monitor system performance in real time within the limits of communication latency to allow an operator to make the decision to intervene as needed.

5.12.3.6.2.3 Control of weapon system. The design shall afford the operator, within the limits of communication latency, access to control of the weapon system for the purpose of changing system parameters or halting its operation in real time.

5.12.3.6.3 Semi-autonomous weapon systems.

5.12.3.6.3.1 Targeting functions. One or more targeting functions, once activated by the operator, will operate autonomously per the instructions of the human operator.

5.12.3.6.3.2 Human on-the-loop. The human operator should remain “on-the-loop” during system operation using an interface that affords the ability to monitor, modify, intervene, or halt autonomous targeting functions.

5.12.4 Unmanned vehicles (UxV). UxV refers to multiple classes of vehicles that operate in any number of environmental domains where the operator of the vehicle is not co-located with the vehicle. A UxV may also be referred to as unmanned, uninhabited, remotely piloted, remotely operated vehicles or systems, or as drones. UxVs come in a wide range of sizes, capabilities, and control strategies. This section applies to those vehicles that can operate beyond visual line of sight or not under manual control. In addition to the requirements found in 5.12.3, the unmanned vehicle system shall meet the specific requirements below.

5.12.4.1 Display. A centralized display (or displays) shall be provided to each operator to convey vehicle system status and alerts.

5.12.4.2 Alerts. At a minimum, the system shall provide alerts under the conditions described in table XXXV to manage operations and emergency states when there are actions available to the operator to correct system operation, alleviate the risk condition, or mitigate risk results.

TABLE XXXV. System alerts.

Alert Condition	Air (UAV/RPA)	Ground (UGV)	Underwater (UUV)	Surface (USV)	Orbital (UOV)
Loss of communication link	X	X	--	X	X
Onboard fuel/power source approaches critical level (e.g., requires return to base or immediate landing)	X	X	X	X	X
Vehicle has navigated all waypoints or does not have positive command of where to maneuver	X	X	X	X	--
Vehicle is approaching its maximum range	X	X	X	X	--
Vehicle is on collision course or is approaching the minimum distance from objects 1/	X	X	X	X	X
Vehicle approaches detection and lethal ranges of a known and relevant hostile defense system 1/	X	X	X	X	X
Vehicle parameter is approaching (a critical value) 2/	Airspeed (stall speed) Altitude (max. and min.)	--	Depth (max. and min.)	--	--

FOOTNOTES:

1/ As determined by the appropriate parameter; for example: vehicle speed, closure rate, and communication range.

2/ The parameters shown in this row are examples only.

NOTE: The information in this table should be considered the minimum set; the procuring activity may provide additional alerting requirements.

5.12.4.3 Latency limits. Latency of displayed data should be limited such that the operator does not perceive a delay between control inputs and the system's response. The amount of tolerable latency is highly dependent upon the nature of the control task. Tasks involving closed-loop (e.g., manual) control strategies are less latency tolerant than supervisory control strategies. Therefore, perceivable delays may be acceptable when the system being operated is not highly dynamic or has been designed to tolerate greater delay. Specific thresholds for certain critical closed loop operations have been established as shown in table XXXVI.

TABLE XXXVI. Latency limits.

Control Operation (Performed by Human)	Air (UAV/RPA)	Ground (UGV)	Underwater (UUV)	Surface (USV)	Orbital (UOV)
Vehicle motion control	100 ms	250 ms	1/	1/	1/
Weapon system control	100 ms	100 ms	1/	1/	1/

NOTE:

1/ Latency limits must incorporate good human engineering practice and state-of-the-art methods until detailed specification data can be developed.

5.12.4.4 Command status feedback. Where perceivable system latency is possible between the control input and the system's response, feedback shall be provided informing the user when the command is sent and received.

5.12.4.5 Decision aiding. Decision aiding shall be provided to help the user with management of vehicle and payload operations. See 5.12.3.4.16 for general decision aiding requirements.

5.12.4.5.1 Computations. The decision aiding system shall perform the computational processing required to present courses of action to the user.

5.12.4.5.2 Operational phases. The decision aiding system shall augment all phases of operations including the following, as applicable:

a. Launch operations.
b. Recovery operations.
c. Route navigation.
d. Transfer of vehicle and payload control between users.
e. Targeting and weapon employment.

5.12.4.5.3 Control of multiple vehicles. In addition to decision aids for managing a single UxV, when the vehicle to crew member ratio is greater than one, decision aids shall be provided to help manage the group of vehicles. These aids shall be designed specifically to assist crew members in the management of vehicle, payload, and mission tasks across vehicles.

5.12.4.6 Symbology.

5.12.4.6.1 UxV mapping symbology. With the exception of primary flight information symbology, as applicable, UxV mapping symbology to support command and control operations shall be in accordance with MIL-STD-2525.

5.12.4.6.2 Unmanned aerial vehicle (UAV) primary flight symbology. UAV primary flight symbology shall comply with MIL-STD-1787 to the extent specified (see 6.2).

5.12.4.7 Monitoring systems. All UxVs shall be monitored by a human operator to the extent appropriate for the system's environmental domain, levels of automation, autonomy, and reliability to ensure mission effectiveness and safety. Monitoring systems shall include, as available, the information in table XXXVII when it is required for system checkout, control, troubleshooting, or mishap investigation.

TABLE XXXVII. Monitored information.

Vehicle State Parameter	Air (UAV/RPA)	Ground (UGV)	Underwater (UUV)	Surface (USV)	Orbital (UOV)
Altitude	X	--	--	--	--
Depth	--	--	X	--	--
Distance	X	X	X	X	--
Heading	X	X	X	X	--
Inclination angle	--	--	X	--	--
Pitch	X	X	X	X	--
Position/location	X	X	X	X	X
Roll	X	X	X	X	--
Speed	X	X	X	X	--
Yaw	X	X	X	X	--
NOTE: To the extent that they support the human operator’s role in managing the system, these vehicle state parameters as well as any others required by the procuring activity shall be displayed to the human operator according to accepted human factors methods.					

5.12.4.8 Manual handling. Manual handling affordances shall be provided to assist the operator during launch and recovery as well as any other mission phases specified (see 6.2).

5.12.4.9 Planning. The system control station shall provide a means to program vehicle missions, pre-mission planning and verification, and post-mission data processing and display.

5.12.4.10 Return home. Automated user-controlled systems shall be designed to provide an automatic safe “return home” capability when communication is lost between the system and users for a time period specified (see 6.2).

5.12.4.11 Neutralize capability. Automated user-controlled systems shall be designed to provide a neutralize capability when communication is lost between the system and users for a time period specified (see 6.2).

5.12.4.12 Transponder. Remote user-controlled systems shall include an emergency transponder to provide location information when communication is lost between the user and the system.

5.12.4.13 Short notice controls. Automation modes shall be provided that afford the operator the ability to immediately enact short notice changes in vehicle state parameters (e.g., heading, altitude, speed) that provide time and space to safely make the more complex changes to the programmed vehicle path (e.g., change in landing runway) required by the controlling authority (e.g., air traffic control).

5.12.5 Telepresence systems. The system shall provide the user with a sense they are part of the system being controlled.

5.12.5.1 Timely feedback. The system should provide feedback for all controls and displays in a timely manner consistent with 5.12.4.3 and table XXXVI.

5.12.5.2 Clear feedback. The system shall provide clear, concise feedback to the user.

5.12.6 Telemedicine. Telemedicine encompasses telediagnosis, telenursing, telemonitoring (patients), telepharmacy, and teletherapy (or telerehabilitation).

5.12.6.1 Telediagnosis. Device designs should be in accordance with the criteria in 5.12.6.1.1 through 5.12.6.1.3.

5.12.6.1.1 Electromagnetic (optical). Electromagnetic (optical) telemedicine and telediagnosis shall be in accordance with ANSI Z136.1 and ANSI Z136.3.

5.12.6.1.2 Electromagnetic (radiofrequency).

a. Field strength and power density for frequencies of 300 kilohertz to 100 gigahertz shall be in accordance with OET Bulletin 56.

b. Specific absorption rate (SAR) limits shall be in accordance with IEEE C95.1; FCC 96-326; and 47 CFR 1.1307(b), 47 CFR 1.1310, 47 CFR 2.1091, and 47 CFR 2.1093, Parts 1 and 2.

5.12.6.1.3 Electrical. Electrical telediagnosis shall be in accordance with IEC 60601-1-2 and ISO 14971.

5.12.6.2 Electronic medical records. Telemedicine devices that generate, store, or transmit protected health information (PHI) or personally identifiable information (PII) shall be as specified (see 6.2).

5.12.6.2.1 National and DoD-level instructions. Electronic medical records shall be in accordance with Public Law 104-191, Public Law 111-5 Title XIII, 5 USC 552, DoDI 6025.18-R, DoDI 5400.11-R, DoDI 8580.02-R, and DoDI 5400.7-R.

5.12.6.2.2 Air Force-level instructions. Electronic medical records shall be in accordance with AFI 33-332, AFI 41-210, and AFI 44-102.

5.12.6.2.3 Army-level instructions. Electronic medical records shall be in accordance with the OTSG/MEDCOM Release of Protected Health Information to Commanders Webpage and AR 40-66.

5.12.6.2.4 Navy-level instructions. Electronic medical records shall be in accordance with NAVMED Policy 08-005, SECNAVINST 5211.5, and SECNAV M-5210.1.

5.12.6.3 Security and encryption protocols.

5.12.6.3.1 Currency. Telemedicine devices shall provide an indication of the level of user authorization and present DoD or service-specific information.

5.12.6.3.2 Service differences. Mitigations and indications for service security regulation differences shall be provided as determined by the procuring activity (see 6.2).

5.12.6.3.3 Authentication. A means for authenticating patient information shall be provided.

5.12.6.3.4 Device access. A means for restricting access to the PHI/PII to only authorized personnel shall be provided.

5.12.6.3.5 Information protection labels. If the device is intended to interact with telecommunications systems (e.g., e-mail), a means to clearly and appropriately label the information shall be provided.

5.12.6.3.6 Interoperability with legacy systems. The device should be compatible with current or legacy systems (i.e., the Armed Forces Health Longitudinal Technology Application and the Composite Health Care System).

5.12.6.4 Remote applications.

5.12.6.4.1 Design approach. Designs should be in accordance with the following references:

a. Human engineering: AAMI HE75 and AAMI 62366-1.

b. Usability engineering: AAMI HE75, AAMI 62366-1, and ISO 9241-210.

5.12.6.4.2 Decision support.

5.12.6.4.2.1 Decision rules. Upon user request, decision support systems should provide descriptions of the decision rules being used, their default levels, or visualizations.

5.12.6.4.2.2 Individual decisions. Decision support systems should provide a method and interface for users to inquire about individual decisions and how they are made (i.e., a decision tree description).

5.12.6.5 User interfaces.

5.12.6.5.1 Text characteristics. The reader is cautioned that some of the criteria below may differ slightly from that given in 5.17. The criteria specified in sections 5.12.6.5.1.1 through 5.12.6.5.1.8 below should be in accordance with the references in 5.12.6.4.1.

5.12.6.5.1.1 Typeface style. Text appearing on screen should have a simple typeface style that is optimized for legibility.

5.12.6.5.1.2 Sans serif. Typefaces should be sans-serif (letters without extra details). Some common examples are News Gothic, Helvetica, and Arial.

5.12.6.5.1.3 Scalable. Typefaces should be scalable to provide a smooth appearance without jagged edges.

5.12.6.5.1.4 Simulation of medical instrument readout. Typefaces should not simulate the look of a medical readout produced by a segmented display.

5.12.6.5.1.5 Text size. Text size should be set to ensure reliable communication at the maximum expected viewing distance.

5.12.6.5.1.6 Critical information. Critical information displayed as text should be at least $\frac{1}{150}$th of the maximum expected viewing distance.

5.12.6.5.1.7 Important information. Important but non-critical information displayed as text should be at least $\frac{1}{300}$th of the maximum expected viewing distance.

5.12.6.5.1.8 Capitalization. Capitalization of letters, words, or portions of words can be utilized to draw attention to important textual information. Use of capitalization as a highlighting technique should be limited to individual letters, full words (when short), and short phrases.

5.12.6.5.2 Choice of device, fixed or mobile. Device selection should be in accordance with AAMI HE75 and AAMI 62366-1.

5.12.6.6 Automation. Refer to AAMI HE75.

5.12.6.6.1 Medical sequence. When automation is used, the system should provide the medical sequence of actions that will be executed.

5.12.6.6.2 Information on current step. Upon request, the system should provide detailed information regarding the current step of the defined automated sequence.

5.12.6.6.3 System safeguards. The system shall provide safeguards to allow the system users to prevent errors and confirm proper operation during setup, initialization, and use.

5.12.6.6.4 Predictable dangerous states. The system shall provide the ability to predict dangerous states to the user so they can intervene to prevent them.

5.13 Individual, crew-served, ground and air weapons systems, and optics.

5.13.1 Weapons systems. Given the rapidly evolving nature of electromagnetic rail-gun, laser, and directed energy weapons, this section has not yet been tailored for those weapons systems. Applicability of MIL-STD-1472 guidance to those systems should be determined by a trained human factors engineer.

5.13.1.1 Ammunition. This section applies to vehicular and towed gun systems employing rounds consisting of fixed or semi-fixed propellant-driven projectiles or gun-tube fired missiles and rockets.

5.13.1.1.1 Rounds storage. Means shall be provided to prevent stowed rounds from dropping or impacting each other when the vehicle is moving or when the gun is fired.

5.13.1.1.1.1 Removal by hoist or manual means. The design shall provide for easy stowage and removal of ammunition by hoist or manual means.

5.13.1.1.1.2 Ready rack. The ready rack, if used, shall be designed so that several different types of ammunition can be stowed and removed without shifting other rounds and to minimize interference with the work area.

5.13.1.1.2 Handling. When manual handling is required, ammunition shall be stowed such that the gun can be loaded safely, rapidly, and effectively.

5.13.1.1.3 Orientation. Rounds shall be stowed such that the loader requires minimum movement and handling of the round in order to achieve proper orientation for positioning the round in the breech.

5.13.1.1.4 Rounds transfer. Unobstructed workspace shall be provided for transferring the rounds from outside the vehicle to the ready rack and from the ready rack to the breech.

5.13.1.1.5 Disposal of empty cases. Provisions shall be made for disposing of empty shell cases in vehicles using fixed and semi-fixed ammunition.

5.13.1.1.6 Ammunition hoist. Where an ammunition hoist is used, the rounds shall be prevented from swinging about, thereby endangering personnel or damaging equipment.

5.13.1.1.6.1 Hoist design. The ammunition hoist design shall include a clamp to prevent accidental release of projectiles.

5.13.1.1.6.2 Manual operation. The ammunition hoist shall provide for manual operation of the hoist in case of a power failure.

5.13.1.1.6.3 Stow without interference. The ammunition hoist shall be capable of being stowed without interference with either the ramming trough or breech lock mechanism.

5.13.1.1.7 Ammunition stowage racks. Ammunition stowage racks, whether loaded or empty, shall not impede escape from the crew compartment, obstruct access to controls, obscure displays, or interfere with the footing of crewmembers during operation of the weapon system.

5.13.1.1.7.1 Ammunition stowage rack location. Ammunition stowage racks shall be located so personnel can remove and replace ammunition from the stowage rack without striking any protrusions.

5.13.1.1.7.2 Ready racks. Where ready racks are located to the rear of the gun breech, sufficient distance shall be provided for a channel between the rack and the breech to accommodate the longest round anticipated plus the thickness of the 95th percentile male hand, including any gloves or protection the user may be wearing, plus an additional 50 mm (2 in) of clearance.

5.13.1.1.7.3 Floor and hull. Floor and hull stowage tube-type ammunition racks shall be spring loaded so that stowed rounds will travel at least 50 mm (2 in) out of the rack when the latching mechanism is released.

5.13.1.1.7.4 Spring loading not feasible. Where spring loading is not feasible, the end of the tube shall be recessed to facilitate gripping by hand.

5.13.1.1.7.5 Upright mounts. Upright-mounted ammunition weighing over 18.1 kg (40 lb) shall have a floor retainer that has sufficient clearance to allow removal by the appropriate dimensions of the 95th percentile male hand, including any gloves or protection the user may be wearing.

5.13.1.1.7.6 Latching mechanisms. Ammunition rack latching mechanisms shall be of a quick-release design that requires no more than 53 newtons (12 pounds-force) of force to operate.

5.13.1.1.7.6.1 Free of sharp edges. Latching mechanisms shall be free of sharp edges or protrusions that can snag clothing or injure personnel during entrance, exit, and movement within the vehicle.

5.13.1.1.7.6.2 Remain in open position. Latching mechanisms shall remain in the open position or fold out of the way by gravity when unlatched to allow the removal and replacement of ammunition in stowage racks.

5.13.1.1.7.6.3 Position apparent. It shall be apparent to personnel when the ammunition rack latching mechanism is in the locked position but not secured.

5.13.1.1.7.6.4 Cushioning material. Latching mechanisms shall have a cushioning material to minimize transmission of undesired dynamic effects to secured rounds.

5.13.1.1.7.6.5 Damage prevention. The latching mechanism shall not allow distortion, bursting, or rupturing of the round or cartridge case.

5.13.1.1.7.6.6 Damage to internal components. The latching mechanism shall prevent damage to the internal components of the missile or round.

5.13.1.1.8 Fuzes.

5.13.1.1.8.1 Surface material. The surface of hand-manipulated fuze controls shall be a material that will maximize the grip the user can maintain on the fuze.

5.13.1.1.8.2 Surface texture. The texture of the surface finish shall not interfere with the aerodynamic performance of the round.

5.13.1.1.8.3 Detents. Fixed detents shall be used for each position on a fuze so that the moving component of the control will snap into place in the selection of each fuze.

5.13.1.1.8.4 Resistance. Sufficient resistance shall be built into the fuze control to prevent the inadvertent change of settings.

5.13.1.1.8.5 Pointers.

5.13.1.1.8.5.1 Pointer color. Markings and pointers shall be of the same color.

5.13.1.1.8.5.2 Pointer contrast. Markings and pointers shall have contrast with their background in accordance with 5.17.25.16.

5.13.1.1.8.6 Separation. The pointer tip and index marks shall not be separated by more than 1.5 mm (0.06 in).

5.13.1.1.8.7 Multi-position selectors. Multi-position selectors shall be designed to resist changes of user settings that may result from the rotational force imparted by the round either during firing or while in flight.

5.13.1.1.8.8 Selector mechanism. The selector mechanism shall be designed such that linear acceleration will lock the selector in place and prevent accidental changes in setting.

5.13.1.2 Primary armament.

5.13.1.2.1 Reversible procedures. Primary armament loading procedures shall be reversible for efficient and safe round removal.

5.13.1.2.2 Minimize vibration. Provision shall be made to minimize vibrations of the gunner's sight from the shock of loading the primary armament.

5.13.1.2.3 Breech design. A breech weighing over 22.5 kg (50 lb) shall not be considered manually removable.

5.13.1.2.3.1 Manual breech operation. For manual breech operation, the operating force shall not exceed 130 newtons (29 pounds-force) of force for one-handed operation and 220 newtons (50 pounds-force) of force for two-handed operations.

5.13.1.2.3.2 Controls for power-operated breeches. The controls for power-operated breeches shall be located away from the breech to protect personnel when the breech is in operation.

5.13.1.2.3.3 Stored mechanical energy. Stored mechanical energy in the breech block which, if released, could injure personnel, shall be protected by interlock from accidental actuation.

5.13.1.2.3.4 Prevention of system damage and injury to personnel. The primary armament recoil mechanism shall be capable of being exercised by crew personnel without damage to the system or danger of injury to personnel.

5.13.1.2.4 Maintenance. Primary armament machined surfaces shall be protected from the environment to minimize maintenance requirements.

5.13.1.2.4.1 Special tools. Crew maintenance of the primary armament shall not require special tools (i.e., tools not listed in the GSA Global Supply Catalog).

5.13.1.2.4.2 Cleaning. The primary armament chamber shall be capable of being cleaned by the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped males of the target user population and the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped females of the target user population.

5.13.1.2.4.3 Servicing machine surfaces. Servicing polished machine surfaces shall not require removing the gun tube.

5.13.1.2.4.4 Drains. The breech design shall provide drains where necessary to preclude trapping cleaning fluids.

5.13.1.2.5 Spent casings. The ejection of spent casings shall be such as to not endanger personnel or equipment.

5.13.1.2.6 Storage of spent casings. Space shall be provided to store spent casings within the fighting compartment or a means shall be incorporated into the design to allow disposal of these casings by another method.

5.13.1.2.7 Boresighting. Boresighting shall be capable of being accomplished by the naked eye and without use of tools from within the fighting compartment.

5.13.1.2.7.1 Boresight without disassembly. Boresighting shall be capable of being accomplished without disassembly in order to achieve the specified convergence with the line of sight or to be parallel with the line of sight.

5.13.1.2.7.2 Quadrants and other devices. Quadrants and other devices mounted on the primary armament shall be accessible to the gunner throughout the full range of elevation and depression.

5.13.1.2.8 Electrical components. The electrical potential of power components shall be capable of being de-energized at the primary power source.

5.13.1.2.8.1 Shielding. Shielding shall be provided to prevent accidental contact with wires and electromagnetic pulse.

5.13.1.2.8.2 Disconnect capability. A disconnect capability shall be provided at both the powered component and power source.

5.13.1.3 Secondary dismountable armament.

5.13.1.3.1 Removal and replacement. The secondary dismountable armament shall be capable of being mounted on the vehicle by crewmembers from a natural working position (i.e., a position that does not extend or contort the body risking injury) with the weapon fully assembled.

5.13.1.3.1.1 Tools. The secondary dismountable armament shall be capable of being removed or replaced without the use of special tools (see 5.13.1.2.4.1).

5.13.1.3.1.2 Number of turns. The number of turns required for installing or removing threaded fastening devices shall be minimized.

5.13.1.3.2 Retaining devices. All secondary dismountable armament retaining devices (pins or bolts) shall be captive or attached to their mounts by a chain or similar captive device.

5.13.1.3.2.1 Retaining pins. All retaining pins should be provided with handles to expedite their removal under conditions of binding or corrosion.

5.13.1.3.2.2 Clamps. Clamps or similar retaining devices shall be hinged to swing away from the mount.

5.13.1.3.2.3 Quick disconnect. Clamps or similar retaining devices shall be the quick-disconnect type.

5.13.1.3.3 Ground mount operation. When required, the secondary dismountable armament shall be capable of being removed and put into a ground mount while hot.

5.13.1.3.4 Pintle. The pintle shall be capable of remaining attached to the weapon, be designed to position itself by gravity, and not need to be held by hand when positioned into the ground mount.

5.13.1.3.5 Sights. The rear sight notch shall be 3 mm (0.12 in) or wider, and the front sight shall be wide enough to fill the notch when sighting.

5.13.1.3.6 Assembly and disassembly. The secondary dismountable armament shall be designed such that barrels are not capable of incorrect assembly and are capable of being changed from the inside of the fighting compartment without affecting the boresight.

5.13.1.3.6.1 Kinetic energy assemblies. The driving rod and spring, or similar kinetic-energy mechanical assemblies, shall have a positive release or lock and not be hazardous if accidentally released during servicing.

5.13.1.3.6.2 Dry fire. After servicing, the weapon shall be capable of being dry-fired without damage to ancillary parts.

5.13.1.3.7 Solenoids. If used, solenoids shall be capable of activating the firing mechanism of the weapon both manually and electrically.

5.13.1.3.7.1 Feedback. When checked electrically, the solenoid shall produce an audible click or visual signal to indicate that it is functioning.

5.13.1.3.7.2 Adjustment. Solenoids shall be adjustable, provided with an adjustment in the linkage to limit or compensate for tolerance buildup, or have sufficient plunger and armature travel to eliminate the need for adjustment.

5.13.1.3.7.3 Removal and replacement. Removing and replacing solenoids shall not require extensive disassembly or assembly of the weapon.

5.13.1.3.7.4 Wiring and connectors. Wiring and connectors shall be mounted such that they will not be caught in turret rings or gun breeches.

5.13.1.3.7.5 Protection against abrading. Wiring shall be protected against abrading through abuse or striking a surface when personnel are removing, replacing, or servicing the weapon.

5.13.1.3.7.6 Guard against misconnection. To guard against misconnection, the solenoid shall have an electrical connector designed to eliminate reverse polarity.

5.13.1.3.8 Operation. A weapon shall be capable of being loaded without being cocked.

5.13.1.3.8.1 Loading. The weapon shall be capable of being loaded by the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped males of the target user population and the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped females of the target user population in both the vehicle and the ground mount.

5.13.1.3.8.2 Headspace and timing. When headspace or timing is used, a simple go/no-go indication shall be provided.

5.13.1.3.8.3 Charging. The weapon shall be capable of being charged by the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped males of the target user population and the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped females of the target user population.

5.13.1.3.8.4 Charging in prone position. For ground mount weapons, charging shall be possible with the user in the prone position.

5.13.1.3.8.5 Charging with wires or chains. Where wires or chains are used to charge the weapon, the action of charging shall be a non-directional reaction to an applied force.

5.13.1.3.8.6 Charging resistance. Charging resistance shall not exceed 340 newtons (250 pounds-force) breakout force or 80 newtons (60 pounds-force) sustained.

5.13.1.3.8.7 Spent rounds. Spent brass and links shall be caught by a spent brass container or be ejected outside the fighting compartment.

5.13.1.3.8.8 Path of ejected casings. The trajectory and path of the ejected casings shall be such that ejection will not injure a crewmember, interfere with crew operations, or affect other equipment.

5.13.1.3.8.9 Remove jammed cases. The weapon design shall permit the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped males of the target user population and the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped females of the target user population to remove jammed cases without disassembly of the weapon and without endangering the hand.

5.13.1.3.8.10 Tools. If a tool is required, it shall be mounted to or be captive to the weapon on which it is to be used.

5.13.1.3.8.11 Ammunition chutes. Flexible ammunition chute openings shall be large enough to allow the ammunition to be guided through the chute by the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped males of the target user population and the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped females of the target user population.

5.13.1.3.8.12 Sharp edges. Ammunition chutes shall be free of sharp edges that could cut the hands of personnel during loading operation. Edges shall be rounded to a radius not less than 0.75 mm (0.03 in) in accordance with 5.7.6.3.

5.13.1.3.8.13 Rate selectors and safeties. Rate selectors, safeties, or triggers shall be clearly identified to indicate their position.

5.13.1.3.8.14 Rate selector, safety size, and resistance. Rate selectors and safeties shall be of sufficient size and resistance to accommodate the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped males of the target user population and the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped females of the target user population.

5.13.1.3.8.15 Rate selector and safety detents. Detents shall be provided for each position on rate selectors and safeties.

5.13.1.4 Small arms.

5.13.1.4.1 General. In this section, the term “user” refers to the rifleman or gunner, as appropriate.

5.13.1.4.1.1 Design. Weapons shall be designed so the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped males of the target user population and the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped females of the target user population can perform all required tasks (both field operation and maintenance) in daylight and at night from any operational firing position.

5.13.1.4.1.2 Field assembly. When the user must reassemble parts under field conditions, their mating surfaces should be beveled to simplify assembly.

5.13.1.4.1.3 Surfaces. Surfaces of the weapon or its attachments that normally contact the user’s body or clothing during firing or maneuvering shall be smooth with no sharp edges or discontinuities.

5.13.1.4.1.4 Thermal insulation. As directed by the procuring activity (see 6.2), any part of the weapon or attachments that generates heat against the user’s skin shall have thermal insulation.

5.13.1.4.1.5 Minimize projections. Weapon design shall minimize projections that could impede movement through vegetation.

5.13.1.4.1.6 Unavoidable projections. Unavoidable projections, such as the front sight post, should be angled toward the back of the weapon rather than perpendicular to its barrel.

5.13.1.4.1.7 Controls or latches. A weapon's controls or latches should be ambidextrous in design and located so they will not be actuated unintentionally during fire or maneuver.

5.13.1.4.1.8 Avoiding weapon damage. Weapons shall be designed so users will not damage them by operating controls in the wrong sequence or by using full-hand force.

5.13.1.4.1.9 Assembly. Design shall incorporate error-proofing measures in equipment mounting, installing, interchanging, connecting, and operating.

5.13.1.4.1.10 Durability. Weapon controls shall be sufficiently sturdy and durable to prevent damage from normal handling in the field.

5.13.1.4.1.11 Captive hardware. Whenever the user is likely to remove retaining pins during field operations or maintenance, captive hardware should be used to prevent pin loss.

5.13.1.4.1.12 Weapon's safety. The weapon's safety selector should be ambidextrous in design and located so the user can change from SAFE to FIRE, and vice versa, quickly without moving either hand from its normal firing position.

5.13.1.4.1.13 Distinctive shape. Weapon controls shall have distinctive shapes and locations to simplify their identification and use during stressful situations.

5.13.1.4.1.14 Safety. Safety shall be designed into weapons by ensuring that no part of the weapon could endanger the user's face during firing when the head is held in the proper eyesight position.

5.13.1.4.1.14.1 Clear eye distance safety. Safety shall be designed into weapons by ensuring that no part of the scope could endanger the user's eye during firing recoil when the head is held in the proper eyesight position

5.13.1.4.1.15 Magazine orientation. Magazines shall only be insertable in the correct orientation (i.e., not with cartridges facing the wrong way).

5.13.1.4.1.15.1 One hand operation for magazines. Magazines shall be designed to be inserted into the weapon with one hand.

5.13.1.4.1.15.2 Magazine surfaces. Magazines shall have a non-slip finish on all surfaces the user will hold during all handling operations.

5.13.1.4.1.15.3 Magazine insertion. Loading the weapon shall require only inserting the magazine and charging the weapon. No additional user tasks shall be required.

5.13.1.4.1.15.4 Magazine loading pattern. A particular loading pattern is not desired; however, where this is required, a magazine loading diagram shall be provided.

5.13.1.4.2 Rifles and machine guns. In addition to the above requirements, rifles and machine guns shall also meet the requirements below.

5.13.1.4.2.1 Charging handle. The charging handle shall not interfere with the bolt during firing.

5.13.1.4.2.2 Bipods. When a bipod is used, it shall be designed with the following characteristics.

5.13.1.4.2.2.1 Use with arctic mittens. A user wearing arctic mittens shall be able to extend or retract the bipod.

5.13.1.4.2.2.2 Extended or retracted setting. Recoil and stresses of field maneuvering shall not disturb the bipod's extended or retracted setting.

5.13.1.4.2.2.3 Grasp without obstruction. With the bipod retracted, the user shall be able to grasp the foregrip without obstruction in any operational firing position.

5.13.1.4.2.2.4 Uneven terrains. The bipod shall accommodate uneven terrain without cant.

5.13.1.4.2.3 Rear sight.

5.13.1.4.2.3.1 Retain component parts. All component parts shall be positively retained.

5.13.1.4.2.3.2 Rear aperture. The rear aperture and other parts shall remain secure during the stresses of carrying and firing.

5.13.1.4.2.3.3 Windage and elevation controls. Windage and elevation controls shall have detents to prevent disturbing of settings as a result of carrying and firing.

5.13.1.4.2.3.4 Set with mission clothing and equipment. The design shall allow the user wearing mission clothing and equipment to precisely set windage and elevation controls without tools.

5.13.1.4.2.3.5 Differentiation of controls. Windage and elevation controls shall be clearly differentiated to minimize confusion.

5.13.1.4.2.3.6 Control settings obvious. Windage and elevation control settings shall be immediately obvious in daylight when the user is in any operational firing position.

5.13.1.4.2.3.7 Verify setting. When in an operational firing position, the user shall able to verify the windage and elevation setting quickly without moving the body or the weapon, manipulating any sight component, counting, or requiring visual or auditory cues.

5.13.1.4.2.4 Spent cases. Weapons shall eject spent cases into the first quadrant (forward and to the right) as a default. Where possible, design should also accommodate left-handed users and allow for adjustability of ejection into the second quadrant (forward and to the left).

5.13.1.5 Weapon system tracking performance.

5.13.1.5.1 Gunner environment. Where applicable, obscuration, shock, and vibration shall be sufficiently minimized to permit resumption of tracking after firing and should be sufficiently minimized to allow continuous tracking and firing.

5.13.1.5.1.1 Time lag. The time lag for post-fire reacquisition tracking of the intended target should not exceed 5 seconds.

5.13.1.5.1.2 Target tracking. The placement and function of target tracking system should be unaffected by the operation (firing) of the weapon.

5.13.1.5.1.3 Compensate for projectile trajectory. The tracking system should include the capability for the weapon system operator to compensate for projectile trajectory corrected for the caliber and characteristics of the weapon and the distance to the intended target.

5.13.1.5.1.4 Confirmation. The weapon system should permit uninterrupted target tracking for confirmation of "hit" or "miss."

5.13.1.5.1.5 Remote weapons system tracking. The remote weapons system shall provide the weapon system operator with the capability for positive acquisition, identification, and tracking of the target, which is synchronized and boresighted with the movement and field of fire of the weapon.

5.13.1.5.2 Crank size. The size of tracking cranks, where used, shall be a function of rotation speed and range of motion required to traverse the full azimuth and elevation arcs as quickly as possible without negative effect upon target tracking, impact verification, or the ability of the operator to maintain total control and stability of the weapon.

5.13.1.5.3 Manual crank speed. Crank speed shall be from 140 to 200 RPM of the crank for radii between 55 and 115 mm (2.2 and 4.5 in). As the radius of the crank increases, the required RPMs to maintain shaft rotational speed may decrease.

5.13.1.5.3.1 Traversing of azimuth. Each full revolution of the manual crank shall equate to actual movement of the weapon such that the complete azimuth arc can be traversed at a steady rate of change of at least 22.5 degrees per second.

5.13.1.5.3.2 Traversing of elevation. Each full revolution of the manual crank shall equate to actual movement of the weapon such that complete traversing of the elevation arc from fully declined to fully inclined, or vice versa, can be accomplished within 3 seconds.

5.13.1.5.4 Two-dimensional tracking. A single integrated control, rather than separate controls for each dimension, shall be used for two-dimensional tracking.

5.13.1.5.4.1 Remotely-controlled electro-mechanical systems. Remotely-controlled point-of-aim (POA) control systems shall offer a means to control azimuth and elevation adjustments.

5.13.1.5.4.2 Hard-mounted weapons systems. Hard-mounted weapon systems or weapon mount mechanical POA systems shall provide a means whereby the gunner may manipulate the weapon directly (local control).

5.13.1.5.5 Supports. Where a tracking control is used, a hand, wrist, or forearm support shall be provided.

5.13.1.5.6 Compatibility. Movement of the tracking control shall be consistent with user expectations.

5.13.2 Optical systems and related equipment. This section pertains only to direct-view visual optical systems.

5.13.2.1 Visual accommodation. Any adjustment of the eyes beyond normal functional ability shall not be required.

5.13.2.2 Viewing angle. Optical systems shall preclude any design that forces the user to adopt unusual postures for an effective viewing angle.

5.13.2.3 Magnification.

5.13.2.3.1 General. Device magnification shall be high enough to permit performance of the required application (e.g., detection, recognition, identification, weapon laying).

5.13.2.3.2 Unstabilized, unsupported, handheld rifle, and pistol sights. Because of hand tremors and body motion, magnification of unstabilized, unsupported, handheld rifle, and pistol sights shall be not more than 4-power unless selectable magnification or stabilization is present.

5.13.2.3.3 Unstabilized, unsupported, handheld monoculars, and binoculars. Because of hand tremors and body motion, magnification of unstabilized, unsupported, handheld monoculars, or binoculars shall be not more than 8-power.

5.13.2.3.4 Varifocal systems. Varifocal system optics provide limited advantage for crew served machine guns or general service rifles. Varifocal optics shall be considered primarily for use on closed breech bolt-action single-shot or semi-automatic high performance rifles, such as those used by snipers/designated marksmen.

5.13.2.3.5 Parallax adjustments. Parallax adjustments shall be provided to ensure aiming accuracy is retained over the full magnification range and intended target distances.

5.13.2.3.6 Laser sights. In accordance with MIL-STD-1425, laser viewing optics with a magnifying power exceeding 1.0 should include a built-in laser safety filter within the optical train that protects the operator from reflections from specular surfaces or exposure from the direct beam.

5.13.2.3.7 Laser sight markings. The system or individual sight shall be marked to indicate the level and type of protection afforded in the viewing optics.

5.13.2.4 Objective lens. The diameter of the objective lens shall be such that when divided by the highest magnification factor, the ocular exit pupil diameter presented shall be no less than 2 mm (0.08 in) and should be 3 mm (0.12 in) or more.

5.13.2.5 Ocular lens and exit pupil.

5.13.2.5.1 General. The diameter of the ocular lens shall be consistent with intended use, size, and weight limitations.

5.13.2.5.2 Daylight. For daylight application, the exit pupil diameter shall be not less than 2 mm (0.08 in) and should be 3 mm (0.12 in) or more.

5.13.2.5.3 Low light levels. For maximizing performance at twilight and lower light levels, the exit pupil diameter shall be not less than 7 mm (0.28 in).

5.13.2.6 Eye relief.

5.13.2.6.1 Long eye relief. A long eye relief (e.g., 90 mm [3.5 in]), shall be provided for vehicular mounted sights if the user must be protected from gun recoil, observe on the move, or maintain field-of-view while wearing a protective mask.

5.13.2.6.2 Wearing of glasses. To permit use by users wearing glasses when recoil is not encountered, eye relief shall be not less than 15 mm (0.59 in).

5.13.2.7 Eyepiece adjustments.

5.13.2.7.1 4-power and less. Fixed-focus eyepieces set between -0.50 and -1.00 diopter may be used for devices 4-power and less.

5.13.2.7.2 Over 4-power. Eyepiece dioptric (focusing) adjustments (-4.0 to +2.0 diopters required, -6.0 to +2.0 diopters desired) shall be provided and marked in 0.5-diopter increments on all devices over 4-power magnification.

5.13.2.8 Optical quality.

5.13.2.8.1 Axial resolution. Axial resolution shall be equal to or better than 300 microradians (μrad) (1 minute) divided by the magnification to provide an eye-limited device.

5.13.2.8.2 Luminous transmission. Luminous transmission shall be not less than 50 percent.

5.13.2.9 Non-illuminated sights and reticles. A plain reticle consists of horizontal and vertical lines. A duplex reticle is a similar configuration of reticles, but its line thickness tapers toward the center or intersecting angle. A Mil-dot reticle is similar to the duplex reticle; however, it has added dots to denote distance measuring. A Mil-Grid reticle is similar to a Mil-dot reticle in that it affords distance measuring; however, it features major line markings, subtensions, and tic marks between major line markings that allow for rapid range estimation and precise point-of-aim adjustment (e.g., holdovers) at long ranges.

5.13.2.9.1 Line thickness. Reticle lines shall be thin enough so as not to obscure targets but thick enough to be easily seen by a user with 20/20 correctable vision.

5.13.2.9.2 Patterns. Reticle patterns shall be as simple as possible and restricted to one main mission (e.g., major weapon ballistic scales) per reticle glass. Multipurpose reticle patterns (e.g., grid patterns used for rapid range estimation and precise point-of-aim adjustment [e.g., holdovers]) for reticle shape and composition shall be considered primarily for use on closed breech bolt-action single-shot or semi-automatic high performance rifles designed for long-range precision, such as those used by snipers and designated marksmen.

5.13.2.9.3 Separate reticle glasses. Additional patterns shall be on separate reticle glasses if warranted for the particular application.

5.13.2.9.4 Format. Line reticles shall be used in preference to reticles containing one, two, or three central spots. Other reticles shapes (e.g., a small cross or very small circle) may be used as specified (see 6.2).

5.13.2.9.5 Parallax. The reticle shall be focused to the target range of primary interest to limit the parallax to an acceptable value throughout the usable range.

5.13.2.9.6 Parallax adjustment control. The operator focus/parallax adjustment control shall be located in the vicinity of the elevation and windage adjustments.

5.13.2.10 Illuminated sights and reticles.

5.13.2.10.1 Night operations. Illuminated reticles shall be provided for sights to be used during twilight or night operations.

5.13.2.10.2 Color. Blue shall not be used as the color of illumination for reticles or sights.

5.13.2.10.3 Dimming. Sight luminance shall be continuously adjustable until it is extinguished.

5.13.2.10.4 Uniformity. Sights shall be evenly illuminated.

5.13.2.10.5 Line thickness. Reticle lines shall be thin enough so as not to obscure targets but thick enough to be easily seen.

5.13.2.10.6 NVD accommodation. If potential operational conditions include NVD use, the spectral output of all light emitting from or illuminating a display shall be in accordance with MIL-STD-3009.

5.13.2.10.7 Laser aiming optics. Calibrated reticules should be considered so that the laser operator can determine the proximity of the laser beam to the target.

5.13.2.10.8 Alignment of optics. Alignment of the optics to the laser beam (boresight) shall be considered a safety critical item.

5.13.2.11 Binoculars and biocular s.

5.13.2.11.1 Biocular viewing. Where continuous use of a sight under low levels of illumination will exceed one minute, a single optical train shall be provided with two eyepieces if this does not lead to unacceptable light losses.

5.13.2.11.2 Continuous low-level viewing. Where continuous use of a sight under low illumination will exceed one minute, the use of biocular systems are recommended if a single optical train is provided with two eyepieces and this does not lead to unacceptable light losses.

5.13.2.11.3 Eyepiece separation. Binocular and biocular devices shall have an eyepiece separation scaled from 50 to 75 mm (2 to 3 in).

5.13.2.11.4 Magnification differences. Magnification differences between the two eyepieces shall not exceed 2 percent.

5.13.2.11.5 Luminous transmission differences. Luminous transmission differences between the two eyepieces shall not exceed 5 percent.

5.13.2.11.6 Matched oculars. To avoid size differences in the images presented to the two eyes that may induce eyestrain or headache, oculars shall be matched in focal length (i.e., shall be matched pairs).

5.13.2.11.7 Weight. The weight of handheld binoculars and biocular s shall be not greater than 1.5 kg (3.3 lb) and preferably not greater than 1 kg (2.2 lb).

5.13.2.12 Eyecups and headrests. Any optical device requiring steady orientation of the eyes shall be provided with a headrest, eyecups, or both.

5.13.2.12.1 Eyecups. Eyecups shall be provided to maintain proper eye relief, eliminate stray light, and when required, protect or cushion the eyes and orbital region against impact with the eyepieces.

5.13.2.12.1.1 Surface of revolution. The radii of figure 91 define a surface of revolution within which a satisfactory symmetrical eyepiece and cup should be designed if interferences with facial features are to be avoided.

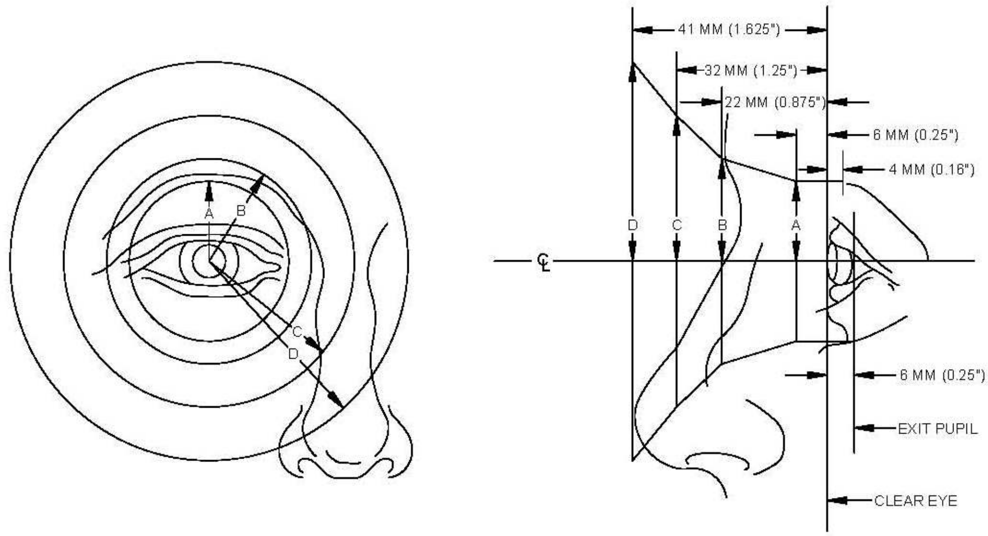


FIGURE 91. Anatomical limits on axially symmetrical ocular parts.

5.13.2.12.1.2 Deform to cushions. Eyecups shall deform to cushions when they are compressed to the maximum.

5.13.2.12.2 Headrests and brow pads. A headrest or brow pad shall be used to absorb energy that would be injurious to the user's head.

5.13.2.12.3 Compatibility with clothing and personal equipment. Eyecups and headrests shall be compatible with helmets, protective masks, and other clothing and personal equipment as specified (see 6.2).

5.13.2.13 Accessories.

5.13.2.13.1 Filters. Light filters for direct-view (eyes at ocular lens) optical devices required to reduce glare or light intensity shall be removable from the optical path of the device without the need for tools to provide unfiltered light transmission via the device.

5.13.2.13.1.1 Laser safety filters. Laser safety filters shall be permanently attached or designed so that the optical train cannot be assembled without the filter.

5.13.2.13.1.2 Evaluate in operational combinations. Filters placed in an optical path have cumulative and altering effects upon prism, clarity, perceived color, color contrast, light transmittance, and luminous contrast. Any filters in an optical path shall have been previously evaluated under expected operational conditions and passed their evaluations for effectiveness and safety.

5.13.2.13.1.3 Visual acuity. Using expected and reasonable operational conditions while viewing performance-relevant visual information, the extent of visual acuity degradation of the device caused by each filter shall be comparable to the unfiltered visual acuity of the device under the exact same conditions when viewing the exact same information.

5.13.2.13.1.4 Filter stowage. Where the single or multiple filters completely detach from the device, provision for stowage of all associated filters shall be made on the device or in the carrying case.

5.13.2.13.2 Shutters. Shutters having closure and reopening times appropriate for each application may be provided in lieu of fixed filters to protect the user exposed to flashes from weapon systems or other bright light sources.

5.13.2.13.2.1 Protection against laser exposure. Shutters may not be used in lieu of fixed filters for protection against laser exposure.

5.13.2.13.2.2 Protection against weapon flash. Shutters, if provided for protection from the user's own weapon system flash that may be actuated just before the weapon is fired, shall not disturb the lay of the weapon before closing or unnecessarily impede the observation of the projectile flight path or resultant impact.

5.13.2.13.3 Positioning aids. Level vials, scales, pointers, and other devices required for positioning the device shall be readily visible and protected from damage or displacement.

5.13.2.14 Compatibility with clothing and equipment. Devices shall be compatible with the special clothing, headgear, protective masks, or other ancillary equipment required by the user that may affect controls, eyepieces, eyecups, headrests, and other user interfaces.

5.13.2.15 Lighting. Means shall be provided for integrated illumination of internal and external scales, level vials, and other devices that must be read under low-light level conditions. Refer to 5.2 for details on lighting.

5.13.2.15.1 Continuously variable control. Continuously variable control of integrated illumination shall be provided as required by the system characteristics.

5.13.2.15.2 Low-level conditions. Integrated illumination to be used under low-light level conditions shall minimally affect the dark adaptation of the user.

5.13.2.15.3 Dark adaptation. Where dark adaptation must be maintained, low-level white lighting with the capability to dim to zero shall be used in preference to low-level red lighting. Where illumination of color-coded items is not required, red lighting may be used.

5.13.2.15.4 Night vision device compatibility. Where compatibility with NVDs is required, the spectral output of all light emitting from or illuminating a display shall be in accordance with MIL-STD-3009.

5.13.2.15.5 Variable lighting. The lighting shall be continuously variable to the full OFF position.

5.13.2.16 Maintenance. (Refer to 5.9 for additional details.)

5.13.2.16.1 Modular design. When practical, optical equipment shall be configured as modules to provide for interchangeability of optical subassemblies.

5.13.2.16.2 Positioning aids. Built-in aligning devices and other aids shall be used wherever possible for ease of positioning optical assemblies within a device or optical modules that have multiple applications.

5.13.2.16.3 Quick-release. Quick-release methods of removing optical devices shall be used.

5.13.2.16.4 Operable by hand. Quick-release mechanisms shall be operable by gloved hand(s) as defined by the procuring activity (see 6.2).

5.13.2.16.5 Collimation. Optical devices shall be provided with built-in collimation features to allow optical adjustments in the field.

5.13.2.16.6 Purging and charging. Where periodic purging and charging of optical devices are required, a label that indicates time interval and pressure requirements shall be provided on the device.

5.13.2.16.7 Accessibility. Purging and charging fittings shall be accessible for required maintenance.

5.13.2.16.8 Component replacement. Internal components (e.g., light bulbs, batteries) that require frequent replacement, checkout, or maintenance shall be easily accessible, removable without special tools, and replaceable without removal or disassembly of other components.

5.13.2.16.9 Storage of tools and equipment. Provision shall be made for readily accessible storage of tools and equipment required for those components that require frequent replacement.

5.13.2.16.10 Storage of spare components. Provision shall be made for storage of spare components and tools in or on the specific equipment.

5.13.2.16.11 Boresighting. Boresight knobs shall be provided with a positive lock.

5.13.2.16.11.1 Settings. The boresighting settings shall not change during the locking process.

5.13.2.16.11.2 Knob locks. Boresight knob locks shall require not greater than 45 newtons (10 pounds-force) of force to lock and unlock.

5.13.2.16.11.3 Adjustment knobs. Boresight adjustment knobs shall be capable of being locked, unlocked, and adjusted by the hands of the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped males of the target user population and the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped females of the target user population.

5.13.3 Unmanned, remotely operated, automated, and autonomous weapon systems. Unmanned, remotely operated, automated, and autonomous systems shall include provisions allowing manned operation when necessary and for immediate human override of automated or autonomous operations when required.

5.14 Ship and industrial structure valves.

5.14.1 General design requirements.

5.14.1.1 Handle location. Valve handles shall be located so the user does not have to stand on nearby pipes, cable trays, handrails, equipment, or any object not meant specifically to be used as a standing surface for the operation, maintenance, repair, or replacement of any valve.

5.14.1.2 Clearance. A clearance measuring at least 75 mm (3 in) shall be provided between the outside rim of a valve handwheel or the end of a valve lever and any obstacle located throughout the handwheel or lever's field of travel (also see table IX for separation of valve handwheels).

5.14.1.3 Emergency valves. Valves used for emergency operations shall not be located below standing surface gratings or behind covers limiting accessibility.

5.14.1.4 Extender rod. If it is absolutely necessary to locate emergency valves below grating, an extender rod shall be provided to place the operating handle or handwheel above grating level.

5.14.1.5 Valve cover. If a valve is located behind a cover (e.g., to meet a regulatory requirement), the cover shall be capable of being opened without requiring any tools or the removal of any securing fasteners.

5.14.1.6 Valve cover label. The valve cover shall be clearly labeled to identify the valve.

5.14.1.7 Valve closure. Valve handles shall close with a right-hand (clockwise) motion of the handwheel or lever when facing the end of the valve stem.

5.14.1.8 Valve position. Valves shall be provided with a valve position indication with respect to the open and closed positions unless physically impractical (as in very small valves).

5.14.1.9 Lever handles. Lever handles, such as for ball valves, shall be perpendicular to the pipe in the closed position and aligned with the pipe in the open position.

5.14.1.10 Indicators. Valve position indicators shall be installed so the indicator is directly visible to the user from the normal body position required to open or close the valve.

5.14.1.11 Mechanical extenders. Valves that cannot be located within the user's reach limits shall be provided with mechanical extenders or other remote operators.

5.14.1.12 Remote control. For valves fitted for remote control, an independent indicator showing the current state of the valve (e.g., open, closed, partially open) shall be provided on or adjacent to the control.

5.14.1.13 Labeling. Labels meeting the requirements of 5.1.1.2.6 and 5.4 shall be used to identify valves.

5.14.1.14 Motorized valves. Motorized valves with internal adjustable devices shall be mounted so the door to the internal compartment opens toward the user.

5.14.1.15 Operating force. Regardless of handwheel orientation, the maximum force required to initially open a manual valve shall not exceed the limits shown in table XXXVIII. In no case shall more than 178 newtons (40 pounds-force) of operator-applied force be necessary to seat (close) or open a valve.

TABLE XXXVIII. Maximum allowable torques.

Handwheel Diameter mm (in)	**Maximum Allowable Torque to Open and Operate Valve N·m (ft·lbf)**	**Handwheel Diameter mm (in)**	**Maximum Allowable Torque to Open and Operate Valve N·m (ft·lbf)**
50 (2)	4 (3)	300 (12)	27 (20)
75 (3)	7 (5)	350 (14)	31 (23)
100 (4)	10 (7)	400 (16)	37 (27)
125 (5)	11 (8)	450 (18)	41 (30)
150 (6)	14 (10)	525 (21)	48 (35)
175 (7)	16 (12)	600 (24)	54 (40)
200 (8)	18 (13)	675 (27)	61 (45)
225 (9)	20 (15)	750 (30)	68 (50)
250 (10)	23 (17)	900 (36)	82 (60)
275 (11)	24 (18)	--	--

5.14.1.16 Heavy valve location. All valves that must be lifted for repair, replacement, or maintenance and that weigh more than the limits defined in 5.20.2.3 shall be located for ease of lifting and use of lifting devices.

5.14.1.17 Maintenance envelope. There shall be sufficient clearance above each valve to attach the lifting device and pull the valve, or valve operating mechanism, and complete all maintenance tasks in place without removing the valve.

5.14.2 Valve criticality and location.

5.14.2.1 Valve criticality. Valves shall be rated by temporal and operational human factors criticality to ensure that critical valves are located to provide for rapid and effective identification and operation. The following three categories shall be used.

5.14.2.1.1 Category 1.

a. Category 1 valves are as follows:

(1) Valves critical for safety or operations.

(2) Valves used at least once in a 6-month period for routine operation and maintenance.

(3) Valves that have a high likelihood of failure.

(4) Valves where the consequence of failure or lack of quick access could lead to personnel injury, equipment damage, or degraded mission performance.

b. Examples of valves typically found in category 1 include the following:

(1) Control valves, their bypasses, and isolation valves.

(2) Relief valves and depressurizing valves.

(3) Trip and anti-surge control valves.

(4) Emergency shutdown valves.

(5) Liquid cargo transfer valves (especially for hydrocarbons and chemicals).

(6) Valves associated with safety and critical systems, such as firefighting, damage control, propulsion, process flow, and steering.

(7) Valves that have operational time constraints, especially in an emergency manual mode.

5.14.2.1.2 Category 2. Category 2 valves are not critical for operations but are required for routine operation and maintenance. Examples of valves typically found in category 2 include the following:

a. Sewage treatment valves.

b. Condensate drain valves.

c. Service oil valves.

d. Potable water valves.

e. Ship service air valves.

f. Hydraulic service valves.

g. Defrost gas valves.

h. Manual valves for normal startup and shutdown operation.

i. Valves where quick action is not required.

j. Drain and vent valves with flange or cap end.

k. Valves for pressure tests.

5.14.2.1.3 Category 3. Category 3 valves are not critical for operations or routine maintenance but are used infrequently for particular tasks, such as commissioning, startup, shutdown, or rarely performed maintenance tasks. Examples of valves typically found in category 3 include the following:

a. Valves used in dry dock only.

b. Valves used in initial vessel or structure commissioning.

c. Valves used for decommissioning.

d. Valves used only during startups after extended shutdowns.

e. Valves used during extended shutdowns.

f. Valves used to isolate items, such as pressure vessels or tanks for inspections.

g. Tie-in valves used for tie-in purpose only (hot-tap valves).

5.14.2.2 Valve location.

5.14.2.2.1 Category 1 valves. Unobstructed access shall be provided for category 1 valves at standing surface level or via a permanent elevated standing surface. If specified (see 6.2), an access by stair may be used for category 1 valves if the design provides the means, clearances, and space to accommodate personnel, tools, parts, and any access equipment.

5.14.2.2.2 Category 2 valves. Category 2 valves shall be located with unobstructed access at standing surface level or via stairs.

5.14.2.2.2.1 Alternative access. If specified (see 6.2), an alternative means of access (e.g., vertical ladders with a purpose-built standing surface, mobile platforms, personnel lift, scaffolding) for maintenance purposes may be used.

5.14.2.2.2.2 Alternative access design. The design for alternative access shall provide the means, clearances, and space to accommodate personnel, tools, parts, and any access equipment.

5.14.2.2.3 Category 3 valves. Category 3 valves should be either accessible or located so that access can be attained with use of auxiliary equipment (e.g., mobile platforms, personnel lift, scaffolding). Access to category 3 valves should consider clearances and space for personnel, tools, parts, and any access equipment.

5.14.3 Handwheel-operated valves, mounting heights, and orientations.

5.14.3.1 One hand. Handwheels of less than 150 mm (6 in) in diameter shall be designed and oriented for one-hand operation.

5.14.3.2 Two hands. Handwheels equal to or greater than 150 mm (6 in) in diameter shall be designed and oriented for two-hand operation.

5.14.3.3 Mounting height. Handwheel valves shall be located as follows:

5.14.3.3.1 Handwheel valves with vertical stems. The mounting height for handwheels with vertical stems shall be between 150 and 1,250 mm (6 and 50 in) above the standing surface; the preferred mounting height is between 450 and 1,250 mm (18 and 50 in) above the standing surface.

5.14.3.3.2 Handwheel valves with horizontal stems.

5.14.3.3.2.1 Mounting height. The mounting height for handwheel valves with horizontal stems shall be between 225 and 1,800 mm (9 and 72 in) above the standing surface; the preferred mounting height is between 600 and 1,800 mm (24 and 72 in) above the standing surface.

5.14.3.3.2.2 Clearance. The minimum clearance between the handwheel and any obstruction in front of the handwheel shall be 600 mm (24 in).

5.14.3.3.3 Handwheel valves with angled stems. Handwheel valves with angled stems shall meet the requirements for overhead valves (see 5.14.5.1) and valves in walkways (see 5.14.5.2).

5.14.3.3.4 Mounting height in preferred range. The mounting height for category 1 valves shall be within the preferred ranges specified in 5.14.3.3.1.

5.14.3.3.5 Category 1 valves. Category 1 valves shall not be mounted overhead if the area is used as a walkway.

5.14.3.3.6 Large handwheels or levers. The mounting height for handwheels or levers greater than 400 mm (16 in) in diameter or length shall be within the preferred ranges.

5.14.3.4 Handwheel diameter. Valve handwheels shall be not larger than 600 mm (24 in) in diameter.

5.14.3.5 Handwheel surfaces. Handwheel grasping surfaces shall have knurling, indentations, or other configurations to maximize the grip on the wheel surface.

5.14.3.6 Rotations. The number of rotations required to go from fully open to closed (or closed to open) shall be minimized.

5.14.4 Lever-operated valves, mounting heights, and orientations.

5.14.4.1 Vertical stem orientation. The handle on all vertical stem valves shall not rotate into walkways or working areas.

5.14.4.2 Horizontal stem orientation. Valves oriented with the stem in a horizontal position shall be located at least 1,250 mm (50 in) above the standing surface.

5.14.4.3 Maximum height. The maximum height above the standing surface to the lever tip shall not exceed 1,875 mm (75 in).

5.14.4.4 Handle length. Valve lever handles shall be as long as necessary to produce the necessary torque to crack open and turn the valve. Handle lengths normally range from 350 to 900 mm (14 to 36 in) in length.

5.14.4.5 Handle cross-section shape. Valve lever handles may be of any shape (cylindrical is preferred) but shall have a cylindrical grasping surface for the final 175 mm (7 in) of its length.

5.14.4.5.1 Grasping surface. The grasping surface shall be between 13 and 25 mm (0.5 and 1 in) in diameter.

5.14.4.5.2 Non-slip surface. The lever grasping surface shall have knurling, indentations, or other non-slip configurations to maximize the grip on the lever surface.

5.14.5 Alternative valve orientations.

5.14.5.1 Overhead valves. Valves located in the overhead with the handwheel or handle rotating in a plane parallel to the walking surface shall be avoided. When it is necessary to locate valves above a user's head with the valve handwheel or lever oriented parallel to the standing surface, the following design criteria shall be applied:

a. The handwheel or lever shall be at least 1,925 mm (77 in) above the standing surface.

b. The handwheel or lever shall be no more than 525 mm (21 in) in diameter or length.

c. The maximum operating force shall not exceed the values in table XXXVIII.

5.14.5.2 Valves in walkways. Valve handwheels or levers shall not protrude into dedicated walkways or work areas below 1,925 mm (77 in) above the standing surface.

5.14.5.3 Valves accessible from one side. When access to a lever-operated valve is available from one side only, the valve shall be mounted such that the lever moves to and from the accessible side where the user will be positioned.

5.14.5.4 Valves at the standing surface. Valves at the standing surface shall meet the following criteria:

a. Category 1 valves shall not be placed in a location that requires the user to squat or kneel.

b. If a category 2 or 3 valve is located at the standing surface that requires stooping or squatting to operate the valve, the distance from the edge of the access opening to the valve stem or lever shall not exceed 650 mm (26 in).

5.14.5.5 Valves below the standing surface. Valves below the standing surface shall meet the following criteria:

a. Valves located below the user's standing surface, either horizontal- or vertical-oriented handwheels or levers, shall be installed as shown on figure 92.

b. Category 1 valves shall not be located so the valve handwheel or lever is below the standing surface.

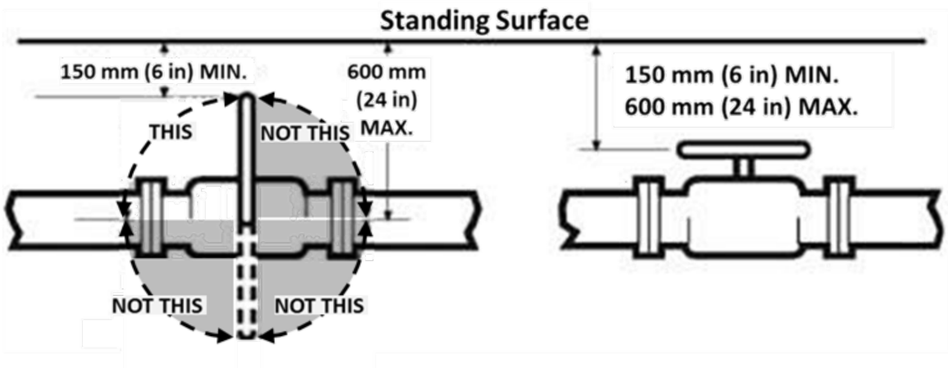


FIGURE 92. Mounting position for valve levers and handwheels below standing surface.

5.14.5.6 Access opening sizes. Access opening sizes to reach and operate levers or handwheels located below the standing surface shall be as shown in table XXXIX.

TABLE XXXIX. Access opening and mounting depth dimensions for levers and handwheels mounted below the standing surface.

Valve Handle Diameter	**Depth Below Standing Surface**	**Access Opening Size**
125 mm (5 in) or less	150 to 250 mm (6 to 10 in)	175 mm (7 in)
	Greater than 250 mm (10 in)	213 mm (8.5 in)
Greater than 125 mm (5 in)	150 to 450 mm (6 to 18 in)	The diameter of the handwheel plus 150 mm (6 in) with a minimum of 350 mm (14 in)
Valve Handle Length	**Depth Below Standing Surface**	**Access Opening Size**
Any lever length	Any depth up to 450 mm (18 in)	250 mm (10 in)
NOTE: The access opening size represents the minimum value of the shortest dimension; that is, the diameter for a circular opening or the shortest side of a rectangular opening.		

5.14.5.7 Valves accessible from ladders. Valves that require operation from a ladder should be avoided.

5.14.5.7.1 Category 1 valves. Category 1 valves shall not be located to require operation from a ladder.

5.14.5.7.2 Ladder operations. Where category 2 or 3 valves must be operated from a ladder, they shall be limited to those that can be operated with one hand (i.e., valves with handwheels less than 150 mm [6 in] in diameter and lever valves).

5.14.5.7.3 Distance. Valve and ladder placement shall conform to the distances and orientations shown on figures 93 and 94.

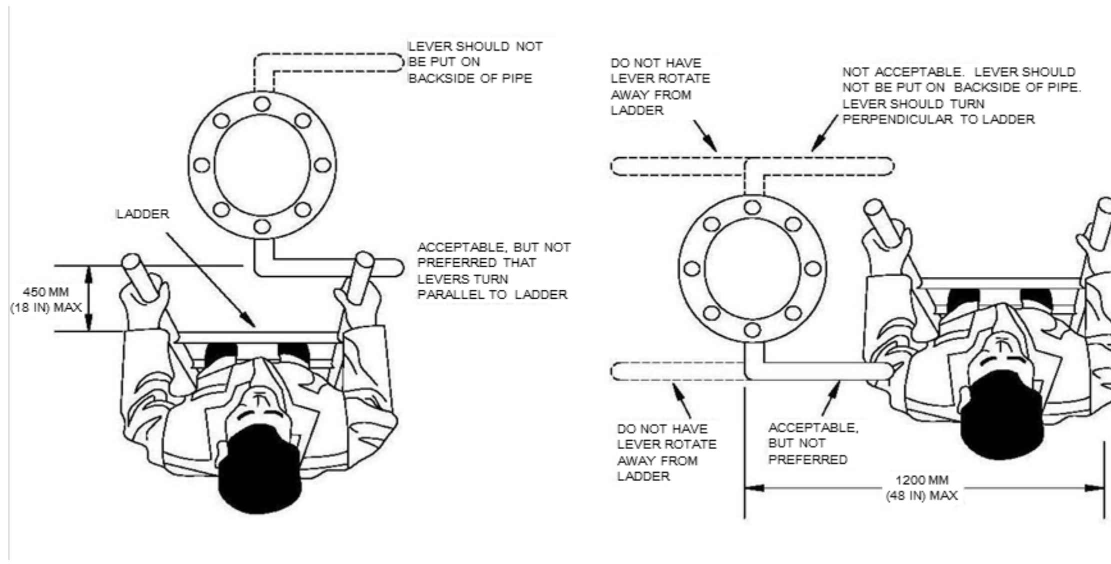


FIGURE 93. Orientation and reach from ladder parallel to valve handles.

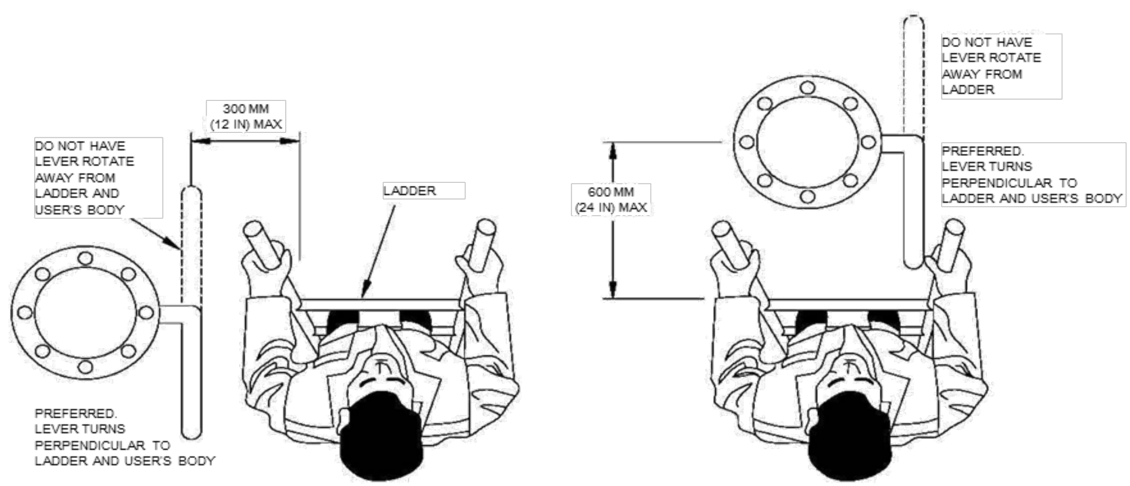


FIGURE 94. Orientation and reach from ladder perpendicular to valve handles.

5.14.5.7.4 Valve handle perpendicular to ladder. It is preferred that the valve handle turn perpendicular to the ladder; if this cannot be achieved, the ladder and valve shall be positioned so the valve handle is not more than 450 mm (18 in) forward of the ladder (see figure 94).

5.14.5.8 Valve manifolds. Where valves are mounted together to create a valve manifold (e.g., fuel oil transfer or ballast water transfer), the spatial arrangement of the valve handles shall be organized such that there is a logical association between the controlled elements and the valve controls. This arrangement shall take into consideration the orientation of the user as he or she is facing the controls (see 5.1.2).

5.15 Habitability. Habitability focuses on crew performance and well-being by prescribing those factors that collectively make up the environment in which the humans in the system are required to work and live efficiently. The design shall consider the number of crew members, inhabitants, personnel, and passengers when designing all accommodations (e.g., sustenance, waste, seating, workspace, and berthing).

5.15.1 General. Many aspects of habitability are covered in the following sections of this standard.

5.15.1.1 Environment.

5.15.1.1.1 HVAC. Indoor HVAC shall be in accordance with 5.5.2.1.

5.15.1.1.2 Outdoor considerations. Outdoor environmental considerations shall be in accordance with 5.5.2.2.

5.15.1.1.3 Lighting. Workspace lighting shall be in accordance with 5.5.3.

5.15.1.1.4 Noise.

5.15.1.1.4.1 Noise limits. Noise limits shall be in accordance with 5.5.4 and MIL-STD-1474.

5.15.1.1.4.2 Audio signals. Audio signals in terms of the noise environment shall be in accordance with 5.5.4.

5.15.1.1.4.3 Ground vehicles. Noise requirements in ground vehicles shall be in accordance with 5.6.1.4.

5.15.1.1.5 Direct and indirect effects of acceleration.

5.15.1.1.5.1 Vibration and shock. Vibration and shock shall be in accordance with 5.5.5.

5.15.1.1.5.2 Gravitational effects. Gravitational effects shall be in accordance with 5.5.6.

5.15.1.2 Physical accommodation. Physical accommodation and anthropometric design shall be in accordance with 5.8.

5.15.2 Habitability requirements.

5.15.2.1 Scoping. Habitability requirements should be scoped to the type and duration of the system's mission ranging from temporary workspace to long-term workspace and living quarters.

5.15.2.2 Coverage. Habitability factors include the physical environment (e.g., light, space, ventilation, sanitation, temperature, and noise control), cultural environment (e.g., beliefs, practices, customs, behaviors), social environment (e.g., intentionally-developed relationships, interactions, and support networks), personal services (e.g., religious, medical, and mess), working environment (e.g., freedom from physical or cognitive stressors) and living conditions (e.g., berthing and personal hygiene). These factors have both direct and indirect impacts on meeting and sustaining mission performance.

5.15.2.3 Personnel safety. Habitability requirements shall be established to ensure that personnel safety, health, and comfort are satisfactory enough to meet system performance goals.

5.15.2.4 Shipboard habitability. Detailed shipboard habitability requirements, design criteria, and practices for new Navy ship designs and modifications to existing ships are provided in T9640-AC-DSP-010/HAB.

5.15.2.5 Aircraft habitability. Detailed aircraft habitability requirements, design criteria, and practices for air systems, air vehicles, and major subsystems are provided in JSSG-2010.

5.15.3 Living conditions.

5.15.3.1 Berthing requirements. As allowed by other system design considerations, berthing compartments on ships should be arranged so that crewmembers working on the same watchstanding schedules share the same compartment, reducing sleep disturbances due to crewmembers awakening and sleeping at different times of the day and night.

5.15.3.2 Troop transport. When military vessels are used to transport troops as passengers, the design should provide comfort for passenger accommodations in accordance with the mission(s) for which the troops will be engaged.

5.15.3.3 Materials. All interior finish materials and furnishings used in manned spaces shall be in accordance with system fire safety requirements.

5.15.3.4 Furniture.

5.15.3.4.1 Durability. Furniture and equipment shall conform to system requirements for durability to withstand conditions in which the system will operate. Requirements for furniture in naval vessels are provided in T9640-AC-DSP-010/HAB.

5.15.3.4.2 Maintainability and safety. Furniture shall meet requirements for maintainability, reliability, fire, and off-gassing of noxious agents.

5.15.3.5 Personnel services. The design shall provide the personnel services appropriate for each system while taking into account the mission, the environment in which the system will operate, and the maximum number of crew personnel and passengers. Personal services include the following:

a. Waste management – collection, storage, and handling of human waste, medical waste, and general refuse.

b. Fresh water facilities – production, stowage, hot water, ice making, emergency wash facilities.

c. Food preparation, storage, and refrigeration and freezer spaces.

d. Space for stowage and security of personal belongings.

e. Sanitary facilities.

f. Recreation and relaxation spaces.

g. Religious spaces.

h. Workout and physical fitness facilities.

i. Medical and dental facilities.

j. Conveniences – shopette, automatic teller machine, barber, post office, dry cleaner, laundry, charging stations for electronic devices, and WiFi and internet facilities for personal use.

5.15.4 Habitability improvements. Since the goal of habitability is to optimize habitability elements, improvements beyond the above requirements are encouraged if feasible in light of all other mission-essential requirements.

5.16 Cybersecurity. Cybersecurity considerations in human engineering are based around the DoDI 8510.01 process and include security controls based on CNSSI 1253 and NIST SP 800-53. The applicable human interaction elements contributing to security controls will be identified, analyzed, selected, and implemented through the risk management framework process. This section focuses on the human performance aspects of cyber threats in terms of access control, user identification, and authentication, which were derived in alignment with NIST SP 800-53. Related requirements may be provided for the IS, the system administrator (SA), or the user. Access control refers to selective restriction of permissions within an IS and the rules that govern the access. User identification and authentication is the process of verifying the identity of a user, process, or device through the use of unique identifiers (e.g., passwords, tokens, biometrics) as a prerequisite for granting access to resources in an IS. Human engineering implications related to other aspects of cybersecurity may be addressed in future versions of MIL-STD-1472. When National Institute of Standards and Technology requirements conflict with human-system integration requirements, it is up to the procuring activity to perform tradeoffs and assume the risk associated with the chosen course of action. It is further understood that certain tactical systems and environments will vary (e.g., there may not be a system-level Information Systems Security Officer [ISSO] present) and those factors will drive the requirements.

5.16.1 Access control.

5.16.1.1 User access. Role-based access control shall be used to manage user access.

5.16.1.2 Access notifications. The SA and the ISSO should be provided with a notification when access authorizations are inconsistent with access restrictions.

5.16.1.3 Multiple roles.

5.16.1.3.1 Linked user profiles. If a user has more than one role within a given system, their user profile shall be linked to their multiple roles and permissions.

5.16.1.3.2 User role login. The user should be informed under which role they are logged in.

5.16.1.4 Visible active accounts. For the duration of a session, the user shall be able to see which system account is currently active.

5.16.1.5 Access to roles and permissions. The SA and ISSO shall have access to the roles and permissions matrices within the system.

5.16.1.6 Separation of duties. The SA and the ISSO should be provided with the roles and associated tasks to help maintain awareness and ensure separation and segregation of organizational duties.

5.16.1.7 Automated restrictions. Invalid logins shall trigger automated access restrictions per the system's cybersecurity plan.

5.16.1.8 Automated notifications. The SA should be provided with an automated notification when a user's access has been restricted by the system.

5.16.1.9 Monitoring logs. The SA shall have the capability to determine who is logged into the system in real time or in the past (via system logs).

5.16.1.10 Unlock an account. The SA shall have the capability to unlock an account. The SA should have the capability to unlock an account remotely.

5.16.1.11 Create user profiles. The SA shall have the capability to create user profiles.

5.16.1.12 Access user profiles. The SA shall have the capability to access user profiles.

5.16.1.13 Edit user profiles. The SA and the ISSO should have the capability to edit user profiles.

5.16.1.14 Account setup feedback. The SA shall be informed when the account setup process is completed.

5.16.1.15 Disabled account feedback. The SA shall be given feedback when the account has been disabled.

5.16.1.16 Purged account feedback. The SA shall be given feedback when the account has been purged.

5.16.2 User identification and authentication.

5.16.2.1 User identification. User identification procedures shall be as simple as possible, consistent with common data protection practices.

5.16.2.2 Notification message or banner. Where required by policy and not precluded by tactical demands, the system shall support the display of notification messages or banners. These typically display privacy and security notices consistent with applicable federal laws, executive orders, directives, policies, regulations, standards, and guidance on the screen until the user makes explicit acknowledgement.

5.16.2.3 Multifactor authentication. Multifactor authentication for network and local access to accounts shall be implemented. Factors shall include at least two of the following:

a. A physical object in the user's possession, such as a common access card (CAC) with a token.

b. Something known only to the user, such as a password or personal identification number (PIN).

c. Biometrics, like a fingerprint or other physical characteristics of the user that can be used by the system as a form of individual identification and access control.

5.16.2.4 Viable multifactor authentication options. The user shall be informed of the viable multifactor authentication options (e.g., CAC, password) to login to the system.

5.16.2.5 Status feedback. The user shall be provided feedback that indicates the status (e.g., accept or reject) of authentication data inputs.

5.16.2.6 Password not echoed on display. If using the username/password factor, the password should not be echoed on the display (e.g., an asterisk [*] is displayed in lieu of each character).

5.16.2.7 Error message. An error message shall be provided to the user when a user/device identifier (e.g., internet protocol [IP] address, device-unique tokens) has been selected that is not viable, and provide instruction to the user that a new identifier must be selected.

5.16.2.8 User and device identifier notification. The user shall be notified when a user and device identifier assignment has been successfully completed.

5.16.2.9 User status. The status of a requested action shall be displayed.

5.16.2.10 Reason for failure feedback. A specific reason(s) for a failed action shall be displayed.

5.16.2.11 Corrective action suggestion. A corrective action shall be suggested upon denial of access.

5.16.2.12 Maximum number of concurrent sessions. The IS maximum number of concurrent sessions for each user account should be enforced with denial of access for a request above the maximum.

5.16.2.13 Concurrent session control. The SA and the ISSO should be provided with information on all active concurrent sessions for each account.

5.16.2.14 Multiple concurrent sessions. If more than one current session per account is permitted, the user shall be informed of all of his or her active concurrent sessions.

5.16.3 Logon processes.

5.16.3.1 Logon procedures. In applications where users must logon to the system, logon shall be a separate procedure that must be completed before a user is allowed to select among any operational options.

5.16.3.2 Automatic logon display. Appropriate prompts for logon shall be automatically displayed on the user's terminal with no special action required other than turning on the terminal.

5.16.3.3 Logon attempts notification. The capability to display the logon history of accounts shall be available to the SA and ISSO.

5.16.3.4 Logon metadata. The name, account, role, date, and time for logon attempts shall be captured.

5.16.3.5 Invalid logon attempts. If the system design enforces a limit on the number of invalid login attempts, then the user shall be informed of the number of login attempts remaining before locking out the user.

5.16.3.6 Logon reset request. If the user is locked out of the system, the user shall be able to request the SA reset the number of logon attempts.

5.16.4 Logoff processes.

5.16.4.1 Automatic logoff. Where required by policy and not precluded by tactical demands, after a predefined period of user inactivity, the user shall be automatically logged off with no loss of data.

5.16.4.2 Logoff procedures. When a user signals for system logoff, application exit, or shutdown, the system shall:

a. Check pending transactions to determine if data loss seems probable and, if so, inform user that continuing will result in a potential data loss.

b. Prompt for confirmation before the logoff command is executed.

5.16.5 Data protection.

5.16.5.1 Displayed security classification. When displayed data are classified for security purposes, a prominent indication of security classification level shall be provided.

5.16.5.2 Warnings. System logic should be provided that will generate messages and alarm signals in order to warn users of attempted intrusion by unauthorized users.

5.16.6 Simulated mode distinction.

5.16.6.1 Simulated data. When simulated data and system functions are provided (perhaps for user training), real data shall be protected.

5.16.6.2 Real system use. Real system use shall be clearly distinguished from all simulated operations.

5.16.6.3 Clear indication. In applications where either real or simulated data can be displayed, a clear indication of simulated data shall be included.

5.16.7 Password creation.

5.16.7.1 Password criteria. The criteria for an acceptable password (e.g., minimum number and types of characters) shall be displayed to the user while generating a password.

5.16.7.2 Dynamic feedback. The user shall be provided with dynamic feedback on which password complexity criteria have not been met while generating a password.

5.16.7.5 Changing passwords. Where passwords are required by policy to be changed at periodic intervals, the IS shall support the enforcement of the password change policy. Within the mandatory periodic interval, users shall be allowed to change passwords whenever they choose.

5.16.7.6 Password managers. When appropriate with respect to system's operations, the system should support the use of password managers for users to input their credentials.

5.17 Information systems.

5.17.1 General.

5.17.1.1 Functional interface. Computer programs and equipment interfaces shall provide a functional interface between the system for which they are designed and users of that system.

5.17.1.2 Compatible with personnel. Interfaces shall be compatible with the work performed by, and the cognitive processes of, personnel.

5.17.1.3 Human performance. The interface should minimize conditions that can degrade human performance or contribute to human error.

5.17.1.4 Display content. Equipment interfaces provide a functional interface between the system for which they are designed and users of that system. This interface should optimize compatibility with personnel and should minimize conditions that can degrade human performance or contribute to human error.

5.17.1.4.1 Overlays. The system shall not require mechanical overlays.

5.17.1.4.2 CBRNE contamination. Displays or indicators that show the presence of CBRNE agents shall also show when such agent contaminations decrease to safe levels.

5.17.2 Command dialogs.

5.17.2.1 Command language.

5.17.2.1.1 Use. Command language may be used for tasks that involve a wide range of user inputs and where user familiarity with command language can be used to take advantage of the flexibility and speed of this control technique.

5.17.2.1.2 User viewpoint. Command language commands shall be logically related to the user's expectation of what the commands will initiate.

5.17.2.1.3 Naming distinctiveness. Command names shall be distinct from one another.

5.17.2.1.4 Punctuation and special characters. The command language dialog shall minimize the use of punctuation and special characters.

5.17.2.1.5 Standardization. All commands and corresponding abbreviations shall be identical across systems and platforms.

5.17.2.1.6 Standard location. Commands shall be entered and displayed in a standard location on the software user interface.

5.17.2.1.7 Command prompts. The user shall be provided a means, such as prompts or tooltips, to determine required parameters or available options for command entry.

5.17.2.1.8 Complexity. The command language shall accommodate the skill levels of users ranging from novice to experienced.

5.17.2.1.9 User definition of macro commands. The command dialog shall not allow a user to name macros with existing command names ("reserved keywords").

5.17.2.1.10 Standard techniques for command editing. Command and data entries shall be edited using the same techniques.

5.17.2.1.11 Destructive commands. If a command entry has destructive consequences, the system shall display the consequences of the command so that the user may review and cancel or confirm before it is executed.

5.17.2.2 Question and answer.

5.17.2.2.1 Use. Question-and-answer dialogs may be used for routine data entry tasks where data items are known, their ordering can be constrained, and where users will have little or no training.

5.17.2.2.2 Questions displayed separately. For multiple questions in a dialog box, each question shall be listed separately.

5.17.2.2.3 Distinct response area. When responses are required for a question, each question shall have a separate and distinct response area.

5.17.2.2.4 Recapitulating prior answers. When a series of system-posed questions are interrelated, answers to previous questions shall be displayed if they provide context to help a user answer the current question.

5.17.2.2.5 Source document capability. When questions prompt entry of data from a source document, the question sequence shall match the data sequence in the source document.

5.17.2.3 Query language.

5.17.2.3.1 Natural organization of data. Query languages should reflect a data structure or organization perceived by users to be natural. For example, if a user would have reason to suppose that all data about a particular topic would be stored in one place, then the query language should permit such data to be retrieved by a single query, even though various pieces of data may be stored in different computer files.

5.17.2.3.2 Coherent representation of data organization. A single representation of the data organization for use in query formulation shall be established (i.e., the user does not need to know if different queries will access different databases via different routes).

5.17.2.3.3 Task-oriented wording. Users shall be able to specify the data being requested in a query without being required to specify where the data are stored.

5.17.2.3.4 Logic to link queries. The query language should be designed to include logic elements that permit users to link (e.g., "and", "or") sequential queries as a single entry.

5.17.2.3.5 Confirming large-scale data retrieval. If a user's query request will retrieve a large amount of data, the user shall be provided the options to continue, cancel, or refine the query during processing.

5.17.2.3.6 Estimate of remaining time. When processing takes a long time, the user shall be provided with an indication of the status that includes an estimate of the proportion remaining in terms of either time or amount.

5.17.3 Visually displayed menus.

5.17.3.1 Menu types.

5.17.3.1.1 Drop-down menu bars. Drop-down menus contain a list of contextual commands that are presented in a menu bar along the top edge of a window. The menu bar shall contain a set of menu category labels (e.g., Edit) from which drop-down menus are accessed.

5.17.3.1.1.1 Use. Drop-down menus and the associated menu bars should be used when there are more than three commands and categories.

5.17.3.1.1.2 Primary windows. Drop-down menus and menu bars should be used when commands appear in primary windows (i.e., popup dialogs).

5.17.3.1.2 Submenus. Submenus shall consist of a group of options related to a higher-level toolbar menu item.

5.17.3.1.2.1 Additional menu options. Submenus should allow additional menu options to be viewed without increasing the length of the overall menu.

5.17.3.1.2.2 Shorten length. Submenus may be used to shorten the length of a long menu when a higher-level menu item may be used to describe several related functionalities.

5.17.3.1.2.3 Frequently needed functions. Submenus should not be used for functions that are frequently needed and accessed.

5.17.3.1.2.4 Indication. An indicator (e.g., a right-pointing triangle) should be used to display the presence of a submenu on a higher-level menu.

5.17.3.1.2.5 Presentation of options. When the higher level option is selected, the options shall be presented without further input from the user.

5.17.3.1.2.6 Number of levels. Submenus should be limited to three levels (i.e., Main>Sub1>Sub2) to ensure discoverability of nested items.

5.17.3.1.3 Menu bar. Users should interact with menu bars by left-clicking the menu category within the menu bar to open the drop-down menu command list.

5.17.3.1.3.1 Toolbar menu. Toolbars may be used to graphically present command actions for easy and efficient access.

5.17.3.1.3.2 Use in primary windows. Toolbars should be used in primary windows to provide a small number of icons as immediate commands.

5.17.3.1.3.3 Use in secondary windows. Toolbars should not be used in secondary windows, with text-only commands, with crowded icons, and with non-immediate commands (e.g., configuring a filter).

5.17.3.1.3.4 Toolbar options. Toolbar options that are fixed should be limited to those commands used most frequently by a large percentage of users. Alternatively, a means may be provided for users who wish to configure them to have access to frequently accessed options.

5.17.3.1.3.5 Toolbar labels. Toolbars with icons shall provide labels via a tooltip (hover over to show label).

5.17.3.1.3.6 Non-standard icons. Non-standard icons should be avoided but if present, shall provide labels via a tooltip (hover over to show label) and should include fixed-text labels.

5.17.3.1.3.7 Selection. Toolbar menus should be left-clicked for devices like mice and trackballs to make a selection.

5.17.3.1.4 Ribbon menus. Ribbon menus separate dedicated task commands within a window. In these menus, a list of task-related commands appears under an active tab. Ribbon menus may be used when there are multiple menu categories with items under each category.

5.17.3.1.5 Right-click and context menus. Right-click menus may be used to provide contextually relevant options and actions pertaining only to the selected item or pane.

5.17.3.1.5.1 Method of accomplishment. Right-click menus shall not provide the only method of accomplishing any command.

5.17.3.1.5.2 Accessibility. Right-click and context menus shall not include options that cannot be accessed elsewhere by a means that is apparent.

5.17.3.1.5.3 Availability. Right-click menus should be available to initiate basic and frequently used commands.

5.17.3.1.5.4 Not substitute. Right-click menus shall not be used as a substitute for primary menus (e.g., drop-down menus).

5.17.3.2 Using menus.

5.17.3.2.1 Interactive menu use. Interactive menu selection shall be used for tasks that involve little or no entry of arbitrary data, users that may have relatively little training, or a command set that is too large to commit to memory.

5.17.3.2.2 Selection method. Selection of devices shall be in accordance with the criteria in 5.17.3.2.2.1 through 5.17.3.2.2.4.

5.17.3.2.2.1 Mouse. A mouse or other pointing input device (including touch technology) shall be an available method for menu selection (see 5.1.3.3).

5.17.3.2.2.2 Pointing. If menu selection is accomplished by pointing, a selection action shall be made to initiate the command (i.e., left click of mouse or tap for touch input).

5.17.3.2.2.3 Submenus. Each submenu shall have a title that clearly identifies the purpose of that menu.

5.17.3.2.2.4 Multiple pages. Menus shall not consist of multiple pages of options.

5.17.3.2.3 Active option presentation. Menu options that are not available shall either not be presented or be greyed out to make it clear that they are not available.

5.17.3.2.4 Format consistency. Menus shall be presented in a consistent format throughout the system and across other related systems the user is expected to operate.

5.17.3.2.5 Accessible. Menus shall be readily accessible at all times.

5.17.3.2.6 Option sequence. Menu selections shall be listed in a logical order, such as alphabetically or by frequency of use.

5.17.3.2.7 Simple menus. If the number of selections can fit on one page in no more than two columns, a single menu may be used. If the selection options exceed two columns, a hierarchical menu structure should be employed.

5.17.3.2.8 Option presentation. Textual menu options should be presented on separate lines to ensure that the items are discriminable and selectable.

5.17.3.2.9 Direct function call. A direct function call capability shall be provided for frequently used options.

5.17.3.2.10 Shortcut commands. Shortcut commands (e.g., "control C" for copy) should be provided for frequently used actions.

5.17.3.2.11 Option coding. When selections may be made by keyboard shortcuts, the shortcuts associated with each alternative option shall be included next to the menu option.

5.17.3.2.12 Keyboard shortcuts. If menu selections are made by keyboard entry of alphanumeric codes, the options shall be coded by letters that are associated with the name of the option or standard shortcuts rather than by more arbitrary codes.

5.17.3.2.13 Duplication. Keyed codes shall not duplicate any other user function codes.

5.17.3.2.14 Position in structure. When menu selection traverses multiple levels, all of the levels shall remain visible until the selection is made.

5.17.3.2.15 Menu hierarchy. A menu tree showing the menu hierarchy shall be included in the user manual or online Help section.

5.17.3.2.16 Tooltips. A tooltip should be displayed over an item as the user hovers the pointer without clicking on the item.

5.17.3.2.17 Icons. Menus may use icons to represent the control options.

5.17.3.2.17.1 Currently being used. When possible, icons should be consistent with icons that are currently being used in other systems, familiar to the user, and used consistently within an application.

5.17.3.2.17.2 Graphic menu use. Graphic menus may use icons to represent control options and be consistent within an application.

5.17.4 Form filling dialogs and dialog boxes.

5.17.4.1 Data entry. Data entry functions shall be designed to establish consistency of data entry transactions, minimize input actions, minimize memory load on the user, ensure compatibility of data entry with data display, and provide the user control over data entry.

5.17.4.2 User pacing. The pace of data entry shall be controlled by the user, rather than by the system.

5.17.4.3 Positive feedback. The system shall provide feedback to the user regarding the acceptance or rejection of an entered datum.

5.17.4.4 Response time. Feedback response times shall be in accordance with 5.17.9.5.

5.17.4.5 Processing delay. Where system overload or other system conditions results in a processing delay, the system shall acknowledge the data entry and provide an indication of the delay to the user.

5.17.4.6 Completion time. The system should provide some indication of the completion time or of the fraction of the process completed.

5.17.4.7 Explicit action. Each data entry shall require an explicit completion action, such as pressing an ENTER key or other key (e.g., TAB key).

5.17.4.8 Validation. Data entries shall be validated by the system for correct format, legal value, and range of values prior to processing.

5.17.4.9 Software-available data. The user shall not be required to enter data already available to the software.

5.17.4.10 Input units. Data shall be entered in units that are familiar to the user.

5.17.5 Cursors. Cursors shall meet the criteria in 5.17.5.1 through 5.17.5.14.

5.17.5.1 Control. The user shall be able to adjust the sensitivity of the cursor movement to be compatible with the required task and user skills where appropriate. The user's ability to adjust the sensitivity of the cursor movement shall only be provided where adjustment of this control could not adversely affect the ability to fulfill the mission.

5.17.5.2 Distinctive cursor. The cursor shall have differing visual attributes that distinguish various usages, such as selecting an object or editing text.

5.17.5.3 Distinctive cursor position. The current cursor position on graphic or image processing application displays that require precise positioning shall be indicated by displaying a distinctive cursor symbol that indicates a point (e.g., a plus-sign or crosshairs whose intersection can mark a position with reasonable precision).

5.17.5.4 Obscuration. The cursor shall not obscure displayed entities.

5.17.5.5 Display boundaries. The cursor shall not move beyond the display boundaries (off of the monitor) and disappear from sight.

5.17.5.6 Cursor movement using arrow keys. If the cursor is moved by pressing a key, releasing the key shall cause the cursor to stop moving.

5.17.5.7 Precise positioning. Where data entry requires exact placement of graphic elements, users shall be provided the capability for expansion of the critical display area (e.g., zooming and panning) to make the positioning task easier and more precise.

5.17.5.8 Home position. The home position for the cursor shall be consistent across similar types of displays.

5.17.5.9 Explicit actuation. A separate explicit action distinct from cursor position, (i.e., pressing a button or toggling) shall be required for a control selection.

5.17.5.10 Incremental cursor positioning. Where cursor positioning is incremented in discrete steps, the step size of cursor movement shall be consistent horizontally (in both right and left directions), and vertically (in both up and down directions).

5.17.5.11 Keyboard cursor control.

5.17.5.11.1 Position designation. When position designation is required in a task emphasizing keyed data entry, cursor control shall be available by the keyboard, preferably using the arrow keys.

5.17.5.11.2 Means of control. If keys other than the arrow keys are used for movement (as with an abbreviated keyboard), the display should clearly indicate the means of control.

5.17.5.12 Movement relationships.

5.17.5.12.1 User expectations. The response of a cursor to user input shall be consistent and compatible with the user's expectations.

5.17.5.12.2 Move in corresponding direction. For cursor control by key action, the cursor shall move in the corresponding direction of the arrow key that was pressed (i.e., left arrow to left, right arrow to right, up arrow up, down arrow down).

5.17.5.12.3 Control by joystick. For cursor control by joystick, movement of the control shall result in the cursor moving in the corresponding direction (i.e., left movement moves the cursor to the left, right movement moves the cursor to the right, push movement moves the cursor upward, pull movement moves the cursor down).

5.17.5.12.4 Cursor responses. Cursor responses to movements of other controls shall be in accordance with 5.17.6.16 or to the movement-related provisions of the applicable control specified in 5.1.

5.17.5.13 Explicit delete action. Data deletion or cancellation shall require an explicit action, such as pressing a DELETE key.

5.17.5.14 Permanent deletion. Permanent deletion (in the absence of an "undo" function) of more than one character shall not be allowed without an affirmative response to a validation query.

5.17.6 Form filling.

5.17.6.1 Use. Form filling interactive control may be used where some flexibility in data entry is needed.

5.17.6.2 Grouping. Displayed forms shall be organized to group related items together.

5.17.6.3 Format and content consistency. The format and content of displayed forms shall duplicate in every major parameter the (paper) form it is intended to represent.

5.17.6.4 Advancing through form fields. When using TAB or ENTER keys to advance through form fields, the system shall require a response for every data entry field; advancing through a field (i.e., leaving a blank) for which no entry is desired shall require an explicit action (TAB or ENTER keystrokes).

5.17.6.5 Separation. Fields or groups of fields shall be separated by spaces, lines, or other delineation cues.

5.17.6.6 Distinctiveness of fields. Required fields shall be distinguished from optional fields.

5.17.6.7 Field labels. Field labels shall be distinctively presented such that they can be distinguished from data entry space.

5.17.6.8 Additional cueing. Labels for data entry fields shall incorporate additional cueing when the data format could logically be made in more than one format (e.g., "DATE (MM/DD/YYYY): _ _ / _ _ / _ _ _ _").

5.17.6.9 Informative labels. Descriptive wording shall be employed when labeling data fields.

5.17.6.10 Arbitrary codes. Use of arbitrary codes shall be avoided.

5.17.6.11 Top-aligned labels. Top-aligned labels shall be used when labels are long or the form requires horizontal space for grouping related input fields.

5.17.6.12 Vertical space limited. Top-aligned labels shall not be used if vertical space is limited.

5.17.6.13 Right-aligned labels. Right-aligned labels shall be used for forms that require users to quickly scan labels and may be used when vertical space is limited.

5.17.6.14 Left-aligned labels. Left-aligned labels shall be used when a form requires users to carefully consider labels.

5.17.6.15 Limited vertical space. Left-aligned labels shall not be used when labels are so long that they do not allow for data entry in the same vertical space.

5.17.6.16 Cursor default position. When a form is displayed, a displayed cursor shall be positioned at the first data entry field by default.

5.17.6.16.1 Cursor advancement. The cursor shall be advanced to the next data entry field by the TAB key or the ENTER key when the user has completed entry of the current field.

5.17.6.16.2 Exceptions. Exceptions to using the ENTER key for advancement occur in cases where some fields require or allow multiple lines to be input; in which case, only the TAB key shall be used to advance the cursor.

5.17.6.17 Entry length indication. The maximum acceptable length for variable length fields shall be displayed.

5.17.6.18 Maximum characters inputted. An indication shall be provided to the user if the maximum number of characters has been inputted.

5.17.6.19 Overwriting. Characters other than those indicating format that must be overwritten shall not be entered into unfilled data fields by default.

5.17.6.20 Dimensional units. When a consistent dimensional unit is intended as the unit of entry in a given field, the dimensional unit shall be provided by the computer to the right of the field.

5.17.6.21 Variable dimensional units. When the dimensional unit may vary for a given field, the user shall be informed and a separate field with options shall be provided to the right of the numeric field for the entry of units from a drop down list.

5.17.6.22 User omissions. The user shall be informed when required data entries have not been entered.

5.17.6.23 Non-entry areas. Non-entry (protected) areas of the display shall be displayed in a way that makes them distinguishable from areas where data may be entered.

5.17.6.24 Inaccessible by cursor. Non-entry areas shall be inaccessible via the cursor.

5.17.6.25 Flexible data entry. When multiple data items are entered, the user shall be allowed to re-enter, change, or cancel any item before submitting.

5.17.6.26 Logical order. Where no source document is involved, forms shall be designed so that data items are ordered in a logical sequence of input.

5.17.6.27 Dialog boxes for control entry. Dialog boxes may be used as an aid for composing complex control entries or for selecting options. For example, for a print request, a displayed form might help a user invoke the various format controls that are available.

5.17.7 Notifications, messaging, and dialogs.

5.17.7.1 Information presentation using speech output. Where possible, speech outputs should be used in applications that are expected to be used in conjunction with another activity that requires focused visual attention or hands-free response.

5.17.7.1.1 Speech output design. Design of speech displays shall conform to the criteria in 5.3.10.

5.17.7.1.2 Hands-free. The device shall have a hands-free method of activation and deactivation.

5.17.7.1.3 Use. Speech recognition should be used when:

a. The consequences of recognition errors are low.

b. Identifying and correcting errors would be easy.

c. Use is expected to be infrequent.

d. The device has an alternative method of input so that speech recognition can be turned off when it is not desired.

5.17.7.2 Communication methods.

5.17.7.2.1 Common method use. Visual displays of communication (e.g., chat) shall be provided under the following conditions:

a. The message is very complex, long, or may need to be referred to at a later time.

b. When the message does not necessarily call for immediate action (e.g., can be addressed after receiver has finished current task).

c. When the auditory system of the receiver is overburdened.

d. When the environment is too noisy to ensure reliable receipt of an aural message.

e. When the receiver will remain in a position where they can continue to watch the visual displays.

f. When joint communication is required (particularly with non-native English speakers).

5.17.7.2.2 Multimodal communication. Visual displays of communication (e.g., chat) shall not be the only means of real-time communication of critical information if high workload situations are to be expected. See 5.3.1 for situations in which auditory information should be provided to the user.

5.17.7.2.3 Notifications. Audio notifications should be programmable and available for instances such as arrival of new message, message from certain individuals, and messages that contain certain key words.

5.17.7.2.4 Chat.

5.17.7.2.4.1 Saving text. Message text should automatically be saved for long-term storage. Additionally, a mechanism for short-term saving of text should be implemented for use during a session.

5.17.7.2.4.2 Receipt after viewing. A confirmation that the communicated message has been seen should be sent to the sender during real-time, two-way discussions.

5.17.7.2.4.3 Promoting typing efficiency. Features such a voice-to-text, auto-fill, hotkeys, and preformatted messages should be used to increase chat efficiency by reducing typing time.

5.17.7.2.4.4 Text-to-speech. The contents of the message should be able to be read via a text-to-speech system if the user is not able to view the window.

5.17.7.2.4.5 Chat integration. Chat windows should be integrated into primary displays that require attention to help keep user focus on the displays.

5.17.7.2.4.6 Standardized lexicon. A standardized lexicon should be provided to ensure that information in the message can be understood across staffs.

5.17.7.2.5 Audio displays. Audio displays may be used as part of the information presentation, where:

a. The common mode of visual display is restricted by overburdening or user mobility needs and it is desirable to cue, alert, or warn the user.

b. The user will be provided feedback after control actuation, data entry, or completion of timing cycles and sequences.

5.17.7.2.6 Supportive function. Audio signals used in conjunction with visual displays shall be supplementary to the visual signals.

5.17.7.2.7 Direct user. Audio signals shall be used to alert users to the appropriate visual display.

5.17.7.2.8 Signal characteristics. Signals may be one-time or intermittent.

5.17.7.2.9 Intermittent signals. Intermittent signals shall be automatically terminated when no longer applicable or terminated by user control. For more information on signal characteristics, see 5.3.4.

5.17.7.2.10 Alarm settings. Alarm settings shall be in accordance with the criteria in 5.17.7.2.10.1 and 5.17.7.2.10.2.

5.17.7.2.10.1 Customized settings. When alarm settings are user-customized, users shall be permitted to view status information regarding current settings established as critical.

5.17.7.2.10.2 Alarm status. Alarm status information shall be provided where responsibility may be shifted from one user to another (e.g., as in changes of shift).

5.17.8 Windows and window interactions.

5.17.8.1 Information from diverse sources. Web portals shall bring information together from diverse sources in a single location.

5.17.8.2 Dedicated area. Each information source shall get its own dedicated area on the page for displaying information in a portlet.

5.17.8.2.1 Title. The title of a portlet should be a short descriptive phrase that clearly indicates the subject of the portlet (see figure 95).

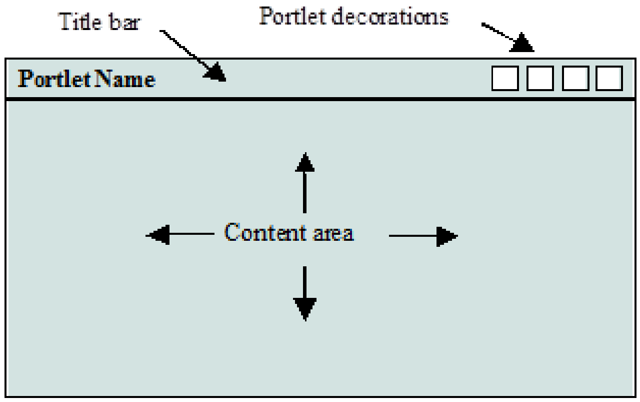


FIGURE 95. Example of portlet.

5.17.8.2.1.1 Multiple screens. If the portlet presents multiple screens of content, a name that indicates the particular screen should be included with the portlet title or appear as a heading in the content area of the portlet.

5.17.8.2.1.2 Screen name part of title. When a screen name is part of the title, the format should include the portlet name followed by the screen name using the format "Portlet Name – Screen Name".

5.17.8.2.1.3 Screen name as part of portlet title. When a screen name is included in the portlet title, it should not be duplicated as a heading in the content area of the portlet.

5.17.8.2.2 Title bar. The title bar of a portlet shall include action buttons (i.e., decorations) that allow the users to perform the following functions:

a. Detach – Allows the user to open the portlet in a separate browser window.

b. Edit – Allows the user to open a page for changing the appearance or content of the portlet.

c. Help – Allows the user to open a page with information about how to use the portlet and its functions.

d. Maximize – Allows the user to maximize the portlet to the full size of the browser window.

e. Open and close – Allows the user to toggle the portlet between displaying the full page and displaying the title bar only.

f. Properties – Allows the user to open a page with information about the portlet (e.g., version, author).

g. Refresh – Allows the user to update the contents of the portlet when the content may change over time.

h. Remove – Allows the user to remove the portlet from a page.

i. Restore down – Allows the user to return a maximized portlet to its original size.

5.17.8.3 Action buttons. Portlet action buttons shall be presented in the same order in each portlet in a portal.

5.17.8.4 Number of portlets. A page should not contain more than seven portlets.

5.17.8.5 Vertical height. The portlets should fit within three or fewer screens in vertical height in order to minimize the amount of scrolling required to view them.

5.17.8.6 Support for multiple tasks. A portlet that supports tasks within a page should be available in multiple pages in which users might be required to support those same tasks.

5.17.8.7 Portlets for specific roles. The portlets that are common to specific roles should be access-controlled via privilege levels. For users who do not have permission to see certain portlets or groups of tasks associated with a particular role, the tab or other control that provides access to that content should be hidden and unavailable for retrieval by users lacking the relevant permissions.

5.17.8.8 Fixed-width portlets. A portlet may be a fixed-width, or it may adjust to fit the width of the column where it is placed. A fixed-width portlet should be used in layouts with fixed-width columns. A variable-width portlet may be used in layouts with either fixed- or variable-width columns and self-adjust to fit the fixed width when used in a fixed-width portlet.

5.17.8.9 Variable-width portlets. Variable-width portlets shall display all content correctly regardless of portlet size.

5.17.8.10 Access control. Portals should support public key infrastructure (PKI)-based access so users can log in once and automatically be authenticated to all components and applications to which they have access.

5.17.8.11 Public pages. A portal shall include a public page that users can access prior to logging on to the portal.

5.17.8.12 Public page content. The public page should provide organizational information (e.g., mission overview, points of contact), information about how to register for a certificate or obtain an account, and either a means for direct log-in or a link to the log-in screen for the portal.

5.17.8.13 Personalization. Users should be allowed to make changes to unrestricted portal pages or to add or delete default and customize pages when permitted by the portal owner.

5.17.8.14 Content areas. Those content areas, which can be changed, shall be predefined and selectable.

5.17.9 User guidance.

5.17.9.1 Feedback. Feedback that presents status information, confirmation, and verification of input throughout system interactions shall be provided.

5.17.9.2 System status. System status information regarding operational modes and availability shall be accessible to users, either automatically or by request as needed.

5.17.9.3 Computer responses. Every input by a user shall produce a consistent perceptible response output from the computer.

5.17.9.4 Alternative form. If the feedback is not presented visually, an alternative form of feedback (e.g., sound) shall be provided.

5.17.9.5 System response time. Maximum system response times for critical systems (e.g., fire control systems, command and control systems) shall not exceed the values provided in table V.

5.17.9.5.1 Non-critical systems. Non-critical systems may permit relaxed response times.

5.17.9.5.2 Existing or predecessor systems. System response times for critical and non-critical systems shall not exceed the response time of equivalent existing or predecessor systems.

5.17.9.5.3 System processing indication. When computer response times will exceed 1 second, the system shall provide a message indicating that the system is processing. For remotely handled automated systems, see 5.12.

5.17.9.6 Task performance time. The time required to accurately complete a standard time-sensitive action or sequence of actions (including system response times) shall not exceed the time to complete the same action(s) on equivalent existing or predecessor systems.

5.17.9.7 Time-consuming processes. The system shall provide warning information when a command is invoked that will be time-consuming or resource-intensive to process.

5.17.9.8 Aborting time-consuming processes. The system shall provide users an option to abort time-consuming processes.

5.17.9.9 System processing. When system processing requires a user to wait before taking further action, an appropriate message or icon shall be displayed until user interaction is again possible.

5.17.9.9.1 Status message. Where the delay is expected to exceed 1 second, the system shall provide a status message.

5.17.9.9.2 Progress indicator. For delays exceeding 10 seconds, the display shall provide a progress indicator.

5.17.9.10 User input rejection. If the system rejects a user input, feedback shall be provided to indicate the reason for rejection and the required corrective action.

5.17.9.11 Highlighted option selection. Any items as an option or input to the system shall be highlighted to indicate acknowledgment by the system.

5.17.9.12 Process outcome. When a control process or sequence of related actions is either completed or aborted by the system, the system shall provide an indication of the outcome to the user.

5.17.9.13 Subsequent actions. Following an aborted action, the system shall provide any requirements for subsequent user action.

5.17.9.14 Feedback message content. Feedback messages shall be explicit and informative.

5.17.9.14.1 Understandable. Feedback shall not require a reference system or codebook to be understood.

5.17.9.14.2 Non-standard abbreviations. Non-standard abbreviations should be avoided in feedback messages.

5.17.10 Error management.

5.17.10.1 Error correction. An easy means for correcting erroneous user entries shall be provided.

5.17.10.2 Partial correction. The system shall permit partial correction of entries.

5.17.10.3 Early detection. A capability to detect and correct errors after keying in but before entering into the system shall be provided.

5.17.10.4 Logical data breaks. Error checking shall occur at logical data entry breaks, such as at the end of data fields rather than characters to minimize disruption.

5.17.10.5 Internal software checks. Software shall provide checks of user entries for validity of item, sequence of entry, completeness of entry, and range of values.

5.17.10.6 Critical entries. The system shall require the user to acknowledge entries that have irreversible or potentially destructive consequences prior to their being implemented by the system.

5.17.10.7 Error message content.

5.17.10.7.1 Describe error. Error messages shall describe the error simply and provide diagnostic information in terms of the application rather than system function (e.g., “too many characters” vs. “stack overflow”).

5.17.10.7.2 Instruct user. Error messages shall instruct the user how to recover from the error or escape from the error situation.

5.17.10.7.3 Constructive and neutral tone. Error messages shall be constructive and neutral in tone, avoiding phrases that suggest a judgment of the user’s behavior.

5.17.10.7.4 Consistent with user understanding. The error message shall be written in a manner consistent with the user’s understanding and expected level of knowledge of the system.

5.17.10.7.5 Correction entry and confirmation. When the user enters correction of an error, such corrections shall be implemented by an explicit action by the user (e.g., actuation of an ENTER key).

5.17.10.7.6 Error correction acknowledgement. The system shall acknowledge all error corrections by the user either by accepting the corrected entry or by providing a separate error message for an erroneous entry.

5.17.10.7.7 Errors in elements not normally visible. References to errors in elements of the system not normally visible to users shall not be included unless the user has explicitly requested detailed diagnostic information for programmer-level troubleshooting.

5.17.10.8 Error description. If a simple error message is presented, users shall be provided access to a more detailed description of the error.

5.17.10.9 Message timing. Error messages shall be provided within 0.2 second of the time in which an error is detected.

5.17.10.10 Error recovery and process change (multi-level "undo"). The user shall be able to stop a control process at any point in a sequence and easily return to previous levels in multi-step processes in order to nullify an error or effect a desired change.

5.17.10.11 Spelling errors. Spelling and other common errors shall not produce valid system commands or initiate transactions.

5.17.10.12 Recognize common misspellings. The system shall recognize common misspellings of commands and inform users of unrecognized entries, provide a similar correct entry, and display the recommendation for revision and confirmation by the user.

5.17.10.13 Errors in stacked commands. To prompt for corrections of an error in stacked commands, the system shall display the stacked command sequence with the error(s) highlighted. Where possible, a procedure shall be provided to correct the error and salvage the stack.

5.17.10.13.1 Error correction procedure. When possible, a procedure shall be provided to correct the error and salvage the stack.

5.17.10.13.2 Partial execution. If the error was not detected until after some of the commands in the stack have executed, the system shall provide a message to inform the user which commands were successfully executed.

5.17.10.14 Display of erroneous entries. An error message shall be displayed continuously until either the error is corrected or the user dismisses the error message.

5.17.10.15 Automatic error correction. Automatic correction of user errors by the system should be provided if:

a. The error being corrected has a unique solution.

b. The correction of the error is apparent to the user.

c. The automatic correction functionality can be disabled upon user request.

5.17.10.16 Location of error messages. Error messages shall appear as near as possible to the user entry that caused the message but not obscure any control or display area the user requires to perform the task.

5.17.10.17 Obscure information. If an error message obscures task-relevant information, a means for the user to move the message shall be provided.

5.17.10.18 Multiple error messages. If a user repeats an entry error, the second error message shall be revised to include a noticeable change so that the user may be certain that the computer has processed the attempted correction.

5.17.11 Simultaneous access.

5.17.11.1 Two or more users. When two or more users must have simultaneous read access to a computer program or data processing results from separate interfaces, operations by one person shall not interfere with the operations of another person unless mission survival may be contingent upon preemption.

5.17.11.2 Preemption. If preemption occurs, provisions shall be made so that the preempted user can resume operations at the point of preemption without information loss.

5.17.12 Help. In addition to the requirements provided herein, detailed guidance and best practices may be found in ANSI\HFES 200.3.

5.17.12.1 Access. The system shall provide built-in guidance by allowing users to easily access built-in technical help.

5.17.12.2 Explicit error management aids. Help shall be available through explicit error management aids (labels, prompts, advisory messages) and implicit aids (cueing).

5.17.12.3 Standard action to request help. A simple standard action shall always be available for the user to access help.

5.17.12.4 Built-in help. At a minimum, built-in help shall include definitions of allowable options, system capabilities, procedures, and ranges of values.

5.17.12.5 Context sensitive help. Context-sensitive help shall be specific to the context from which it was accessed. After initial access, the system shall provide the user the ability to query the help documentation.

5.17.12.6 Minimize cross-referencing. Individual built-in help displays should contain enough information to respond to a user's query even if this capability produces redundancy in the built-in help system as a whole.

5.17.12.7 Definitions. The help section should contain a list of abbreviations and acronyms that are used in the main application.

5.17.12.8 Multilevel help. If an initial Help display provides only summary information, more detailed explanations shall be available via user query or drill-down.

5.17.12.9 Consistent help terminology. Online documentation, offline documentation, and help instructions shall use identical terminology to describe or define identical concepts or processes.

5.17.12.10 System-initiated help. For systems expected to have novice or infrequent users, a system-initiated Help function may be used. When provided, such functionality shall have the following characteristics.

5.17.12.10.1 Specific. System-initiated help shall only provide help specific to the user's current task or context.

5.17.12.10.2 Non-intrusive. System-initiated help shall not interfere with or obscure any control or display area the user requires to perform the current task.

5.17.12.10.3 Easy to enable and disable. A relatively novice user shall be able to disable and enable system-initiated help functionality with minimal effort.

5.17.13 Prompts. Prompts shall be in accordance with the criteria in 5.17.13.1 through 5.17.13.10.

5.17.13.1 Use. Prompts and help instructions shall be used to explain commands, error messages, system capabilities, display formats, procedures, and sequences as well as to provide data.

5.17.13.2 Prompts for special modes. When operating in special modes, the system shall display the mode designation and file(s) being processed.

5.17.13.3 User confirmation. Before processing any user requests that would result in extensive or final changes to existing data, the system shall require user confirmation.

5.17.13.4 Confirm abort operations. When data entries or changes will be nullified by an abort action, the system shall require user confirmation.

5.17.13.5 Prompt for missing data. When missing data are detected, the system shall prompt the user to supply the missing data.

5.17.13.6 Standard display. Prompting messages shall be displayed in a standardized area of the displays.

5.17.13.7 Explicit prompts. Prompts and help instructions for system-controlled dialog shall be explicit.

5.17.13.8 Memorization. Prompts shall be presented in such a way that the user is not required to memorize lengthy sequences or refer to secondary written procedural references in order to respond.

5.17.13.9 Prompt clarity. Prompts shall be clear and understandable.

5.17.13.10 Coding schemes. Prompts shall not require reference to coding schemes or conventions that may be unfamiliar to occasional users.

5.17.14 Information content.

5.17.14.1 Amount of information. The amount of information required shall be in accordance with the criteria in 5.17.14.1.1 through 5.17.14.1.5.

5.17.14.1.1 Scope. Information displayed to a user shall be clear enough to allow the user to perform the intended mission.

5.17.14.1.2 Precision. Information displayed shall be limited to the precision required to perform specific actions or to make decisions.

5.17.14.1.3 Context for displayed data. Each data display shall provide contextual information, including data from prior displays as necessary.

5.17.14.1.4 Combining operator and maintainer information. Operator and maintainer information shall not be combined in a single display unless the information content, format, and timeliness support the needs of both users.

5.17.14.1.5 Information density. Critical information shall be separate and distinct enough to be salient from non-critical information.

5.17.14.2 Presentation of information. Information shall be presented in accordance with the criteria in 5.17.14.2.1 through 5.17.14.2.7.

5.17.14.2.1 Plain text. Information shall be displayed in language appropriate to the user's level of training and be as specific as possible to the user's particular application.

5.17.14.2.2 Abbreviations. Abbreviations should be in accordance with JSSG-2010.

5.17.14.2.3 New abbreviations. New abbreviations, if required, shall be developed using logical rules.

5.17.14.2.4 Distinctive. Abbreviations shall be distinctive to avoid confusion.

5.17.14.2.5 Consistent. Words shall have only one consistent abbreviation.

5.17.14.2.6 Punctuation. No punctuation shall be used in abbreviations.

5.17.14.2.7 Definitions. Definitions of all abbreviations, mnemonics, and codes shall be available to access within the system.

5.17.14.3 Quantitative information. Quantitative information shall be displayed in accordance with the following rules.

5.17.14.3.1 Numeric digital displays. Digital displays shall be used when the task requires identifying a specific numeric quantity.

5.17.14.3.2 Pattern display. Analog or graphic displays shall be used when the comparison of quantities is important.

5.17.14.3.3 Comparison of quantities. Numeric digital displays shall not be used as the only display of information when the comparison of quantities is important for accurate interpretation.

5.17.14.3.4 Hybrid displays. Hybrid displays, which combine both digital and analog or graphic displays, shall be provided when a task requires both identification of a specific numeric quantity and the ability to compare quantities.

5.17.14.3.5 Units. Displays of quantitative information shall include units of measure.

5.17.15 Format.

5.17.15.1 Critical data. Critical data shall not be obscured by pagination or scrolling.

5.17.15.2 Readily usable form. Information shall be presented to the user in a directly usable form that does not require the user to transpose, compute, interpolate, or mentally translate the information into other units, number bases, or languages.

5.17.15.3 Format consistency.

5.17.15.3.1 Display output consistency. The content of displays and their formats shall be consistent within a system and across systems that are used by the same users.

5.17.15.3.2 Consistency between output and input. The same format shall be used for inputting data and displaying the output within a task (e.g., a date entered in the form of "mm/dd/yyyy" will be outputted in the same form).

5.17.15.3.3 Recurring data field labels. Recurring data fields within a system and across systems used by the same users shall have consistent labels.

5.17.15.3.4 Comparative data fields. Data fields to be compared on a character-by-character basis shall be positioned one above the other with alignment of characters to be compared.

5.17.15.3.5 Position of recurring data fields. Recurring data fields within a system and across systems used by the same users shall occupy consistent relative positions across displays.

5.17.15.3.6 Consistency of data entry formats. Whenever data has to be entered by hand, order and format should be as consistent as possible.

5.17.15.4 Critical messages in dialog boxes. Messages that are critical or that require user acknowledgment (e.g., error messages) shall appear in their own dialog boxes.

5.17.15.5 Page numbering. Each page of a multiple-page display should be labeled to identify the currently displayed page and the total number of pages, if applicable (e.g., "Page 2 of 5").

5.17.15.6 Display titles and headers. Each display shall be labeled with a title or header.

5.17.15.6.1 Unique. The title or header shall be unique within the system.

5.17.15.6.2 Position. The title or header should be positioned at the top left corner or centered on the page.

5.17.15.6.3 Content. The title or header shall briefly describe the contents or purpose of the page.

5.17.15.6.4 Meaningful. The title or header shall be meaningful enough to be learned and remembered easily.

5.17.15.7 Use of frames. Frames shall border the window.

5.17.15.7.1 Position. Frame identification shall be prominently displayed in the top left corner of the frame.

5.17.15.7.2 Size. Frame identification shall not exceed the size of the frame when resized to its minimum size.

5.17.15.7.3 Meaningful. Frame identification shall be meaningful enough to be learned and remembered easily.

5.17.15.7.4 Content. Frame identification shall describe the content within that frame.

5.17.15.7.5 Separation. At least one blank line shall separate the frame identification and the body of the frame.

5.17.15.8 Grouping of multiple displays.

5.17.15.8.1 Grouping. All displays necessary to support a user activity or sequence of activities shall be grouped together.

5.17.15.8.2 Frequency of use. Displays used most frequently shall be grouped together and placed in the optimum visual zone.

5.17.15.8.3 Importance. Important or critical displays shall be located in the optimum projected visual zone or otherwise highlighted.

5.17.15.8.4 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 such that order in functional groups provide a viewing flow from left-to-right or top-to-bottom. This requirement does not apply to master warning, caution, or advisory indicators.

5.17.15.8.5 Consistency. The arrangement of displays within a system shall be consistent in principle from one application to another.

5.17.16 Use with individual protective equipment. Where users may be required to use visual displays while wearing CBRNE or other mission-required PPE gear, displays shall be designed for foveal vision under relatively high levels of illumination; displays in the peripheral field of view shall only be used to attract attention.

5.17.17 Grouping within a display. Information or data shall be ordered in accordance with a specific purpose or context. When the purpose or context does not suggest a method of grouping information or data on a display, they may be grouped according to the following guidelines listed in order of preference.

5.17.17.1 Order and sequences. When data fields have a naturally occurring order, such as chronological or sequential, such order should be reflected in the format organization of the fields.

5.17.17.2 Grouped by importance. Displayed data items that are critical or require immediate user response may be ordered at the top of the list.

5.17.17.3 Ordered by function. Sets of data that are associated with specific questions or related to particular functions may be ordered together to signify those functional relationships.

5.17.17.4 Ordered by frequency. Data items used more frequently than others may be ordered at the top of the list.

5.17.18 Text and alphanumeric presentation.

5.17.18.1 Aircrew station signals. Aircrew station signals shall be designed using the guidance of JSSG-2010.

5.17.18.2 Alphanumeric character and symbol sizes. When measured from the greatest anticipated viewing distance, the height of alphanumeric characters and pictorial symbols shall subtend not less than 2.9 milliradians (10 minutes) of visual angle and should subtend not less than 4.5 milliradians (15 minutes) of visual angle.

5.17.18.3 Alphanumeric character and symbol sizes for viewing from ejection seats. Aircraft display characters and symbols that must be read in flight shall subtend not less than 7 milliradians (24 minutes) of visual angle.

5.17.18.4 Character stroke width. Assuming that the character height conforms to 5.17.18.2, stroke width shall be not less than 0.0834 nor greater than 0.1667 of the number of pixels used for character height.

5.17.18.5 Character width. Character width shall be approximately 0.9 of the height.

5.17.18.6 Symbol size and image quality for complex shapes. The size of a symbol or graphic shall be such that all text or graphics embedded within the symbol (e.g., label within symbol) shall subtend not less than 2.9 milliradians (10 minutes) of visual angle from the greatest anticipated viewing distance.

5.17.18.7 Font characteristics. Font style shall enable discrimination of similar characters (e.g., letter l/number 1, letter Z/number 2).

5.17.18.7.1 Standard font. A common standard font shall be used (e.g., Arial, Times New Roman, Courier, Verdana).

5.17.18.7.2 Sans-serif. Where users must read under adverse conditions (e.g., poor lighting), a sans-serif style shall be used (e.g., Arial, Verdana, Helvetica).

5.17.18.8 Protective gear. Display characteristics (e.g., legibility) shall be compatible with viewing while wearing a CBRNE or other mission-required PPE protective mask.

5.17.18.9 Viewing with PPE. Symbols viewed while wearing a CBRNE or other mission-required PPE mask shall subtend not less than 5.8 milliradians (20 minutes) of visual angle.

5.17.18.10 Alphanumerics.

5.17.18.10.1 Alphanumeric organization. When five or more alphanumeric characters are presented, they shall be separated into groups per their natural organization and punctuation schemes (e.g., “mm/dd/yyyy”, “(123) 555-6789”, and “123-45-6789”).

5.17.18.10.2 Combination of letters and digits. When a code consists of both letters and digits, common character types shall be grouped together.

5.17.18.10.3 Blocking. When five or more alphanumeric characters without natural organization are displayed, characters shall be grouped in blocks of three to five characters.

5.17.18.10.4 Separation of groups. When five or more alphanumeric characters without natural organization are displayed, groups of characters and digits shall be separated from one another by a minimum of one blank space.

5.17.18.10.5 Long numeric fields. When five or more numeric characters without natural organization are displayed, long numeric fields shall be punctuated with commas, spaces, or slashes.

5.17.18.10.6 Leading zeros. Leading zeros shall not be used in numerical data.

5.17.19 Text and program editing. Text and program editing shall be in accordance with the criteria in 5.17.19.1 through 5.17.19.12.

5.17.19.1 Buffer. When appropriate, when inserting characters, words, or phrases (e.g., editing), items to be inserted shall be collected in a buffer area and displayed in the prescribed insert area of the screen for subsequent insertion by user command.

5.17.19.2 Edit commands. Edit commands, such as MOVE, COPY, PASTE, INSERT and DELETE, for adding, inserting, or deleting text and program segments shall be provided.

5.17.19.2.1 Text edit commands. In text editing, editing commands shall be based on character, word, sentence, paragraph, and higher-order segments.

5.17.19.2.2 Program edit commands. In program editing, the special commands shall be based on lines or subprograms.

5.17.19.2.3 Program lines. Program lines shall reflect a numbering scheme for ease in editing and error correction.

5.17.19.2.4 Syntax checking. Line-by-line syntax checking shall be under user control.

5.17.19.2.5 Tab controls. For editing programs or tabular data, cursor tab controls or other provisions for establishing and moving readily from field to field shall be provided.

5.17.19.2.6 Keying edit commands. Where editing commands are made by keying into the display, the editing commands shall be readily distinguishable from the displayed textual material.

5.17.19.3 Highlighted text. Where text has been specified to become the subject of control entries (e.g., for underlining, bolding, moving, copying, or deleting), the affected segment of text shall be highlighted to indicate its boundaries.

5.17.19.4 String search. A string search capability shall be provided to allow the user to specify a string of text (words, phrases, or numbers) and request the computer to advance (or back up) the cursor automatically to the next (or previous) occurrence of that string.

5.17.19.5 String search variance. The string search capability shall provide the flexibility to select search variance.

5.17.19.6 Automatic word wrap. An automatic word wrap (carriage return) shall be provided when the text reaches the right margin for entry or editing of unformatted text.

5.17.19.7 Override of word wrap. User override of automatic word wrap shall be provided.

5.17.19.8 Format control. A means shall be provided for users to specify required format control features during text entry or editing (e.g., margins, tab settings, line spacing).

5.17.19.9 Predefined formats. When text formats must follow predefined standards, the required format shall be provided automatically.

5.17.19.10 Text formats as a user option. Where text formats are a user option, a convenient means shall be provided to allow the user to specify and store the formats that have been generated for particular applications for future use.

5.17.19.11 Frequently used text. The capability to label and store frequently used text segments (e.g., signature blocks, organizational names, call signs, coordinates), and to later recall (copy into current text) stored segments identified by their assigned labels shall be provided.

5.17.19.12 Head and foot of file. The means shall be provided to readily move the cursor to the head (beginning) or the foot (end) of the file.

5.17.20 Organization of information.

5.17.20.1 Labels. Every element on a display shall be labeled unless its purpose is intuitively obvious to the intended user population

5.17.20.1.1 Use. User-requested element identification (e.g., tool tips) is acceptable where space constraints preclude the use of labels.

5.17.20.1.2 Label characteristics. Labels should adhere to the following requirements:

a. Be unambiguously related to the element they describe.

b. Be consistent in appearance with all other labels on the display.

c. Be readily distinguishable from and more salient than all other elements on the display.

d. Use an accentuating technique different than any method used to highlight or code emergency or critical messages (e.g., use upper case to highlight the criticality).

5.17.20.2 Default values. Default values shall meet the following requirements.

5.17.20.2.1 Use when feasible. To reduce user workload, default values shall be used where feasible.

5.17.20.2.2 Display automatically. Currently defined default values shall be displayed automatically in their appropriate data fields with the initiation of a data entry transaction.

5.17.20.2.3 Acceptance. The user shall be able to indicate acceptance of the default by a single keystroke.

5.17.20.2.4 Replace default value. The user shall be able to replace any default value during a given transaction without changing the default definition.

5.17.20.2.5 Generate default values. The user shall have the option of generating default values if the system has not provided them.

5.17.20.2.6 Default options. Where a series of default values has been defined for a data entry sequence, the user shall be able to accept those default entries.

5.17.20.3 Tabular data. Tabular data shall meet the following requirements.

5.17.20.3.1 Use. Tabular data displays shall be used to present row-column data to aid detailed comparison of ordered sets of data.

5.17.20.3.2 Standard formats. Location of recurring data shall be consistent among all tabular data displayed and common throughout the system.

5.17.20.3.3 Arrangement. When tabular data are sorted within rows, it should be in increasing order from left to right. Tabular data sorted within columns should be in an order dictated by context.

5.17.20.3.4 Titles. When tabular data are divided into classifications, the classification titles shall be displayed.

5.17.20.3.5 Vertical extension – titles. When tabular data extend over more than one page vertically, the columns shall be titled identically on each page.

5.17.20.3.6 Horizontal extension. Tabular displays should not extend over more than one page horizontally.

5.17.20.3.7 Horizontal extension – titles. If horizontal extension over more than one page is required, the rows shall be titled identically on each page.

5.17.20.3.8 Distinctive and informative labels. Rows and columns shall be labeled distinctively to guide data entry.

5.17.20.3.9 Layout of numeric entry. Users shall be allowed to make numeric entries in tables without concern for justification. The computer shall right-justify integers or justify with respect to a decimal point if present.

5.17.20.3.10 Labeling units of measurement. The units of displayed data shall be consistently included in the displayed column and row labels.

5.17.20.3.11 Consistent column spacing. The widths of columns containing the same data elements shall be uniform and consistent within a table and from one table to another.

5.17.20.3.12 Consistent row spacing. The heights of rows containing the same data elements shall be uniform and consistent within a table and from one table to another.

5.17.20.3.13 Column scanning cues. A column separation not less than three spaces shall be maintained.

5.17.20.3.14 Row scanning cues. A group of rows shall be separated at regular intervals of not more than every five lines.

5.17.20.4 Lists.

5.17.20.4.1 List arrangement. Items in lists shall be arranged in a recognizable order, such as chronological, alphabetical, sequential, functional, or importance.

5.17.20.4.2 List lines. Each item in a list shall start on a new line.

5.17.20.4.3 Vertical extension. Where lists extend over more than one display page, the last line of one page shall be the first line on the succeeding page.

5.17.20.4.4 Marking multi-line items in a list. Where a single item in a list continues for more than one line, such items shall be marked in some way (e.g., blank line, indentation) so that the continuation of the item is obvious.

5.17.20.4.5 Vertical ordering in multiple columns. Where items in a list are displayed in multiple columns, items shall be ordered vertically within each column.

5.17.20.4.6 Arabic numerals. When listed items will be numbered, Arabic numerals shall be used rather than Roman numerals.

5.17.20.4.7 Hierarchic structure for long lists. Where lists are long and must extend beyond a single displayed page, a hierarchic structure shall be used to permit the logical partitioning into related shorter lists.

5.17.21 Graphic and representational displays.

5.17.21.1 Graphical user interfaces. See ANSI/HFES 200 for additional graphical user interface guidance.

5.17.21.1.1 Selecting from displayed attributes. During graphic data entry, users shall be allowed to specify attributes for displayed elements (e.g., text font, plotting symbol, line type).

5.17.21.1.2 Examples. The capability to specify attributes for displayed elements should include examples that illustrate the available options.

5.17.21.1.3 Selecting graphic elements. Users shall be provided some means for designating and selecting displayed graphic elements when manipulation of those elements is required. Normally this function is performed by a pointing device or cursor.

5.17.21.1.4 Displaying current attributes. The attributes that will be affected by a change shall be highlighted.

5.17.21.1.5 Easy storage and retrieval. The user shall be provided a means for saving and retrieving graphic data displays.

5.17.21.1.6 Automatic data registration. The computer shall provide automatic registration or alignment of computer-generated graphic data so that variable data are shown properly with respect to fixed background or data map at any display scale.

5.17.21.1.7 Predefined graphic formats. Where graphic data must be plotted in predefined standard formats (e.g., target areas on maps, flight plans), templates or skeletal displays shall be provided for those formats to aid data entry.

5.17.21.1.8 Changing size. When editing graphic data, users shall be provided with the capability to change the size (scale) of any selected element on the display rather than delete and recreate the element in a different size.

5.17.21.1.9 Highlighting critical data. When a user's attention must be directed to a portion of a graphic display showing critical or abnormal data, that feature shall be highlighted with some distinctive means of data coding.

5.17.21.1.10 Computer derivation of graphic data. Common or complex data computations, such as curve fitting or plotting a list of coordinates, should be performed by the system upon user request.

5.17.21.1.11 Normal orientation for labels. The text on dynamic graphic displays shall remain upright when the displayed image rotates.

5.17.21.1.12 Display of scale. If a map or other graphic display has zoom functionality, the current zoom level or scale shall be displayed.

5.17.21.1.13 Display accuracy. If applicable, the current display accuracy shall be displayed.

5.17.21.1.14 Interpolation. The system shall provide accurate numeric information for any point on the graphic display upon request from the user.

5.17.21.1.15 Unobtrusive grids. Any displayed grid lines shall be unobtrusive.

5.17.21.1.16 Obscuration of data elements. Displayed grid lines shall not obscure data elements.

5.17.21.1.17 Grid line suppression. Users shall be provided the option to suppress or display gridlines.

5.17.21.2 Graphs and charts. Graphs and charts shall be in accordance with the criteria in 5.17.21.2.1 through 5.17.21.2.6.

5.17.21.2.1 Graph axes. The axes of graphs shall be labeled.

5.17.21.2.2 Trend lines. When trend lines are to be compared, they should be displayed on a single graph.

5.17.21.2.3 Reference index. When a user must compare graphic data to some significant level or critical value, that level or value shall be included in the display.

5.17.21.2.4 Data annotation. When precise reading of a graphic display may be required, the capability to supplement the graphic representation with the represented numeric values shall be provided.

5.17.21.2.5 Consistent scaling. When users must compare graphic data across a series of charts, the same scale shall be used for each chart.

5.17.21.2.6 Single scale only. Where graphs are presented, only a single scale shall be shown in each axis, rather than including different scales for different curves in the graph.

5.17.21.3 Drawing shapes and lines.

5.17.21.3.1 Drawing shapes. When shape drawing is required, users shall be provided with aids for drawing shapes.

5.17.21.3.2 Drawing lines. When line drawing is required, users shall be provided with aids for drawing straight line segments.

5.17.21.3.3 Drawing intersecting lines. When a user draws the end of a line segment in close proximity to a displayed element, the system should automatically connect between the line segment and displayed element.

5.17.21.3.4 Override. The user shall be provided a means to override the automatic line segment connection feature.

5.17.21.3.5 Drawing lines and figures with numeric coordinates. When lines or figures must be drawn to represent numeric coordinates, computer aids shall include methods for entering the coordinates and selecting the appropriate units for those coordinates.

5.17.22 Specific purpose user interfaces.

5.17.22.1 Dynamic displays.

5.17.22.1.1 Changing values. Alphanumeric values that change in real time shall be updated according to the criteria in 5.17.22.1.1.1 through 5.17.22.1.1.2.

5.17.22.1.1.1 Reliable reading. Values that the user must reliably read shall not be updated more often than once per second.

5.17.22.1.1.2 Identify rate of change. Changing values that the user uses to identify rate of change or to read gross values shall be updated three to four times per second.

5.17.22.1.2 Update rate. Update rate should be in accordance with programmatic-specific requirements.

5.17.22.1.2.1 Display freeze. A display freeze mode shall be provided to allow viewing any selected frame that is updated or advanced automatically by the system.

5.17.22.1.2.2 Resume from freeze. A single action option shall be provided to allow resumption at the freeze point or at the current real-time point.

5.17.22.1.2.3 Display freeze prohibition. The user shall be prohibited from entering display freeze mode when doing so would have an adverse effect on the mission being performed by the system.

5.17.22.1.2.4 Freeze feedback. A label shall be provided to remind the user when the display is in the freeze mode.

5.17.22.1.2.5 Timeliness. Displays requiring refreshed information (e.g., head-up displays) shall be updated in a synchronous manner.

5.17.22.1.2.6 Advisory and alerting. Devices displaying simultaneous and integrated information (e.g., multifunction displays) shall alert or cue operating personnel to information prior to it becoming critical within the display.

5.17.22.2 Printing display.

5.17.22.2.1 Hard copy. The system shall provide the capability for the user to obtain a paper copy of the exact contents of the alphanumeric or digital graphic display, where mass storage is restricted, mass stored data that can be lost by power interruption, or where record keeping is required or desirable.

5.17.22.2.2 Display print. The system shall provide the capability for the user to print a display screen by simple request (e.g., PRINT-SCREEN).

5.17.22.2.3 Print page. The system shall provide the capability for the user to request printing of a single page or sequence of pages by specifying the page numbers or printing all pages without specifying page numbers.

5.17.22.2.4 Text displayed as printed. The system shall provide the capability for the user to display text as it will be printed, including underlining, boldface, subscript, superscript, special characters, special symbols, and different styles and sizes of type.

5.17.22.2.5 Flexible printing options. In printing text, the system shall provide the capability for the user to select among available output formats (e.g., line spacing, character size, margin size, headers, footers) and to specify the pages of a document to be printed.

5.17.22.3 Data and message transmission.

5.17.22.3.1 Functional integration. Data transmission functions shall be integrated with other information handling functions within a system such that a user is able to transmit data using the same computer system and procedures used for general entry, display, and other processing of data.

5.17.22.3.2 Consistent procedures. Procedures for preparing, sending, and receiving data and messages shall be consistent from one transaction to another and consistent with procedures for other information handling tasks.

5.17.22.3.3 Minimal memory load on users. The system shall provide computer aids for automatic insertion of standard information, such as headers and distribution lists, in order to minimize memory load on the user.

5.17.22.3.4 Messages. Messages shall be in accordance with the criteria in 5.17.22.3.4.1 through 5.17.22.3.4.8.

5.17.22.3.4.1 Stored message forms. Where message formats conform to a defined standard or are predictable in other ways, pre-stored forms shall be provided to aid users in message preparation.

5.17.22.3.4.2 Incorporate existing files. Users shall be allowed to incorporate an existing data file in a message, combine several files into a single message for transmission, and combine stored data with new data when preparing messages for transmission.

5.17.22.3.4.3 Reenter data. It shall not be necessary to reenter any data already entered for other purposes.

5.17.22.3.4.4 Interrupt. Users shall be allowed to interrupt message preparation, review, or disposition and then resume any of those tasks from the point of interruption.

5.17.22.3.4.5 Data group labels. Each individual data group or message shall contain a descriptive title, phrase, word, or similar device to designate the content of the group or message.

5.17.22.3.4.6 Location of message labels. Labels shall be consistently located adjacent to (and preferably above or to the left of) the data group or message they describe.

5.17.22.3.4.7 Emergency or critical messages. Labels shall use an accentuating technique different and easily distinguished from the method used to highlight or code emergency or critical messages.

5.17.22.3.4.8 Originator identification. Except for broadcast communication systems, the transmitter of each message in inter-user communications shall be automatically identified, if possible.

5.17.22.3.5 Addresses. When users must specify the address for messages, prompting shall be provided to guide the user in the process.

5.17.22.3.6 Directories. Users shall be provided with a built-in directory showing all acceptable forms of message addressing for each destination in the system and for links to external systems.

5.17.22.3.6.1 Computer aids. Computer aids shall be provided so that a user can search an address directory by specifying a complete or partial name.

5.17.22.3.6.2 Extract addresses. Users shall be able to extract selected addresses from a directory for direct insertion into a header in order to specify the destination(s) for a message.

5.17.22.4 Geospatial displays.

5.17.22.4.1 Use. Geographic displays shall only be used for data that can be geo-referenced.

5.17.22.4.2 Types. Editable geographic coordinate displays allow users to enter a specific geographic location in one of several coordinate systems, such as decimal degrees; military grid reference system (MGRS); or degrees, minutes, seconds (DMS). Non-editable displays are system-generated values that match system or user-selected geographic coordinate system format.

5.17.22.4.3 Default geographic coordinate systems. Geospatial displays should have the option to save a default geographic coordinate system (e.g., decimal, MGRS, DMS).

5.17.22.4.4 Geospatial display options. Geographic displays are normally composed of a base map, overlays, and individual drawings. To permit customization and decluttering functionality, a list of options of available visual elements should be available to the user. Functionality of these options may include, but is not limited to, the following elements:

a. Toggle element visibility – the ability to show and hide individual visual elements.

b. Opacity – the ability to control how many visual elements can be seen when overlapped with other visual elements.

c. Precedence – the ability to set the order in which visual elements are layered over each other.

d. Hierarchical grouping – the ability to apply the above functionality to both individual visual elements and logical groupings, as required.

5.17.22.4.5 Geospatial display drawings. If the user is provided the capability to draw on the geospatial display, the following functionality should be provided:

a. Manipulation – drawings should be able to be moved, resized, or deleted after being initially placed. Resizing should include the capability to keep the aspect ratio locked.

b. Zooming and panning – the user should be able to zoom and pan the underlying base map while drawing.

c. Editing – relevant drawing properties (e.g., color, opacity, labeling) should be editable before and after the drawing is made.

5.17.22.4.6 Relative positioning. Drawings should be able to be aligned relative to other visual elements, such as other drawings or a grid overlay.

5.17.23 Automated system displays. See 5.12.3.

5.17.24 Coding of information.

5.17.24.1 Use of coding. Coding shall be used to facilitate discriminating between individual views (e.g., different modes of operation); identifying functionally related displays; showing the relationships between displays; and identifying critical information, unusual values, changed items, items to be changed, high priority messages, special areas of the display, errors in entry, criticality of command entry, and targets.

5.17.24.2 Meaningful coding. Meaningful codes shall be used.

5.17.24.3 Common coding conventions. Commonly used coding conventions should be used.

5.17.24.4 Impact on performance. Coding shall not reduce legibility or adversely impact user or system performance.

5.17.24.5 Consistent coding. All coding within the system shall be consistent.

5.17.24.6 Techniques. The following visual characteristics may be used for coding: color, brightness, flash, size, pattern, location, underlining, symbol, or shape.

5.17.24.7 Aircrew display symbology. Aircrew display symbology shall be coded in accordance with JSSG-2010 and MIL-STD-1787.

5.17.25 Color coding. Color coding shall be in accordance with the criteria in 5.17.25.1 through 5.17.25.16.4.

5.17.25.1 Use. Color coding may be employed to differentiate between classes of information in complex, dense, or critical displays or to provide a means of indicating similarity among items (grouping items) along some meaningful dimension.

5.17.25.2 Foveal view only. Color shall not be used for gaining attention outside the optimum visual field.

5.17.25.3 Consistency. Color coding shall be used consistently within a display and, where appropriate, across displays of other systems used by the same users.

5.17.25.4 Color customization. Color customization by users shall be allowed only for information that is not tactically significant.

5.17.25.5 Color recognition. When the user must recognize categories of information (e.g., represent different variables on a graph, different types of information on a map) a maximum of 11 nameable colors shall be used to represent and distinguish between categorically different information.

5.17.25.6 Color differentiation. When using color to group elements of a display together (i.e., to show parts are related or different) and the color has no meaning beyond a grouping function, colors should be discriminable.

5.17.25.7 Saturation coding. Hue saturation may be used to indicate relative intensity (e.g., best, hottest, wettest, safest, deepest). The following are standardized uses of saturation that should be followed:

a. Hotter to cooler where saturation changes from red to blue.

b. More dangerous to less dangerous – saturation of red increases as danger increases.

5.17.25.8 Color meanings. Colors shall be associated with the common meanings presented in table XL.

5.17.25.8.1 Cool colors. Cool colors (those with shorter wavelengths, such as blue or green) shall be used to display information used infrequently and to convey status of background information.

5.17.25.8.2 Warm colors. Warm colors (those with longer wavelengths, such as red or orange) shall be used to convey action or the requirement for a response.

TABLE XL. Common color association meanings.

Color	Maps and Tactical Meaning	Classification Meaning	Alarm, Alert, Threat Meaning	Equipment Meaning	Other Common Meaning
Red	Red alert Forces or situation at critical condition Hostile target identification	Secret	Critical consequences Danger or unsafe Severe threat Emergency Alarm	Closed/stopped Oxygen Malfunction Ordnance handling	Stop Heat or fire Failure OFF (as opposed to ON)
Orange		Top Secret	Alarm, alert, or hazard High threat		Value between red and yellow
Yellow	Forces or situation at marginal condition Unknown target affiliation CBRNE areas		Warning, caution, or hazard Elevated threat Approaching critical Extreme caution Impending danger	Oil	Abnormal state Delay Check or recheck
Green	Non-alert Neutral target affiliation Obstacles Forces or situation at acceptable condition	Unclassified	Normal Safe Low threat	Open/flowing	Maintenance personnel ON (as opposed to OFF) In tolerance, acceptable Ready, proceed, satisfactory
Blue	Friendly affiliation Deep water		Safe Guarded threat	Non-critical items Water or flooding Nitrogen	Cool or cold
Cyan	Friendly affiliation		Advisory	Aerated water	Cool
Dark (navy) blue			Advisory	Untreated water	
Magenta			Alarm state		
			Radiation hazard		

TABLE XL. Common color association meanings – Continued.

Color	Maps and Tactical Meaning	Classification Meaning	Alarm, Alert, Threat Meaning	Equipment Meaning	Other Common Meaning
Purple (violet)				Aviation fuels	
White			Advisory	Steam	Medical personnel Empty Functional or physical position Action in progress
Black	Political boundary Image or figure edge				Outline or border
Gray				Smoke	Inactive or unavailable options or actions

5.17.25.9 Dark adaptation. When color coding is used, luminance shall be more than 10 cd/m² (2.9 fL).

5.17.25.10 Color-blind users. If the user population includes color-blind users, every effort should be made for non-confusable colors to be used for coding.

5.17.25.11 Redundant coding. If non-confusable colors cannot be used for coding for color-blind users, redundant coding shall be used.

5.17.25.12 Induced color-blindness. Operational requirements occasionally result in the need to introduce protective eyewear, visors, or other filters in the optical path that are designed to absorb or reflect measurable and uniquely specifiable wavelengths of directed energy within the visible spectrum. This results in selectively induced color deficiencies or color blindness. As such, color coding in display design shall not be the only means of coding information for affected operational systems.

5.17.25.13 Object size. When accurate color perception is required, the major dimension of isolated large symbols shall subtend not less than 8.7 milliradians (30 minutes) of visual angle and should subtend not less than 13.1 milliradians (45 minutes).

5.17.25.14 Object height. When accurate color perception is required, the height of small symbols and characters should subtend at least 5.8 milliradians (20 minutes) of visual angle, as measured from the longest anticipated viewing distance.

5.17.25.15 Fill symbols. To enhance detectability and discriminability, color-filled symbols shall be used instead of outlined symbols.

5.17.25.16 Color contrast and differences.

5.17.25.16.1 Color contrast. Colored symbols shall differ from their background by not less than 100 ΔE (color difference) (CIE L*u*v*) distances when calculated using the formula below. The elements required for the calculation are the luminance (Y), the UCS coordinates (u', v') for foreground and background colors, and the maximum luminance for the display (Y_M). As with the (CIE L*u*v*) distances, caution should be used in assessing legibility for characters in colors having small luminance differences. This caution applies not only to characters in color but also to small luminance differences in background colors and for very small luminance differences between characters in color and background in color. Unusually large or small characters may lead to erroneous estimates of legibility. The metric is as follows:

ΔE (Yu'v') =	[(155 * ΔY/Y_M)2 + (367 * Δu')2 + (167 * Δv')2](1/2) where,
ΔY =	difference in absolute luminance between foreground (e.g., text) and background.
Y_M =	the maximum luminance of any color on the display (i.e., pure white), measured in the same units as ΔY
Δu' =	difference between foreground and background values of the u' coordinate in accordance with EIA TEB 26
Δv' =	difference between foreground and background values of the v' coordinate in accordance with EIA TEB 26
Values of the u' and v' coordinates range from 0 to 1. The range of luminance variables (ΔY and YM) is not limited.	
The values 155, 367, and 167 are empirically derived weights.	

5.17.25.16.2 Color differences. Colors in a set shall differ from one another by not less than 20 ΔE (CIE L*u*v*) distances when calculated using the formula below.

For color displays, the reference white can be taken as the white on the display obtained with full-intensity red at 6,500 Kelvin (K) or 9,300 Kelvin. The difference formula is:

ΔE units (CIE L*u*v*) =	$[(L^*_1 - L^*_2)^2 + (u^*_1 - u^*_2)^2 + (v^*_1 - v^*_2)^2]^{(1/2)}$ where subscripts denote the values calculated for each of two colors,
L* =	$116 * (Y/Y_0)^{(1/3)} - 16$; (assuming that $1.0 > Y/Y_0 > 0.01$)
	L* is the color's value, which is a measure of the color's luminance relative to reference white. It ranges from 0 to 100.
	Y is overall luminance in cd/m^2. It is one of the three tristimulus values (X, Y, Z) measured as the integral of a weighted spectral power distribution curve. The CIE provides three weighting curves in their specification for calculating each of the tristimulus values from a given spectral power distribution curve.
	Y_0 is the luminance of the reference white.
u* =	$13 * (L^*) * (u' - u'_0)$
v* =	$13 * (L^*) * (v' - v'_0)$
u' =	$(4X) / (X + 15Y + 3Z)$
v' =	$(9Y) / (X + 15Y + 3Z)$
u* and v* are versions of the UCS coordinates (u', v') scaled and adjusted to the reference white and used for calculating color difference.	
u' and v' are the UCS coordinates for the color in question based on the tristimulus values. Note that the tristimulus values can be normalized for use in the u' and v' equations, but Y cannot be normalized for the L* equation.	
u'_0 and v'_0 are the UCS coordinates for the reference white derived from EIA TEB 26.	
For reference white at D6500 Kelvin (The "D" describes a spectral power distribution curve for the reference white. Other curves are available with corresponding chromaticity values.): $u'_0 = 0.198$ and $v'_0 = 0.468$	
For reference white at 9300 Kelvin + 27 MPCD (MPCD = Minimum Perceptible Color Difference): $u'_0 = 0.181$ and $v'_0 = 0.454$	
Note that the 9300 Kelvin + 27 MPCD values are based on a white point located at the intersection of the ISO temperature line for 9300 Kelvin with the daylight locus. Y_0 in this use of the ΔE (CIE L*u*v*) distance metric is defined differently than suggested by CIE.	

5.17.25.16.3 Text and background pairings for daytime or artificial lighting. Text 14-point font or less should have a luminance contrast ratio of above 4.5:1. Text larger than 14-point font should have a contrast ratio of at least 3:1. Black or dark text should be on a light background.

5.17.25.16.4 Text and background pairings for dark conditions. White or light text should be on a dark background.

5.17.26 Brightness coding.

5.17.26.1 Use. Brightness intensity coding should be employed only to differentiate between an item of information and adjacent information.

5.17.26.2 Brightness intensity levels. No more than two levels of brightness shall be used, and each level shall be separated from the nearest other level by not less than a 2:1 ratio.

5.17.26.3 Brightness inversion. When a capability for brightness inversion is available (so-called “reverse video” where dark characters on a bright background can be changed under computer control to bright on dark, or vice versa), it may be used for highlighting critical items that require user attention. When a capability for brightness inversion is available and when used for alerting purposes, brightness inversion shall be reserved for that purpose and not be used for general highlighting.

5.17.27 Flash coding.

5.17.27.1 Use. Flash coding should be employed to call the user’s attention to mission-critical events only.

5.17.27.2 Duty cycle. The percentage of “on” time shall be equal to but not less than the percentage of “off” time; a 50 percent duty cycle is preferred.

5.17.27.3 Flash rate. No more than two flash rates shall be used.

5.17.27.3.1 Flash rate differences. The two flash rates shall differ by not less than 2.0 hertz.

5.17.27.3.2 Higher flash rate. The higher flash rate shall be not greater than 5.0 hertz.

5.17.27.3.3 Slower flash rate. The slower flash rate shall be not less than 0.8 hertz.

5.17.27.3.4 Critical information. The higher flash rate shall reflect more critical information.

5.17.27.4 Flash rate synchronization. Items flashing at the same rate shall be synchronized.

5.17.27.5 Flash rate text. Characters that must be read shall not flash; an adjacent flashing symbol, flashing background, or alternating brightness intensity may be used to add emphasis to text.

5.17.27.6 Flash suppression. Event acknowledgment or flash suppression control shall be provided.

5.17.27.7 Flashing area. Only a small area of a display should flash at any time.

5.17.28 Size coding. No more than three size levels shall be used. The major dimensions of the larger size shall be not less than 150 percent of the major dimension of the smaller.

5.17.29 Pattern and location coding. Pattern and location coding may be used to reduce user search time by restricting the area to be searched to prescribed segments.

5.17.30 Underlining coding. Underlining may be employed to indicate unusual values, errors in entry, changed items, or items to be changed.

5.17.31 Symbol coding.

5.17.31.1 Use. Symbol coding may be used to enhance information assimilation from data displays.

5.17.31.2 Symbol selection. Symbols shall be analogs of the event or system element they represent or be in general use and well known to the expected users.

5.17.31.3 Special symbols. When special symbols are used to signal critical conditions, they shall be used for only that purpose.

5.17.31.4 Markers close to words marked. When a special symbol is used to mark a word, the symbol shall be separated from the beginning of the word by one space.

5.17.32 Shape coding. Shape coding may be used for search and identification tasks. When shape coding is used, the codes selected should be based on established standards or conventional meanings.

5.18 Ship bridge design. This section addresses human engineering design criteria for ship bridge design. A ship's bridge is the area from which a vessel is navigated, controlled, and operated. It is composed of the enclosed wheelhouse (or pilot house) and chartroom and, if present, bridge wings, which may be open or enclosed and extend from the pilot house to the vessel's side. This section is not intended for application to submarines.

5.18.1 Controls. Design, selection, and placement of specific controls as well as control and display integration shall be in accordance with 5.1 as well as the bridge-specific requirements below.

5.18.1.1 Location. The most important and frequently used controls, including steering, propulsion, bridge-to-bridge communications, and time-critical functions, shall be placed within reach of the expected location of the associated bridge personnel.

5.18.1.2 Arrangement. The arrangement of functionally similar controls should be consistent across different systems on the bridge.

5.18.1.3 Grouping. Controls shall be grouped primarily by commonality of function, conditions of use, expected primary position of the intended operator(s), and secondarily by frequency and sequence of use.

5.18.1.4 Coding. Coding by shape, size, location, or mode within and across different systems on the bridge shall be used in accordance with table IV and shall be used in accordance with 5.1.1.4 to allow the operator to differentiate between controls.

5.18.1.5 Software interface controls. Graphical user interface controls should not be used as the sole means for ship steering, propulsion, or emergency functions (e.g., emergency control transfer and alarm controls).

5.18.1.5.1 Hardware steering and throttle controls. Hardware-based controls shall be provided for direct steering and throttle control at the primary control position(s).

5.18.2 Displays. Visual displays shall be in accordance with 5.2 as well as the bridge-specific requirements below.

5.18.2.1 Display arrangement. Displays within the bridge as well as both permanent and temporary displays used on bridge wings shall be arranged as follows.

5.18.2.1.1 Number of displays. The number of displays should be minimized based upon the information requirements of the crew, reliability of the displays, and redundancy of critical displays.

5.18.2.1.2 Co-location of warning, caution, and advisory displays. All warning, caution, and advisory displays associated with safety of navigation or catastrophic events for individual operator positions shall be presented within the operator's 30-degree (total included angle) forward cone of vision.

5.18.2.1.3 Placement of warning, caution, and advisory displays. If more than one display is present at a crewstation, the display farthest to the left should display all warning, caution, and advisory messages.

5.18.2.1.4 Readability of displays. The location, orientation, and expected operator viewing angle of displays shall be such that displays can be read in a full sunlight illumination environment of 108,000 lx (10,000 fc) with a 6,800-cd/m^2 (2,000-fL) glare source.

5.18.2.1.4.1 Readability of interior displays. Displays installed on the interior of the bridge that will be shaded from direct sunlight shall be readable in a partial sunlight illumination environment of 3,240 lx (300 fc) with a 6,800-cd/m^2 (2,000-fL) glare source.

5.18.2.1.4.2 Accommodations for readability. The use of filters, coatings, or hoods to achieve readability requirements is acceptable if approved by the procuring activity.

5.18.2.1.4.3 Filters for color displays. Any filters used for color displays when operators are required to utilize color coding shall be neutral density filters.

5.18.2.1.5 Ambient illumination during night operations. Arrangement of bridge displays and equipment shall support the following ambient illumination requirements during night operations with all overhead lighting off, excluding natural external lighting levels.

5.18.2.1.5.1 Ambient illumination for primary positions of operators. The ambient illumination within the field of regard (including head rotation) of the primary position of each operator shall not exceed 0.001 lx (0.0001 fc) (0.0001 lx [0.00001 fc] preferred).

5.18.2.1.5.2 Ambient illumination for anticipated locations of operators. The ambient illumination within the field of regard (including head rotation) of each anticipated operator location should not exceed 0.001 lx (0.0001 fc).

5.18.2.1.5.3 Ambient illumination for positions along the aft bulkhead. The ambient illumination on the bridge when viewed from forward-facing positions along the aft bulkhead shall not exceed 0.005 lx (0.0005 fc).

5.18.2.1.6 Primary displays. Primary displays for critical and interactive functions shall be installed below the operator's external line of sight and preferably below the level of the bridge windows.

5.18.2.1.7 Secondary displays. Secondary displays (for visual reference or supporting information) may be mounted above the bridge windows.

5.18.2.1.8 Display mounting locations. Only primary and secondary displays shall be mounted in the vicinity (e.g. above and below) of the bridge windows.

5.18.2.1.9 Reflections. All displays shall face away from bridge windows to avoid reflections, to the extent supported by window locations.

5.18.2.2 Display characteristics.

5.18.2.2.1 Image polarity – day. Where ambient illumination is expected to be 540 lx (50 fc) or greater, displays shall use dark characters and symbols on a light background.

5.18.2.2.2 Image polarity – night. Displays to be used by personnel maintaining dark adaptation shall use light characters and symbols on a dark background.

5.18.2.2.3 Display luminance for bridge equipment. Display luminance for bridge equipment shall meet the following requirements. Separate day and night color palettes may be necessary for displays to meet these requirements and maintain legibility.

5.18.2.2.3.1 Range of adjustment. The luminance of displays on the bridge shall provide the full range of continuous adjustment to allow readability in sunlight through night lighting (dark adaptation) conditions.

5.18.2.2.3.1.1 Adjustment control accessibility. Controls for display or indicator luminance adjustment shall remain accessible when the display or indicator is fully dimmed.

5.18.2.2.3.1.2 Adjustment control visibility. If on-screen controls are used for display or indicator luminance, they shall remain visible without the use of external lighting when the display or indicator is fully dimmed.

5.18.2.2.3.2 Direct sunlight. Displays exposed to direct sunlight shall provide a minimum difference luminance measured in accordance with MIL-L-85762 of not less than 685 cd/m^2 (200 fL) over the display's viewing envelope in full daylight ambient lighting conditions.

5.18.2.2.3.3 Indirect sunlight. Displays shaded from direct sunlight shall provide a minimum difference luminance measured in accordance with MIL-L-85762 of not less than 340 cd/m^2 (100 fL) over the display's viewing envelope in full daylight ambient lighting conditions.

5.18.2.2.3.4 Dark adaptation not required. Display luminance for operator positions used during night operations when dark adaptation is not required shall be variably dimmable to a minimum of at least 3.5 cd/m^2 (1 fL).

5.18.2.2.3.5 Dark adaptation required. Display luminance for operator positions requiring dark adaptation shall be variably dimmable between at least 0.35 cd/m^2 (0.10 fL) and at least 0.03 cd/m^2 (0.01 fL) (0.003 cd/m^2 [0.001 fL] preferred) to support dark adaptation.

5.18.2.2.4 Display hoods. Displays for individual operators shall have an upper ⅓ hood when necessary to improve display legibility, limit light leakage, or maintain dark adaptation of other users. Hoods shall be removable and have rounded corners in accordance with 5.7.6.4.

5.18.2.3 Indicator and status lights.

5.18.2.3.1 Impact on dark adaptation. Indicator and status lights shall not be so bright as to create "dazzle" or damage user dark adaptation where it is required.

5.18.2.3.2 Reflections. Equipment shall be installed to minimize bridge window reflections and other lighting impacts of indicator and status lights at operator positions.

5.18.2.3.3 Visibility of indicator and status lights for maintenance. Indicator and status lights used solely for maintenance and adjustment shall be covered or not visible during normal operation.

5.18.2.3.4 Accessibility of indicator and status lights for maintenance. Indicator and status lights used for maintenance and adjustment shall be readily accessible when they are required.

5.18.3 Lighting. Bridge illumination and equipment lighting shall be in accordance with 5.5.3.

5.18.3.1 Task illumination.

5.18.3.1.1 Bridge task illumination locations. Task illumination (lighting provided to support task execution) shall be provided for all operator positions that require use of non-backlit keyboards or control panels and logs, charts, and other paper materials.

5.18.3.1.2 Illumination of critical controls. Dimmable lighting shall be provided for critical and emergency operator controls for which backlighting or other integral illumination is not provided.

5.18.3.1.3 Bridge task illumination levels. Task illumination for operator positions shall be not less than 540 lx (50 fc).

5.18.3.1.4 Chart table illumination level. Task illumination for the chart table, if applicable, shall be not less than 810 lx (75 fc).

5.18.3.2 Dimmable lighting.

5.18.3.2.1 White lighting. White lighting shall be provided for operator positions where dark adaptation is necessary and where use of color-coded displays is required.

5.18.3.2.2 Red lighting. Red lighting should be provided for operator positions where maintaining maximum dark adaptation is critical, if use of color-coded displays is not required, and if external detection or NVD usage is not an issue.

5.18.3.2.2.1 Color coding for red lighting. If red lighting is to be used during a portion of the mission, controls that would otherwise be coded red shall be coded by orange-yellow (SAE AMS-STD-595 13538, 23538, or 33538) and black (SAE AMS-STD-595 17038, 27038, or 37038) striping.

5.18.3.2.2.2 Alternative to red lighting. An alternative to red lighting shall be available at chart tables and other workstations requiring use of colored indicators or readability of color maps and symbols.

5.18.3.3 Dim to zero. Operator task lighting (white and red) shall have the capability to dim to zero.

5.18.3.4 Curtains. Curtains or visual barriers shall be provided at points of entry to the bridge to avoid light leakage from internal ship spaces and passages with higher levels of ambient lighting.

5.18.3.5 Light leakage from task lighting. Task lighting for operator positions requiring higher ambient or task lighting levels shall be designed and arranged to prevent light leakage and reflectance or glare at other operator positions. The use of hoods, curtains, or other barriers is acceptable.

5.18.3.6 Watchstander visibility. Devices used to block light shall not interfere with the bridge watchstander's required field of regard.

5.18.3.7 Glare. Bridge lighting sources and equipment shall be designed and arranged to avoid creating glare from working and display surfaces from expected operator positions.

5.18.3.7.1 Placement of reflective surfaces. Placement of smooth highly polished surfaces within 60 degrees of an operator's normal field of view regard be avoided.

5.18.3.7.2 Reflectivity of bridge equipment. The bridge equipment and work surfaces should have non-reflective or matte finished surfaces to reduce glare.

5.18.3.7.3 Reflectivity of bridge bulkheads. The bridge bulkheads shall be matte black or dark blue with a reflectance less than 20 percent (10 percent preferred).

5.18.3.8 Window reflections. When reflection from window glass could be a problem, the window shall be angled forward at the top between 10 and 30 degrees depending on the operational application.

5.18.4 Noise.

5.18.4.1 Ambient sound pressure levels. Ambient sound pressure levels on the bridge during normal operations shall not exceed 65 dBA (55 dBA preferred).

5.18.4.2 Airborne sound pressure levels. The airborne sound pressure levels on the bridge shall meet the A-12 requirement (or A-3 if specified [see 6.2]) for shipboard compartments in accordance with MIL-STD-1474.

5.18.4.3 Bridge equipment. Bridge equipment shall meet the sound pressure levels for grade A-12 shipboard equipment in accordance with MIL-STD-1474.

5.18.4.4 Intermittent noise sources. The allowable sound pressure level shall be increased by 10 dBA when intermittently-operated machinery and equipment are in use, including bow thrusters, ballasting or de-ballasting equipment, and flight operations.

5.18.5 Bridge watchstander duties and maintenance actions.

5.18.5.1 Support for bridge duties. All duties required of bridge watchstanders shall be executable using the installed equipment of the bridge and without leaving the bridge.

5.18.5.1.1 Maintain proper lookout. The overarching duty to maintain a proper lookout by unaided sight and hearing shall not be impeded. This capability may be augmented with mechanical, electronic, optical, or other means when necessary.

5.18.5.1.2 Communications access. Lookout positions shall provide access to required communications equipment without impeding external field of view and field of regard requirements.

5.18.5.1.3 Supplementary equipment and materials. Supplementary equipment and materials used by bridge watchstanders should be available on the bridge precluding the need to depart the bridge and impairing execution of duties or dark adaptation.

5.18.5.1.4 Equipment not available on the bridge. Equipment, material, and facilities not available on the bridge but used by bridge watchstanders should be adjacent to or readily accessible from the bridge.

5.18.5.1.5 Bridge watchstanders not available on the bridge. Under circumstances where one or more bridge watchstanders must leave the bridge to address other watchstanding duties that cannot be done from the bridge, the task design and equipment shall enable the remaining watchteam members to fully execute all necessary bridge duties.

5.18.5.2 Maintenance actions. Equipment selection and installation shall allow maintenance activities required during ship operations to be executed without interfering with bridge watchstander duties and visibility or the watchstander's ability to move about as necessary on the bridge.

5.18.6 Bridge equipment.

5.18.6.1 Ship control. The ship control workstation (e.g., console and supporting equipment) is used to control steering and propulsion and includes the helm (combined steering and propulsion or steering only) and lee helm (propulsion only) positions. The workstation for ship control shall include the following elements:

a. Internal (including bridge wing) and other requisite communications equipment.

b. Steering control, both manual and (if present) automated.

c. Propulsion controls and basic monitoring instrumentation.

d. Speed, heading, position, and rudder indicators.

e. Indication of which position(s) have control of steering and propulsion functions.

5.18.6.1.1 Additional equipment. Additional equipment should be provided as required for special aspects of particular ships, such as cargo and weapons monitoring and safety and security monitoring.

5.18.6.1.2 Control ship. In all cases, the equipment furnished shall be sufficient to allow the watchstanders to control the ship safely and without distractions.

5.18.6.1.3 Indication of operational control. If control of steering and propulsion can be transferred among different operating positions, the active control position shall have a clear and salient indication of its status as the controlling position.

5.18.6.2 Navigation and maneuvering. The navigation and maneuvering workstation (e.g., console and supporting equipment) is used to observe or monitor and control or direct ship operations and includes the conning position. The workstation for navigation and maneuvering shall include the following elements:

a. External and internal communications equipment.

b. Electronic navigation and charting.

c. Provision for use of manual navigation methods.

d. Speed, heading, position, and rudder indicators.

e. Line of sight to chronometer or clock.

f. Controls and monitors for installed aids to navigation (e.g., radar, ship location and identification display, echosounders, weather instrumentation).

5.18.6.2.1 Monitor and direct ship. In all cases, the equipment furnished shall be sufficient to allow watchstanders to monitor and direct the ship safely and without distractions.

5.18.6.2.2 External displays. Critical navigational information (e.g., ship speed, heading, and position; surface radar or track picture) shall be provided external to the bridge at locations specified (see 6.2) as required for supervisory and command-level personnel to monitor operations.

5.18.6.3 Monitoring. The monitoring workstation (e.g., console and supporting equipment) is used to observe ship and bridge operations and provide control and advisory functions as required. The monitoring role may be provided by an Officer of the Deck (OOD), Officer of the Navigation Watch (OOW), Master, or Pilot. The monitoring workstations shall include the following elements:

a. External and internal communications equipment.

b. Speed, heading, position, and rudder indicators.

c. Line of sight to chronometer or clock.

d. Controls and monitors for installed aids to navigation (e.g., radar, ship location and identification display, echosounders, weather instrumentation).

5.18.6.4 Supervisory and command positions. Supervisory and command positions may be required for oversight of the ship monitoring position and all ship and bridge operations. Supervisory and command positions may include the roles of Commanding Officer and Executive Officer.

5.18.6.4.1 Supervisory and command required equipment. Position(s) provided for ship supervision and command shall include the following elements:

a. External and internal communications equipment.

b. Line of sight to speed, heading, position, depth, and rudder indicators.

c. Line of sight to chronometer or clock.

5.18.6.4.2 Supervisory and command recommended equipment. Position(s) provided for ship supervision and command should include the following elements:

a. Traffic, speed, heading, and position indication.

b. Electronic navigation and charting.

c. Basic propulsion monitoring instrumentation.

5.18.6.5 Communications.

5.18.6.5.1 Bridge communications systems.

5.18.6.5.1.1 Accessibility. Communications systems shall be accessible at anticipated operator positions. Additional equipment may be necessary in place of extended cords or connectors.

5.18.6.5.1.2 Interference. Placement of communications systems and anticipated locations of headset cords shall not interfere with workstation access or passage of personnel within the bridge.

5.18.6.5.1.3 Two-way communications. All order and action communication systems shall be two-way.

5.18.6.5.2 Internal bridge communications.

5.18.6.5.2.1 Internal communication system. An internal communication system between workstations on the bridge shall be provided when the distance between the workstations is greater than 10 m (33 ft) and preferably for distances greater than 4.6 m (15 ft).

5.18.6.5.2.2 Communication with bridge wings. An internal communication system shall be provided between the workstation for navigating and maneuvering and the open bridge wings.

5.18.6.6 Environmental exposure. Bridge equipment shall be designed and installed to preclude external temperature (heat and cold), moisture (rain, humidity, and wet operators), or foreign debris (dirt and grease) from impairing operator use of displays and controls.

5.18.7 Bridge configuration.

5.18.7.1 Overall arrangement. Overall arrangement shall meet the following requirements for placement of individual workstations as described on figure 96 with accommodations as required for ships with bridge locations off ship centerline.

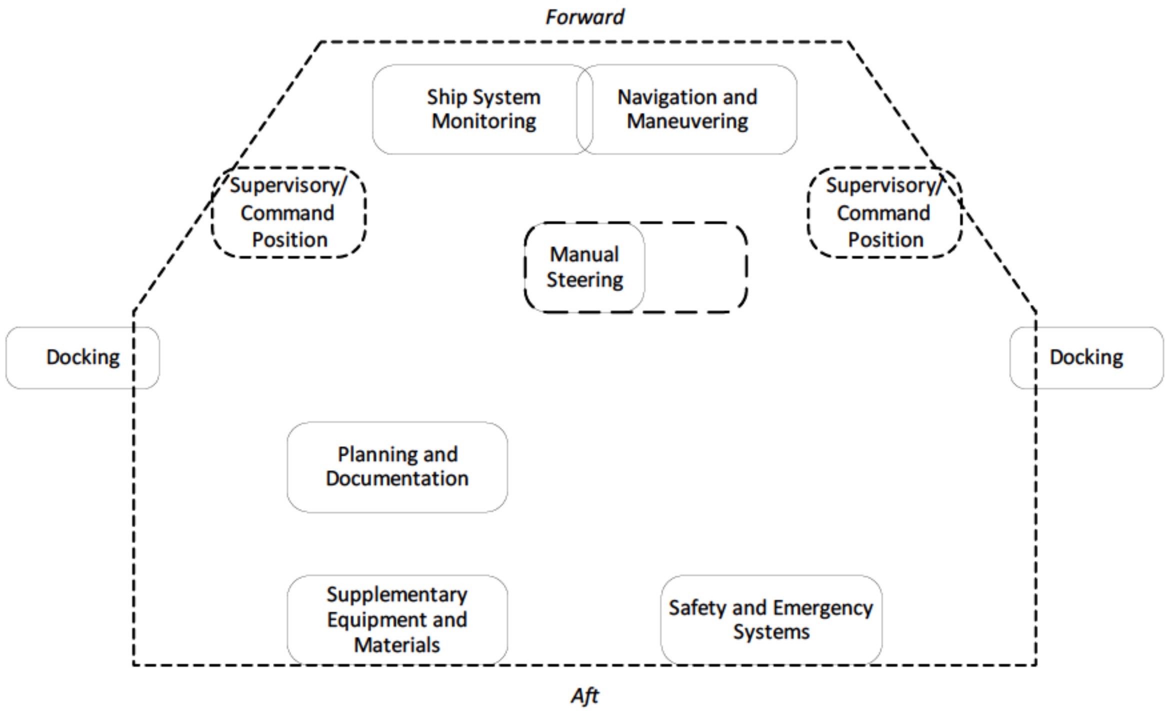


FIGURE 96. Typical bridge arrangement.

5.18.7.1.1 Workspace design. Bridge workspace design shall be in accordance with 5.10.2.

5.18.7.1.2 Workstation design. Bridge workstation design shall be in accordance with 5.10.3.

5.18.7.1.3 Navigation and maneuvering workstation. The navigation and maneuvering (or conning) workstation should be laid out on the starboard side close to the centerline.

5.18.7.1.3.1 Dedicated navigation displays. If the navigation and maneuvering workstation is co-located with other workstations, it may use the same input devices but shall use dedicated displays.

5.18.7.1.3.2 Interference with navigation tasks. If other workstations are co-located with the navigation and maneuvering workstation, then operations conducted at these workstations shall not interfere with a watchstander's ability to navigate the vessel safely and without distractions.

5.18.7.1.4 Manual steering workstation. The manual steering workstation (or helm) should be located on the ship's centerline.

5.18.7.1.4.1 Obstructed view. If the view ahead of the manual steering workstation is obstructed by large objects (e.g., masts, cranes), the manual steering workstation should be located starboard of the centerline, sufficient to obtain a clear view ahead.

5.18.7.1.4.2 Steering references. If the manual steering workstation is located off the centerline, special steering references for day and night use should be provided (e.g., sighting marks forward).

5.18.7.1.5 Monitoring workstation. The workstation for monitoring of ship systems should be located on the port side of the bridge close to the centerline.

5.18.7.1.6 Consolidated workstations. Workstations intended to support multiple roles (e.g., navigation and maneuvering, manual steering, and monitoring) shall meet the equipment, arrangement, and visibility criteria of all included roles.

5.18.7.1.7 Safety and emergency systems. Safety and emergency systems and equipment should be co-located to facilitate their concurrent use in emergency situations.

5.18.7.1.8 Safety observers. Workstation displays, clearances, and communications equipment should be designed to accommodate additional safety observers as required during ship operations.

5.18.7.1.9 Planning and documentation. Any workstations used for planning and documentation (e.g., chart table, logbook station) should be placed aft of the primary operating positions and away from the navigation and maneuvering position.

5.18.7.1.10 Supplementary equipment and materials. Supplementary equipment and materials required by bridge watchstanders should be placed in the aft portion of the bridge.

5.18.7.1.11 Additional workstations. Additional workstations or workspace should be provided for voyage management and route planning, training, and administrative functions inherent to bridge operations.

5.18.7.1.12 Workstation interference. Additional workstations shall minimize interference with primary bridge functions and avoid conflicts with movement of personnel.

5.18.7.1.13 Voice recording. Bridge arrangement and equipment selection shall support non-repudiable synchronized recording of verbal communications from all bridge positions to include open air and all internal and external voice communications in accordance with MSC.333(90).

5.18.7.2 Visibility.

5.18.7.2.1 Internal visibility.

5.18.7.2.1.1 Displays. Internal visibility from operator positions to required displays shall not be obstructed by other installed equipment.

5.18.7.2.1.2 Operator positions. Internal visibility between operator positions should be provided at all times.

5.18.7.2.2 External visibility. Bridge design and space arrangement shall meet the following requirements for external visibility with accommodations, as required, for ships with bridge locations off ship centerline.

5.18.7.2.2.1 Forward bridge windows. The forward bridge windows shall meet the following requirements for height and visibility and as described on figure 97.

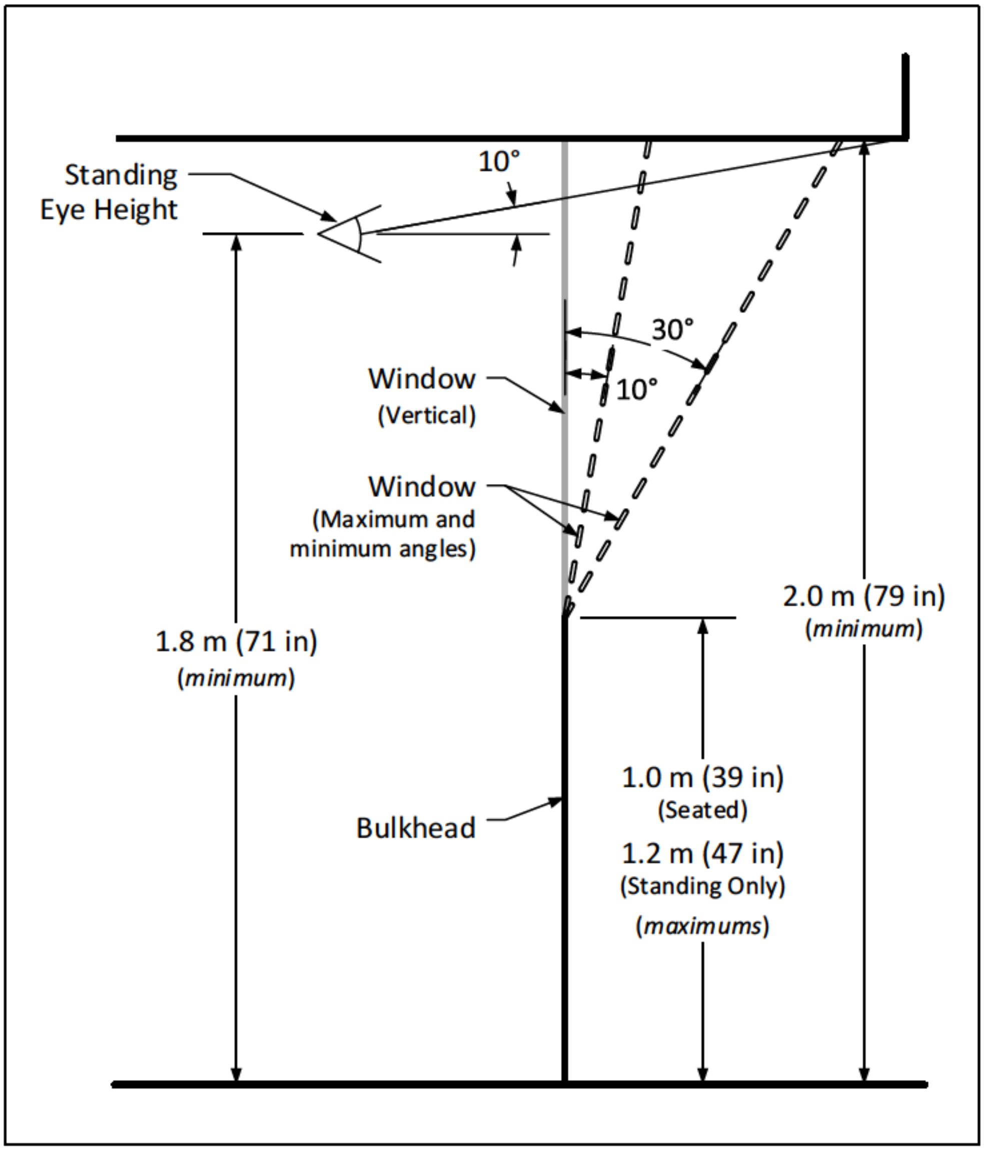


FIGURE 97. Forward bridge window heights.

5.18.7.2.2.1.1 Lower edge of forward windows. The height of the lower edge of the forward bridge windows should be no more than 1 m (39 in) above the deck to support seated operations or no more than 1.2 m (47 in) above the deck to support standing-only operations.

5.18.7.2.2.1.2 Bow visibility. Equipment installed by the forward bridge windows and the height of the lower edge of the forward bridge windows should allow an operator at the navigation and maneuvering workstation(s) and the monitoring workstation to have a clear view over the bow.

5.18.7.2.2.1.3 Upper edge of forward windows. The height of the upper edge of the forward bridge windows shall be not less than 2 m (79 in) above the deck.

5.18.7.2.2.1.4 Horizon visibility. Equipment installed in the overhead and the height of the upper edge of the forward bridge windows shall allow an operator with a standing eye height of up to 1.8 m (71 in) at the navigation and maneuvering workstation to have a clear view of the horizon when the bow is 10 degrees down from the even keel position.

5.18.7.2.2.2 View of sea surface. The view of the sea surface from the navigation and maneuvering workstation(s) shall not be obscured by the lower edge of the forward windows or installed equipment by more than two ship lengths or 500 m (1,640 ft), whichever is less, forward of the bow to 10 degrees on either side of the ship centerline under all conditions of draft, trim, weapon status, and deck cargo.

5.18.7.2.2.3 Horizontal field of regard – navigation and maneuvering workstation. The horizontal field of regard from the navigation and maneuvering workstation(s) shall be not less than 112.5 degrees from right ahead to each side of the ship.

5.18.7.2.2.4 Horizontal field of regard – monitoring workstation. The horizontal field of regard from the ship system monitoring workstation should extend from at least 90 degrees on one side of the ship to at least 112.5 degrees from right ahead on the other side of the ship.

5.18.7.2.2.5 Horizontal field of regard – manual steering workstation. The horizontal field of regard from the manual steering workstation shall be not less than 60 degrees on each side of the ship.

5.18.7.2.2.6 Horizontal field of regard – bridge wings. The horizontal field of regard from the bridge wing shall extend from at least 45 degrees on the opposite side of the bow from the wing through forward to 180 degrees aft.

5.18.7.2.2.7 View of total ship. While moving about the bridge, it shall be possible to visually encompass 360 degrees around the ship. This field of regard may be supplemented through the use of remote cameras or other visual and virtual displays to display the obscured quadrant(s) that are to be visible from the ship's navigation and maneuvering position.

5.18.7.2.2.8 View of ship's sides. The ship's side down to the waterline shall be visible from the bridge wing without obstruction.

5.18.7.2.2.9 Bridge wings. Bridge wings shall be provided out to the maximum beam of the ship.

5.18.7.2.2.10 Window transparency. Selection of materials, coatings, and treatments for bridge windows shall not degrade through extended exposure to environmental conditions.

5.18.7.2.2.11 Blind sectors. Blind sectors imposed by window framing, anti-rain/icing equipment, bridge equipment, or items external to the bridge (e.g., booms, masts, weapon systems) shall not exceed 5 degrees total within any 20-degree sector.

5.18.7.2.2.12 Equipment supporting external visibility. Systems for wiping and cleaning, de-icing, and de-misting the bridge windows should be provided to ensure a clear view through all front windows supporting the field of regard requirements for the monitoring and the navigation and maneuvering workstations in all operating conditions.

5.18.7.2.2.13 Sunscreens. Readily removable sunscreens with minimum color distortion should be provided at all windows in front of workstations.

5.18.7.3 Traffic.

5.18.7.3.1 Passageways. Internal routes within the bridge shall provide clearance of at least 760 mm (30 in).

5.18.7.3.2 Passageway at forward bulkhead. The athwartships passageway used for access across the forward bridge windows shall provide clearance of at least 915 mm (36 in).

5.18.7.3.3 Bridge entrance clearances. Doors and hatches providing entrance to the bridge and bridge wings shall not interfere with standard or common personnel locations.

5.18.7.3.4 Bridge wing entrance locations. Port and starboard bridge wing entrances should be directly across from each other to facilitate provision of a clear visual line of sight across the bridge.

5.18.7.3.5 Bridge wing entrance obstructions. Bridge wing entrances shall not be obstructed by equipment or expected operator positions.

5.18.7.3.6 Passageway between bridge wings. The passageway between bridge wings shall provide at least a 1.2-m (4-ft) clearance.

5.18.7.3.7 Movement between bridge wings. The passageway between bridge wings shall allow passage of two persons in opposite directions.

5.18.8 Alerting and alarm systems.

5.18.8.1 Presentation. The presentation of both audible and visual alarms shall be clear, distinctive, unambiguous, and consistent.

5.18.8.2 System requirements. Visual and audible alarms shall be in accordance with 5.7.3.and 5.3.2, respectively; speech and audio systems shall be in accordance with 5.3.1.

5.18.8.3 Discriminability. Audible and visual alarms associated with different bridge systems or functions should be readily discriminable.

5.18.8.4 Priority. Audible and visual alarms associated with different bridge systems or functions should be compatible with their relative order of urgency or priority.

5.18.8.5 Criticality. Displays of system failure results to operators shall facilitate the distinction between either critical or non-critical failures.

5.18.8.6 Operator notification of automated system mode changes. Operators shall be notified of changes in automated system status (e.g., modes or states) and be provided with clear indications of current automated system status in accordance with 5.12.

5.18.8.7 Auditory and visual alerts for changes in automated system status. Critical system mode changes should be indicated by an auditory and visual alert.

5.18.9 Virtual, remote, and automated bridges.

5.18.9.1 General requirements.

5.18.9.1.1 Virtual environments. Bridges employing the use of virtual environments, remotely handled systems, automated systems, telepresence, or teleoperations shall be in accordance with 5.12.

5.18.9.1.2 Alternative implementations. Bridges that are remotely operated or that do not provide direct sight and hearing (whether within or external to the bridge) shall provide comparable support for instrumentation and for external sight and hearing (or visual and audible) requirements as manned bridges.

5.18.9.1.3 Security. Cybersecurity and physical security provisions shall prohibit unauthorized local or remote takeover of ship control functions.

5.18.9.2 Optionally manned bridges.

5.18.9.2.1 Allow manned operations. Bridges that are normally operated unmanned or have the capability to be operated unmanned should include provisions allowing manned operation.

5.18.9.2.2 Human override. Bridges that are normally operated unmanned or have the capability to be operated unmanned shall provide for immediate human override of automated or autonomous operations.

5.18.9.3 Remotely operated bridges. In systems where the operating tasks are performed via remote control by a human operator, whether onboard the ship or elsewhere, comparable support for all requirements of manned bridges shall be provided.

5.18.9.3.1 Latency. System latency time shall be such that the remote operator's actions are executed in the same time frames as that of a manned bridge.

5.18.9.3.2 Local indication of operation control. If control can be transferred between different operating positions, each position shall have a local indication when it has operational control.

5.18.9.3.3 Operational control identification at primary position. The primary operating position shall have an indication as to which position has operational control.

5.18.9.3.4 Operational control identification at secondary positions. All positions shall have an indication as to which position has operational control.

5.18.9.4 Automated bridges.

5.18.9.4.1 Onboard decision support systems. On bridges where onboard advanced decision support systems undertake operational decisions to assist a local or remote human operator, provisions shall be made to allow complete override of the automated features by the operator.

5.18.9.4.2 Fail-safe provisions. The automated bridge shall include fail-safe provisions for safe return to port or position hold if system or communication failures affect safe navigation and maneuvering.

5.18.9.5 Autonomous bridges.

5.18.9.5.1 Onboard decision support systems. On bridges where onboard advanced decision support systems undertake operational decisions without intervention of a human operator, the requirements of automated bridges shall be met.

5.18.9.5.2 Additional considerations. The autonomous system shall address considerations for ship's navigation and maneuvering in accordance with the USCG Navigation Rules and Regulations Handbook, 72 COLREGS, and 33 CFR 83.

5.18.10 Slip and fall avoidance.

5.18.10.1 Non-skid surfaces. Wheelhouse, bridge wings, and upper bridge decks shall have non-skid surfaces effective in both wet and dry conditions.

5.18.10.2 Hand holds or railings. Hand holds or railings shall be provided at common operator locations and transit routes to enable personnel to move or stand safely during inclement weather.

5.18.10.3 Fall protection. Areas where personnel are working at heights (light replacement, bridge window wiper maintenance, camera maintenance) shall be fitted with anchor points and personal fall protection systems, such as personal fall arrest, travel restraint, or positioning systems so that they may be secured at all times while performing maintenance.

5.18.10.4 Other surfaces. The surface of chart tables, workstations, and other equipment where objects may be placed shall be provided with non-slip surfaces or other means to protect objects set upon them from sliding off.

5.18.11 Vibration.

5.18.11.1 Vibration and shock levels. All vibration and shock requirements shall be in accordance with 5.5.5.

5.18.11.2 Health risk. Vibrations on the bridge shall be reduced to such extent that the bridge personnel are neither hindered in their functions nor put at a health risk.

5.18.11.3 Vibration and habitability. Unless otherwise specified (see 6.2), levels of vibration on the bridge shall be in accordance with ISO 20283-5.

5.19 Handheld and wearable PEDs. This section addresses PEDs that are carried and operated with one or two hands or worn by the user. This includes, but is not limited to, devices such as mobile telephones, tablets, and body-worn sensors. This section does not represent the sum total of all human engineering requirements related to handheld and wearable PEDs. There are other sections within this standard (e.g., specific requirements for controls, warnings, audio systems, maintenance) that also contain relevant requirements. The reader is cautioned to examine all sections of the standard for requirements relevant to the specific design effort at hand.

5.19.1 General.

5.19.1.1 Mission-related functions. PED design shall permit performance of mission-related operations, communications, maintenance, and resupply under all intended operational conditions.

5.19.1.2 Operational considerations. PEDs shall be designed, selected, or adapted to withstand the operational conditions within which they are intended to operate in accordance with procuring activity requirements (see 6.2).

5.19.1.3 Compatibility with clothing and protective equipment. PEDs shall be compatible with CBRNE defense and other equipment that will be worn by users in the intended environments of operation.

5.19.1.3.1 Operable with bare hands and gloves. PEDs shall be operable by users with bare hands and users wearing gloves.

5.19.1.3.2 Limitations of weather-related and PPE gear. Use and selection of PEDs for extreme cold environments or for CBRNE-contaminated environments shall address user limitations related to gear, such as arctic mittens or PPE like mission-oriented protective posture (MOPP) gloves.

5.19.1.4 Anthropometrics. The design and selection of PEDs will be dependent on relevant user anthropometrics (e.g., wrist, finger, hand). PEDs shall be designed to be operated, stowed, fastened, or worn by the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped males of the target user population and the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped females of the target user population (see 5.8.4).

5.19.1.5 Device attachment. PEDs shall have a means for attaching to the user while also ensuring that the equipment and attachment mechanism do not interfere with the accomplishment of other tasks.

5.19.1.6 PED casings or pouches. PED casing or pouches should have the capability to be integrated with a body-mounted load bearing or carrying system.

5.19.1.7 Physical design for operation.

5.19.1.7.1 Operable by either hand. PEDs should be operable with either hand.

5.19.1.7.2 Ease of gripping. PEDs shall be easy to grip, have room for finger grips if needed, and be operated or positioned to reduce flexion and extension of the hand and wrist when aligned with the forearm.

5.19.1.8 PED distinctive features. Users should be able to distinguish a PED and its controls from other devices during night operations by means other than vision, such as placement on the body or through tactile features.

5.19.1.9 Security.

5.19.1.9.1 Inadvertent activation. PED accidental activation shall be avoided by defining unique user action sequences required for activation.

5.19.1.9.2 Cybersecurity. During use, PEDs should have security measures in place to avoid tampering and adhere to the appropriate DoD cybersecurity requirements and 5.16.

5.19.1.9.3 Data erasure.

5.19.1.9.3.1 Zeroize capability. Users shall have the capability to zeroize (e.g., permanently delete or erase data, including but not limited to, electronically stored data, cryptographic keys, and critical security parameters) both locally and remotely in accordance with applicable organizational information assurance requirements.

5.19.1.9.3.2 Procedures for zeroizing. Procedures for zeroizing PEDs shall be executed by a unique but easily executed user action sequence to prevent accidental activation. For example, the user could press the "off" and "number 1" keys simultaneously and have the PED display ask for a confirmation from the user.

5.19.1.10 Speech interaction. PEDs incorporating speech interaction shall meet the requirements in 5.3.10 and 5.3.13.

5.19.1.11 Audible alerts and signals.

5.19.1.11.1 Audibility. PED audible alerts and signals should be audible in high ambient noise environments as required by the intended operational environment and consistent with 5.3.2 and 5.3.12.

5.19.1.11.2 Disabling audible alerts. Users shall have the ability to disable or silence audible alerts and signals with respect to proximity to hostile environments.

5.19.1.11.3 Audible alert status. The PED should provide an indication of alert status, such as an icon indicating silent mode.

5.19.2 Suitability.

5.19.2.1 Support to user mobility. The PED design shall support the user's mobility and expected range of motion in that its size, weight, placement, and attachment to the body are appropriate for the environment and workflow. Implementation of this requirement shall include not interfering with the following elements:

a. The length of step.
b. Movements of the head.
c. The ability to perform individual movement techniques or negotiate obstacles.
d. The ability to see where the feet are placed when walking.
e. The ability to stand, kneel, assume a prone position, and squat.
f. Regulation of body temperature.
g. The maintenance of normal posture.

5.19.2.2 Avoiding discomfort and pain. The PED design and operation shall not cause discomfort or pain, including avoiding pressure and pinch points.

5.19.2.2.1 PED ergonomics. PEDs shall be designed or selected to incorporate ergonomic characteristics that promote comfortable handling, carrying, and operation.

5.19.2.2.2 PED mounting methods. PED mounting methods shall:

a. Permit adjustment for comfortable carriage by the user and provide for secure mounting.
b. Avoid excessive PED movement, such as bouncing or twisting during user conduct of individual movement techniques, such as walking, running, crawling, climbing, ingress, or egress.

5.19.2.3 PED mounting compatibility with user environment. PED mounting methods shall be compatible with the intended user environment, such as use in a vehicle or aircraft.

5.19.2.4 Power supply. Power supplies should meet the requirements contained in MIL-PRF-32383 or equivalent.

5.19.2.4.1 Power supply capacity versus size restrictions. PED developers shall consider and balance the need for long power supply life and capacity with the size restrictions imposed on equipment used in the field as dictated by operational requirements.

5.19.2.4.2 Power supply life. PEDs shall have sufficient power supply life (i.e., time and capacity) for task completion based on mission profiles and operational requirements.

5.19.2.4.3 Power supply status indication. PEDs shall provide an indication of remaining power supply life for rechargeable power supplies (e.g., percentage of battery life or time remaining).

5.19.2.4.4 Power supply replacement. PED power supplies should be capable of being replaced without the use of tools (see 5.9.19).

5.19.2.4.5 Power supply recharging. Where rechargeable power supplies are used by the PED, the power supply shall be capable of being recharged by an external source.

5.19.2.4.6 Usable while being recharged. The PED shall be usable while being recharged.

5.19.2.4.7 External power source attachment. PEDs shall not require attachment to an external power source to operate.

5.19.2.5 Connectivity.

5.19.2.5.1 Connecting to other systems. PEDs should have an easy means of connecting or tethering to other systems through defined interfaces for voice communication or transferring data.

5.19.2.5.2 Indication of connection status. PEDs should provide an indication of the status of connection in terms of strength or reliability in both wireless and wired modes.

5.19.2.6 Covers. If PEDs have covers to protect the display, ports, or other fragile parts, the covers should be permanently attached.

5.19.2.7 Durability. PEDs shall withstand the drops and knocks associated with normal use in all intended use environments (e.g., heat and cold extremes, vibration, shock) in accordance with operational requirements.

5.19.2.8 Cable quick disconnect capability. Where appropriate, PEDs should provide the capability for the quick disconnect (e.g., not threaded) of cables and connectors.

5.19.2.8.1 On-axis connection orientation. To achieve a quick-disconnect capability for deliberate manual attempts at disconnecting cables, the cables shall be oriented along the same axis (i.e., on-axis) as the connector to achieve the disconnection at the desired pull force.

5.19.2.8.2 Quick disconnect cable damage prevention. When a quick disconnect capability is not required, cables should not break or be damaged by a pull force up to 445 newtons (100 pounds-force) when the cable is not oriented along the same axis as the connector.

5.19.2.8.3 Cable quick disconnect separation force. For user-mounted PEDs requiring quick release of cables used for power or data transfer, the cables shall incorporate a common quick disconnect connector with a separation force between 40 and 67 newtons (9 to 15 lb).

5.19.2.9 Quick-release capability. When PEDs are equipped with body mounting mechanisms, a capability for quick release from the body mounting mechanism shall be provided.

5.19.2.9.1 Impact on body mounting systems. PED quick release capability should not impede the operation of or make it more difficult to doff or access a user's body mounting system or load-bearing vest.

5.19.2.9.2 Impact on vehicle systems. PED quick release capability shall not:

a. Impede the operation of vehicle systems.

b. Make it more difficult to ingress or egress all vehicle platforms.

c. Introduce snag hazards, especially regarding vehicle hatches or doors or air ejection seat mechanisms.

5.19.2.10 Shape.

5.19.2.10.1 Rounded corners and edges. PEDs shall have rounded corners and edges in accordance with 5.7.6.4 and 5.7.9.3.

5.19.2.10.2 Projections. The shape of a PED shall be free of projections that may be harmful to the user (e.g., pinch points), impede ejection or escape, or create snag hazards.

5.19.2.10.3 Non-slip design. A PED should have a surface and shape that prevents it from slipping out of the user's hand.

5.19.2.11 Temperature.

5.19.2.11.1 Operating temperature.

5.19.2.11.1.1 Contact with the user's body. PEDs that come into contact with the user's body shall maintain an ideal operating temperature at or below the core body temperature of 37 °C (98.6 °F) and be consistent with 5.7.5.9.

5.19.2.11.1.2 Solar loading. Solar loading characteristics consistent with 5.5.2.2.3 should not raise skin temperatures beyond acceptable limits.

5.19.2.11.1.3 Heat shield. Where it is not possible to prevent a rise in skin temperatures, a heat shield, such as additional cloth or material, shall be used to protect the user.

5.19.2.11.2 Heat trapping. PEDs that come into contact with the user's body should not trap heat against the body.

5.19.3 Controls. In addition to the requirements below, design of controls for PEDs shall comply with the relevant criteria of 5.1.

5.19.3.1 Accessibility. The location of controls on PEDs shall be readily accessible for use when the device is attached to the user while wearing operationally relevant clothing and equipment.

5.19.3.2 Inadvertent activation and damage protection. Devices either worn on the body or stowed in a pocket, backpack, or pouch, shall withstand typical movements of the user, such as running, crawling, and climbing, without damage or accidental activation.

5.19.3.3 Data input. PED data input should be via virtual or physical keyboard or keypad. Unless specifically required for the intended purpose, handwriting recognition as data input should be avoided.

5.19.3.4 Direct input pointers. Direct input pointers (e.g., touch-screen, light pens) shall be used in preference to indirect input pointers (e.g., trackball, mouse).

5.19.3.5 Stylus. If a stylus is provided to assist PED data input, it should be permanently attached and the PED shall have a means to securely store the stylus on the device.

5.19.3.6 Control actuating force. The actuating force required for PED keypads should fall between 0.3 and 3.9 newtons (0.9 and 14 ounces), except for touch-activated keypads, which should meet the requirements in 5.1.3.1. The larger actuating forces should be used where the user wears gloves or the device and user experiences substantial vibration or acceleration.

5.19.3.7 Control labeling. PED controls should be a labeled in accordance with 5.4.

5.19.3.8 Keypads.

5.19.3.8.1 Keypad spacing. Minimum PED keypad key spacing from the centers of adjacent keys should be 10 mm (0.4 in) with the preferred spacing of 14 mm (0.6 in). The maximum spacing should be 19 mm (0.7 in).

5.19.3.8.2 Telephone layout. PED keypads used for communication should use a telephone rather than calculator layout.

5.19.4 PED displays. In addition to the requirements below, design of PED displays, defined as those screens with a diagonal smaller than 12.7 cm (5 in), shall comply with the relevant criteria of 5.2.

5.19.4.1 Operational lighting suitability. The PED display should accommodate all expected operational lighting conditions and shall be designed in accordance with 5.2.1.9.

5.19.4.1.1 Dark adaptation and NVDs. When dark adaptation and NVD compatibility are operational requirements, displays shall comply with 5.5.3.6 and 5.13.2.10.6.

5.19.4.1.2 Daylight readability. For daylight readability, the display shall be in accordance with 5.2.1.5.

5.19.4.2 Brightness adjustment. PED visual display brightness shall be adjustable by the user to permit readability in both bright and dark tactical environments while allowing the user to limit detectability as required by operational conditions.

5.19.4.2.1 Adjustment range. PED visual displays brightness shall be full range continuously adjustable by the user.

5.19.4.2.2 Fully dimmed setting. For the fully dimmed setting, the display shall still be readable in natural lighting when the backlight is off.

5.19.4.2.3 Backlight duration. When the backlight is turned on, PEDs shall have a user-configurable backlight duration setting so that the backlight times out after no user interaction within the set period of time. When the user interacts with the device, the backlight shall turn on and the backlight time duration shall reset.

5.19.4.3 Glare. PED displays should include design features to limit glare, such as glare filters or anti-glare coating.

5.19.4.4 Tactile displays.

5.19.4.4.1 Vibration frequency. PED tactor vibration frequencies should be between 150 and 300 hertz for optimal sensitivity and shall not exceed the range of 20 to 500 hertz.

5.19.4.4.2 Vibration interval. PED tactor vibration intervals should be selectable by the user.

5.19.4.4.3 Vibration duration. The duration of PED vibrotactile alerts should be between 50 and 200 milliseconds.

5.19.4.4.4 Amplitude. PED vibration amplitude settings shall not be so high as to produce pain or discomfort for users.

5.19.4.4.5 Perception. The number of PED tactile indicators used shall be kept to a minimum in order limit the number of indicators that can be reliably discriminated by the user without increasing training time or cognitive processing.

5.19.4.5 Alerts and notifications. PEDs shall have the capability to set alert type (e.g., audible, visual, tactile).

5.19.5 Application design.

5.19.5.1 General. In addition to the requirements below, PED applications shall be designed in accordance with the applicable criteria contained in 5.1, 5.2, and 5.17.

5.19.5.1.1 PED adaptation of existing design. When a PED application is based on an existing design, it shall adapt but not replicate the existing design and be tailored for the size of the PED display screen.

5.19.5.1.2 Design around PED capabilities and constraints. PED applications should be designed around the PED capabilities and constraints.

a. Where users will work with the same application across multiple devices, consistency of appearance and interaction should be provided. Elements of PED interface such as labels, color schemes, and dialog appearances should be the same across multiple devices.

b. Applications should focus on the tasks performed by the PED users by following logical sequences and dialogs (see 5.19.5.4).

5.19.5.1.3 Dynamically changing operational contexts. PED application design shall support operations across dynamically changing operational contexts (e.g., brightness, noise, weather). For example, the design should allow users to do the following:

a. Configure output to their needs and preferences (e.g., text size, brightness).

b. Change key attributes like display brightness with minimal steps.

c. Provide options for the user to access functions or key attributes.

5.19.5.1.4 Limited and divided attention. PED design should accommodate limited and divided attention through the use of audible, visual, or tactile displays. PED use should not distract users from other tasks when the user has the following levels of attention:

a. Limited attention available when doing a task not on the PED.

b. Divided attention when doing PED and non-PED tasks.

c. Limited attention when doing a task on the PED and information for another task is received.

5.19.5.1.5 Application optimization. PED applications should be optimized for performance (e.g., time to load, time to play multimedia file, time to save, time to connect to data) as well as minimize power drain on the PED.

5.19.5.1.6 Application design consistency.

5.19.5.1.6.1 Use of industry guidelines. Industry guidelines for use and development of PED functionalities (e.g., camera, gyroscope) and platforms (e.g., iOS, Android, Windows) should be used rather than creating interactions and behaviors that differ from the default expected behavior.

5.19.5.1.6.2 User expectations. PED application design should enable users to apply existing knowledge and to quickly build a mental model of the application's functional concept through familiar objects and consistency of design, reducing surplus mental load and additional concentration effort.

5.19.5.1.6.3 Multiple applications. PED applications should be designed to behave consistently to other applications on the PED with which users are familiar.

5.19.5.1.6.4 Designing for multiple PEDs. If designing for multiple PEDs, established design conventions for each PED should be followed and the appearance and functionality should be consistent across PEDs.

5.19.5.1.7 Facilitation of intended action. PED application functions shall support time-critical intended user actions.

5.19.5.1.8 Textual information. Where appropriate, the amount of textual information presented should be minimized to limit the amount of reading required by the user and be consistent with 5.17.18.

5.19.5.2 Error control. PED applications shall meet the requirements for error control contained in 5.1.2.1.7.

5.19.5.3 Feedback. PED application feedback to the user shall meet the requirements for feedback contained in 5.1.2.1.6.

5.19.5.4 Interaction.

5.19.5.4.1 Critical information. When designing PED displays, critical information should be reachable in no more than two key actions (e.g., scrolling and tapping).

5.19.5.4.2 Command shortcuts. Shortcuts, such as hot keys, voice activation, or keystroke combinations, should be provided for frequently used PED commands and interactions, such as repetitive tasks.

5.19.5.4.3 Application control. PED applications should be designed for speed and recovery. For example, applications should load quickly and be stopped, started, resumed, or changed with minimal effort.

5.19.5.4.4 Auto-rotation of screen. PED applications shall be designed to support user selectable auto-rotation of the screen to accommodate information presentation and efficient data entry.

5.19.5.4.5 Simplicity of application design. PED application design should be simple and uncluttered by using approaches such as:

a. Hierarchical nesting where the user can decide whether or not to retrieve details.

b. Word selection rather than text input.

c. Plain language rather than jargon, unless the application is intended for a specific user population.

5.19.5.4.6 Language. Language usage shall be consistent with 5.1.3.11.1.8.

5.19.5.4.7 Simplicity of text input. User input should be simple and based on operational context and need. The application should:

a. Minimize text input.

b. Provide clear and obvious indication of the type and format of input required for text fields.

c. Allow the user to choose by selecting an item instead of manually entering text.

d. Show prepopulated data in forms wherever possible.

5.19.5.4.8 PED application navigation.

a. Navigation structures should be simple and focus on one specific task at a time.

b. Navigation between fields in forms should be predictable.

5.19.5.4.9 Dialog closure. Dialogs, which are an interaction between the user and the PED that is finite, should yield closure by providing a clear beginning, middle, and end of the sequence of actions that make up the dialog.

5.19.5.5 Screen design.

5.19.5.5.1 Minimize clutter. The PED application should provide the user with essential data and functionality for immediate action. Unnecessary elements, clutter, or information on the screen for other actions should be minimized.

5.19.5.5.2 Selection highlighting. The item selected on a PED screen shall be clearly indicated to facilitate the user's ability to identify that it has, in fact, been selected. Color, background, text change, or other visual mechanisms shall be used.

5.19.5.5.3 Basic control availability. PED software or hardware controls used to provide basic navigation (e.g., "Back to home", "Back to search results", "Back", and other relevant commands) shall always be available to the user.

5.19.5.5.4 Content density. PED screen content density should be minimized. The following criteria should apply:

a. Content and interaction should not be split across so many screens that it leads to confusion and loss of awareness of where one is in the application.

b. Screens should be designed so that they can be scrolled only in one dimension.

c. PED display design should minimize the amount of text information presented in order to decrease the reading requirement, which is a difficult task in dismounted and moving conditions.

5.19.5.5.5 Text organization.

5.19.5.5.5.1 Ability to skim text. To increase ability to skim text, subtitles and hypertext shall be used in text passages that are longer than a single screen.

5.19.5.5.5.2 Avoid variable line lengths. Variable line lengths shall be avoided by hyphenating words at line breaks to improve readability on small screens.

5.19.5.5.5.3 Scrolling markers. Scrolling markers shall be provided to enable users to identify where they are on the page when content cannot be displayed in one screen.

5.19.5.5.6 Screen readability. A range of high contrast text color and typefaces should be selectable to allow for the PED user to optimize readability as dictated by the intended operational environment.

5.19.5.5.7 Color usage. The following criteria shall apply:

a. Color shall be used carefully and consistently throughout the design of PEDs and be consistent with 5.17.25.

b. Dual coding, such as shape or labeling, shall be used with color.

5.19.6 Single-handed PEDs.

5.19.6.1 Size. Single-handed PEDs shall be less than 10.2 cm × 25.4 cm × 12.7 cm (4 in × 10 in × 5 in) and have an ergonomic shape for efficiency and comfort.

5.19.6.2 Weight. Single-handed PEDs shall weigh less than 1.4 kg (3 lb).

5.19.6.3 Precise manipulation. If manipulated with precision, single-handed PEDs shall weigh less than 400 grams (0.9 lb).

5.19.6.4 Control buttons.

5.19.6.4.1 Size. On single-handed PEDs, buttons should accommodate single finger usage.

5.19.6.4.2 Location. When holding a single-handed PED device that allows the use of a thumb, buttons should not be placed where they cannot to be activated by the thumb.

5.19.6.5 Open-grip single-handed PEDs. For open-grip single-handed PEDs (those gripped without the thumb wrapping around the PED), controls should be operable by the thumb holding the device and should not be located near the edge where they might be inadvertently activated by the user's grip.

5.19.7 Two-handed PEDs.

5.19.7.1 Size. The size of PEDs intended for two-hand use shall permit users to comfortably grasp the device with both hands and shall permit control manipulation without the need to remove a hand from the device.

5.19.7.2 Weight. PEDs intended for two-hand use should not exceed 4.5 kg (10 lb).

5.19.8 Wearable PEDs.

5.19.8.1 Weight. Weight of wearable PEDs should not impede body movement or balance.

5.19.8.2 Body conforming shape. The shape of wearable PEDs should conform to the body, including while the body is moving, to ensure a comfortable fit.

5.19.8.2.1 Interior and exterior shape. A concave interior and a convex exterior should be used for wearable PEDs to achieve a form factor tapering towards the edges and with curved corners.

5.19.8.2.2 Body wrapping. Wearable PEDs should wrap around body parts, which is typically more comfortable to the user compared to single-point fixing systems like clips or straps.

5.19.8.3 Unobtrusive design. Wearable PEDs should be able to be worn on the body without the need to use hands to hold in place.

5.19.8.4 Stability. Wearable PEDs should be resistant to vibrations induced by the operational environment and body movement.

5.19.8.5 Wearable PED user preference. Wearable PEDs designed for alternative body mounting shall be operable when worn at all potential user-preferred body locations and within users' capabilities.

5.20 Strength and handling.

5.20.1 General. These requirements apply to all DoD personnel unless user population-specific or other strength data are specified (see 6.2). When defining the intended user population, the combination of human anthropometry (i.e., data-driven univariate or multivariate) criteria with one or more data sets from MOS categories will achieve greater accommodation in use of the system. Despite gender differences in strength and injury rates, accommodation for strength and handling across the full range of the target audience personnel is required. When designing for military personnel, a holistic systems approach shall be used to include the human as an intact system in addition to being an integrated part of a larger system in which they will operate. Designing to these requirements may provide users with a potential to limit risk of musculoskeletal injury and avoid long-term reduction in quality of life.

5.20.1.1 Strength. Because of the low correlation between strength and size, size shall not be used to determine accommodation of strength and endurance; rather, strength shall be considered separately. Specifically, it is very unlikely that military members of minimum size also have minimum strength and endurance.

5.20.1.2 Operability. The strength and endurance performance characteristics of the weakest personnel performing the actual or equivalent task shall be accommodated to ensure operability. The maximum force that can be applied will depend on such factors as the type of control, the body member used to operate it, the position of this body member during control operations, the general position of the body, and whether or not external support is provided. Because human strength and endurance are specific to the task performed, accommodation of operability must be based on performance of the equivalent activity. Where accommodation is based on strength or endurance of a different activity, there must be a valid relation between the performance of the two activities.

5.20.2 Human strength and handling capacity.

5.20.2.1 Exerted forces. The maximum amount of force or resistance designed into a control shall be determined by the greatest amount of force that can be exerted by the weakest person likely to operate the control.

5.20.2.2 Break strength. Where critical items may be damaged by the exertion of large forces, the break strength should be not less than can be exerted by the strongest person.

5.20.2.3 Load carriage – body borne weight.

5.20.2.3.1 Pressure avoidance. Pressure shall be avoided or minimized on sensitive body areas, including large blood vessels, nerves, and areas lacking muscular padding.

5.20.2.3.2 Weight distribution. Individual portions of equipment shall be designed so that, when carried, the weight of the load will be distributed effectively through as many appropriate muscle groups as possible.

5.20.2.3.3 Weight and distribution compatibility. Design of load-carrying systems shall be compatible with the weight and distribution of individual items to be carried by the user. The limit on weight of the items to be carried varies according to the climatic zone, mission to be performed, and occupational specialty. The typical load for the mission, climate, and occupational specialty for the system being acquired will be as specified (see 6.2).

5.20.2.3.4 Quick-release capability. Load carrying systems shall be provided with a quick-release capability.

5.20.2.3.5 Portability. In general, "portable" refers to an item that is able to be carried a distance of not more than 2.1 kilometers (1.25 miles) by the number of personnel dictated by the weight of the item.

5.20.2.3.5.1 Component weight.

5.20.2.3.5.1.1 Individual item weight. Individual portions of equipment shall not exceed 16 kg (35 lb) with load balanced and distributed over many appropriate muscle groups.

5.20.2.3.5.1.2 Aggregate item weight. Aggregate weight of equipment items to be carried by a single individual shall not exceed 16 kg (35 lb) unless it is not necessary for the individual carrying the load to maintain the pace of an infantry movement (typically 6.5 kilometers per hour [4 miles per hour]).

5.20.2.3.5.2 Total weight. Total weight shall meet the criteria of 5.20.2.3.5.2.1 through 5.20.2.3.5.2.3.

5.20.2.3.5.2.1 Desired total weight. The total load carried by an individual, including clothing, weapons, and equipment, should not exceed 30 percent of the body weight of target audience personnel for close combat operations or 45 percent for marching.

5.20.2.3.5.2.2 Excessive total weight. When the total load carried by an individual must exceed 30 percent of the bodyweight of target audience personnel for close combat operations or 45 percent for marching, the load to be carried shall be identified by user trials with the target population, modeling and simulation, and existing data and literature, while focusing on performance characteristics of military personnel as a system conducting combat tasks.

5.20.2.3.5.2.3 Low body weight. Where personnel with 5^{th} percentile body weight or lower must be accommodated, the total load for close combat operations shall not exceed 18.5 kg (41 lb) and 27.7 kg (61 lb) for marching.

5.20.2.3.6 Lifting aids. When necessary, lifting aids, such as handles, shall be provided to permit a second person to assist the individual carrying the load in placing the load on their body.

5.20.2.3.6.1 Non-backpack units. Units for which no backpacking aids are required shall be equipped with handles designed for two-handed lifting and carrying.

5.20.2.3.6.2 Backpacks and backpacking aids. For loads over 20 kg (44 lb) to be carried in a backpack by a single individual, the backpack shall be designed to include handles or other assist devices to permit a second person to assist the individual carrying the load in placing the load on their body.

5.20.2.3.6.2.1 Distribute load. Backpacking aids shall distribute the load over as many muscle groups as possible by means of buttock and hip supports in addition to padded shoulder straps and a chest strap.

5.20.2.3.6.2.2 Center of gravity. Backpacking aids shall bring the center of gravity of the load as close to the individual's center of gravity (generally located at the spine at the waistline) as possible without any part of the load contacting the body.

5.20.2.3.6.3 Load-carrying design. Load-carrying design shall minimize pressure or compression to the chest or armpits.

5.20.2.3.6.3.1 Local strain. Load-carrying design shall eliminate local strain by transmitting weight to the ground through bone.

5.20.2.3.6.3.2 Minimize pressure on sensitive tissues. Load carriage systems should minimize pressure over sensitive tissues, such as the breasts or areas under which lie superficial nerves like the anterior and posterior shoulder over the brachial plexus.

5.20.2.3.6.3.3 Distribute pressure. Straps should be sufficiently wide and padded to distribute pressure over a wider surface area and reduce compression forces where they contact the body.

5.20.2.3.6.4 Interference with movement. Aids shall not produce unbalanced loads, interfere with normal head movements, limit squatting, interfere with walking or climbing over low obstacles, interfere with movements of the shoulder girdle, produce strain on the shoulder muscle, cause compression on blood vessels, cause static compression due to lengthy sitting, or interfere with regulation of body temperature beyond those effects already caused by the load.

5.20.2.3.7 Body armor.

5.20.2.3.7.1 Configuration. The load shall be designed to permit freedom of movement required to perform essential tasks.

5.20.2.3.7.2 Projections. The shape of the load shall be free of sharp edges or projections that may be harmful to the user or present a snag hazard. Covers or cases may be provided to meet this requirement.

5.20.2.3.7.3 Shape. The shape and weight of the load shall not interfere with the normal loaded gait pattern; movements of the head; the ability to raise and lower the load when going over obstacles; the ability to see where the feet are placed when walking; the ability to get into a squatting, kneeling, or prone position; regulation of body temperature; or the maintenance of a normal posture.

5.20.2.3.7.4 Carrying by two persons. Where the load is designed for carrying by two persons, a combination of stretcher-type handles and shoulder support shall be used, if feasible.

5.20.3 Lifting limits.

5.20.3.1 Scope. The lifting limits are determined based on the body posture used for lifting in relation to the load, frequency, and duration of lifting. Unless otherwise specified (see 6.2), the lifting limits are designed to accommodate the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped males of the target user population and the multivariate central 90 percent (95 percent preferred) of the suitably clothed and equipped females of the target user population to minimize risk of musculoskeletal injury (using dimensions applicable to the tasks). The lifting limits do not apply to lifting conditions involving lifting outside of a stationary location, holding for more than 3 seconds, lifting with one hand, lifting with hands and other body parts (shoulder or leg), lifting for more than 8 hours, lifting while seated or kneeling, lifting in restricted space, lifting on an unstable surface, lifting while operating equipment, lifting with high speed (faster than 75 centimeters per second [30 inches per second]), lifting on slippery floors (<0.4 coefficient of friction between the sole and the floor), and lifting in cold or hot environments (outside temperature 19 to 26 °C [66 to 79 °F]). The equation is generally not applicable for lifting with an unbalanced load or body posture; a biomechanical analysis for this condition is recommended. The lifting limits apply to lifting objects that weigh more than 2.3 kg (5 lb).

5.20.3.2 Maximum allowable weight. The maximum allowable weight limit for a single lifter is 23 kg (51 lb) for two-handed lifting in the ideal lifting condition (see 5.20.3.3).

5.20.3.2.1 Maximum allowable weight for team lifting. See table XLI.

5.20.3.2.1.1 Two-person lifting. Double the weight limits (determined in 5.20.3.3) shall be used as the maximum value in determining the design weight of items requiring two-person lifting, provided the load is uniformly distributed between the two lifters.

5.20.3.2.1.2 Three or more lifters. Where three or more persons are lifting simultaneously, not more than 75 percent of the one-person value should be added for each additional lifter, provided that the object lifted is large enough that the lifters do not interfere with one another while lifting and that a secure grip can be attained by each person.

TABLE XLI. Maximum design weight limits.

Number of Lifters	Maximum Design Weight Limit kg (lb)
1	23 (51)
2	46 (102)
3	63 (140)
4	81 (178)
5	98 (216)
6	115 (254)

5.20.3.2.2 Maximum permissible number of lifters.

5.20.3.2.2.1 Multi-person lifting teams. Multi-person lifting teams may be used when the weight of the object is evenly distributed and fair or better coupling between the object and hands is achievable. To encourage equal weight sharing among members, an even number of members should be assigned to lifting teams (i.e., 2, 4, or 6 lifters). Whenever possible, challenges coordinating lifting efforts between members should be avoided by assigning no more than four lifters to a team.

5.20.3.2.2.2 Maximum number of lifters. The maximum permissible number of lifters assignable to a lifting team shall be calculated by rounding to the nearest whole number the result of dividing the perimeter of the object in centimeters by 60 (inches by 24). For example, the maximum permissible number of lifters that could be assigned to lift an object with length of 62 cm (25 in) and width of 88 cm (35 in) would be expressed by the following equation:

$$(2 \times 62 + 2 \times 88) / 60\ [(2 \times 25 + 2 \times 35) / 24] = 5 \text{ lifters}$$

5.20.3.3 Determination of maximum weight limit. The maximum weight limit (WL) is determined by the following equation:

$$WL = LC \times HM \times VM \times DM \times AM \times FM \times CM$$

where: LC is the load constant that is equal to 23 kg (51 lb)

HM is the horizontal multiplier

VM is the vertical multiplier

DM is the distance multiplier

AM is the asymmetry multiplier

FM is the frequency multiplier

CM is the coupling multiplier

The above multipliers are determined by the formulas shown in table XLII. The term “task variable” refers to the measurable task descriptors (i.e., H, V, D, A, F, and C); whereas, the term “multipliers” refers to the reduction in the equation (i.e., HM, VM, DM, AM, FM, and CM). The load constant is the maximum allowable weight limit. In the ideal lifting condition, all the multipliers are set to 1.0. If the lifting condition is not ideal, some of the multipliers may be reduced to be less than 1.0, resulting in a reduction in the maximum allowable weight limit.

TABLE XLII. Formulas for multipliers.

Task Variable	**Abbreviation**	**Metric (cm)**	**US Customary (in)**
Horizontal Multiplier	HM	25/H	10/H
Vertical Multiplier	VM	$1 - (0.003 \lvert V-75 \rvert)$	$1 - (0.0075 \lvert V-30 \rvert)$
Distance Multiplier	DM	0.82 + (4.5/D)	0.82 + (1.8/D)
Asymmetry Multiplier	AM	1 - (0.0032A) [1/]	1 - (0.0032A) [1/]
Frequency Multiplier	FM	From table XLV	
Coupling Multiplier	CM	From table XLVI	

TABLE XLII. Formulas for multipliers – Continued.

FOOTNOTE:

1/ The unit of measure for A is degrees.

NOTES:

1. This table is sourced from the Applications Manual for the Revised NIOSH Lifting Equation.
2. The multipliers may not exceed 1.0. If the calculation yields a value of greater than 1.0, it is considered to be "ideal" and is set to 1.0. If the travel distance (D) is 10 cm, the equation yields 0.82+(4.5/10) = 1.27. Since this is greater than 1.0, the DM is set to 1.0, the max value.

5.20.3.4 Lifting task variables. Definitions of the task variables H, V, D, and A are shown in table XLIII. The task variables H, V, and A are graphically presented on figures 98 and 99. The task variables are measured at the origin and destination of the lift. The control of the lift at the destination will result in two weight limits; one for the origin and one for the destination of the lift, respectively. The lower weight limit of the two values should be used as design guideline for the entire course of the lift.

TABLE XLIII. Definitions of lifting task variables.

Task Variable	Definition
Horizontal Distance (H)	Distance between the point of projection of the center of gravity of the load and the point of projection of the center of gravity of the person
Vertical Distance (V)	Vertical distance from the center of gravity of the load to the floor
Travel Distance (D)	Vertical travel distance between the origin and destination of the lift
Asymmetry Angle (A)	Angular displacement of the load from the sagittal and asymmetry lines

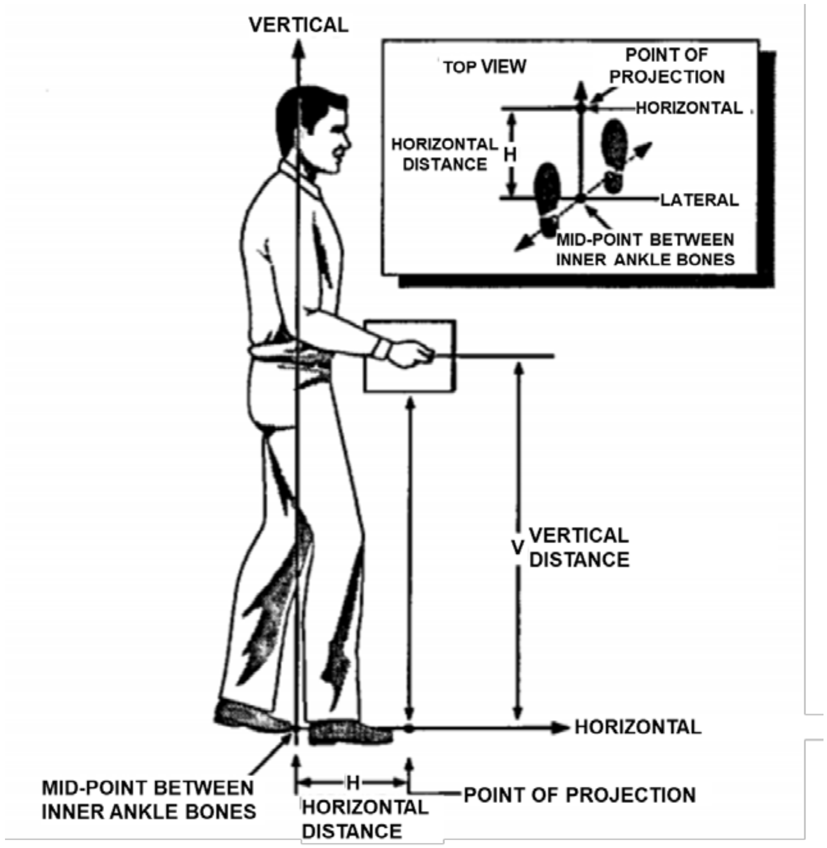


FIGURE 98. Graphic representation of task variables H and V.

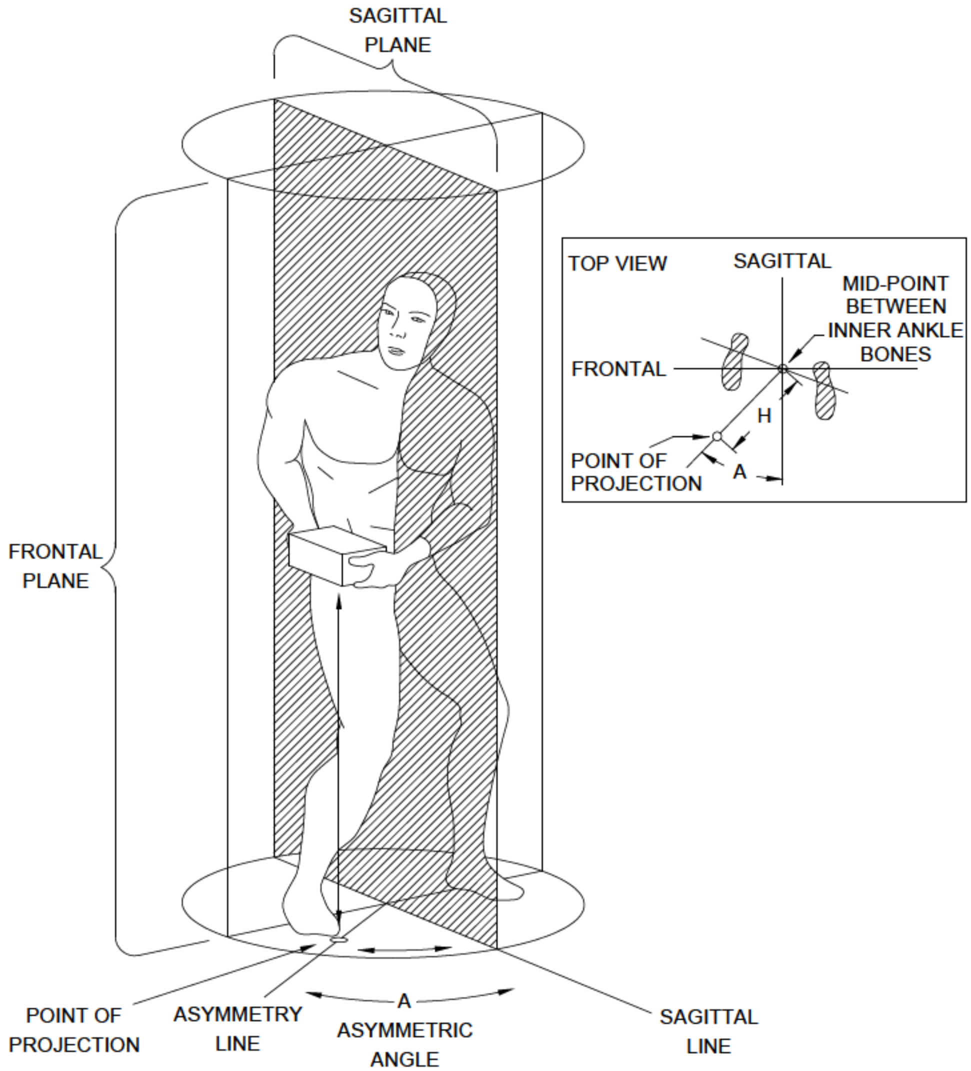


FIGURE 99. Graphic representation of task variable A.

5.20.3.4.1 Lifting duration. Lifting duration is classified into the following three categories: short-duration (less than 1 hour), moderate-duration (1 to 2 hours), and long-duration (2 to 8 hours). These categories are based on the pattern of continuous work-time and recovery-time (i.e., non-lifting light work) periods. Operational definitions of the three duration categories are presented in table XLIV.

TABLE XLIV. Lifting duration category.

Duration Category	Duration of Time (t)	Required Resting Period
Short	t ≤ 1 hour	≥100% of duration of continuous lifting task
Moderate	1 hour < t ≤ 2 hours	≥30% of continuous lifting task
Long	2 hours < t ≤ 8 hours	No amount specified
NOTE: If sufficient rest is not provided, the next higher category is used in the calculation of the frequency multiplier.		

5.20.3.4.2 Frequency multiplier. The frequency multiplier is defined by the number of lifts per minute (F), the amount of time engaged in the lifting activity (WD), and the vertical height of the lift from the floor (V). Lifting frequency refers to the average number of lifts made per minute, as measured over a 15-minute period. If significant variation exists in the frequency of lifting over the course of the day, standard work sampling techniques should be used to obtain a representative work sample for determining the number of lifts per minute. If the lifting task is performed infrequently during the day, the number of the lifts divided by 8 (or work hours a day) is the lifting frequency for the lift. If this frequency is less than 0.2, use 0.2 for determining the multiplier. Under any lifting conditions, a lifting task shall not be designed to have a lifting frequency greater than 15 lifts per minute. Values of frequency multipliers are shown in table XLV.

TABLE XLV. Frequency multipliers.

Frequency (F) (Lifts/Min)	Work Duration (WD)					
	≤1 Hour		>1 Hour but ≤2 Hours		>2 Hours but ≤8 Hours	
	V < 75 cm (30 in)	V ≥ 75 cm (30 in)	V < 75 cm (30 in)	V ≥ 75 cm (30 in)	V < 75 cm (30 in)	V ≥ 75 cm (30 in)
≤0.2	1.00	1.00	0.95	0.95	0.85	0.85
0.5	0.97	0.97	0.92	0.92	0.81	0.81
1	0.94	0.94	0.88	0.88	0.75	0.75
2	0.91	0.91	0.84	0.84	0.65	0.65
3	0.88	0.88	0.79	0.79	0.55	0.55
4	0.84	0.84	0.72	0.72	0.45	0.45
5	0.80	0.80	0.60	0.60	0.35	0.35
6	0.75	0.75	0.50	0.50	0.27	0.27
7	0.70	0.70	0.42	0.42	0.22	0.22
8	0.60	0.60	0.35	0.35	0.18	0.18
9	0.52	0.52	0.30	0.30	0.00	0.15
10	0.45	0.45	0.26	0.26	0.00	0.13
11	0.41	0.41	0.00	0.23	0.00	0.00
12	0.37	0.37	0.00	0.21	0.00	0.00
13	0.00	0.34	0.00	0.00	0.00	0.00
14	0.00	0.31	0.00	0.00	0.00	0.00
15	0.00	0.28	0.00	0.00	0.00	0.00
>15	0.00	0.00	0.00	0.00	0.00	0.00

TABLE XLV. Frequency multipliers – Continued.

NOTES:
1. For lifting less frequently than once per 5 minutes, set F = 0.2 lifts/minute.
2. This table is sourced from the Applications Manual for the Revised NIOSH Lifting Equation.

5.20.3.4.3 Coupling multiplier. The coupling multiplier is a function of how easy the lifter can grasp the load. A poor coupling requires higher grasp forces and decreases the acceptable weight for lifting. The coupling shall be classified as good, fair, or poor. A good coupling classification depends on the presence of power grips used for lifting. If power grips can be used for both hands, such as lifting a box with cutout handles, the coupling is classified as good. When power grips cannot be used but fingers are able to flex to form a 90-degree angle for lifting, the coupling is classified as fair. All other coupling is considered to be poor. If one hand's coupling is fair while the other is good, fair coupling should be used. The values of the coupling multiplier are shown in table XLVI.

TABLE XLVI. Coupling multiplier.

Coupling Type	**Coupling Multiplier**	
	V < 75 cm (30 in)	**V ≥ 75 cm (30 in)**
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90
NOTE: This table is sourced from the Applications Manual for the Revised NIOSH Lifting Equation Applications Manual.		

5.20.4 Carrying limits.

5.20.4.1 Scope. The carrying limits apply to lifting and carrying for more than 1 m (3.3 ft). Unless otherwise specified (see 6.2), the carrying weight limits are based on psychophysical data for the multivariate central 90 percent (95 percent preferred) of suitably clothed and equipped males of the target user population and the multivariate central 90 percent (95 percent preferred) of the suitably clothed and equipped females of the target user population. Power grips for carrying shall be provided, such as handles for boxes or totes. The carrying limits apply to objects grasped with the hands and not to objects borne by other parts for the body, such as backpacks, body armor, equipment belts, leg pouches, or similar types of equipment. The weight limits may be reduced when body armor or equipment worn on the body exceeds 9 kg (20 lb). If the load carriage weighs more than 9 kg (20 lb), a biomechanical analysis and an energy expenditure estimation shall be performed for determining reductions in the weight limits for carrying. In all cases involving lifting and carrying, the lifting limit for the origin of the lift prior to carrying and the lifting limit for the destination of the lift after carrying shall be determined. Choose the weight limit that is the lowest among all three weight limits as the design guideline in the lifting and carrying situation.

5.20.4.2 Two-person carry. Double the weight carrying limit shall be used as the maximum value in determining the design weight of items requiring two-person carrying, provided the load is uniformly distributed between the two carriers.

5.20.4.3 More than two-person carry. Where three or more persons are carrying a load together, not more than 75 percent of the one-person value may be added for each additional person, provided that the object is sufficiently large that the workers do not interfere with one another while carrying the load.

5.20.4.4 Carrying methods. To minimize risk of injury and increase load carrying capacity, the load should be grasped with both hands as close to the body as possible and reside at a vertical height that lies between the middle of the carrier's thighs and the bottom of the carrier's ribcage. While carrying, the carrier shall keep the body torso as upright as possible. The use of a cart or other assist devices is recommended for transporting a load greater than 7 kg (15 lb) and transported more than 15 m (50 ft).

5.20.4.5 Carrying limits. The carrying weight limits are a function of carrying distance and frequency using the carrying method described in 5.20.4.4. The weight limits in table XLVII shall be used as the maximum value in determining the design weight for repetitive carrying tasks.

TABLE XLVII. Carrying weight limits as a function of carrying distance and frequency.

Carrying Weight Limit, kg (lb)				
Frequency	**Distance, m (ft)**			
One Carry Every	**≤2.1 m (7 ft)**	**>2.1 to 4.2 m (7 to 14 ft)**	**>4.2 to 8.5 m (14 to 28 ft)**	**>8.5 to 15 m (28 to 50 ft)**
15 seconds	11 (25)	11 (25)	9 (20)	7 (15)
30 seconds	11 (25)	11 (25)	9 (20)	7 (15)
1 minute	13 (28)	13 (28)	11 (25)	9 (20)
5 minutes	14 (30)	13 (28)	11 (25)	9 (20)

5.20.4.6 Labeling. Items weighing more than the one-person lift or carry shall be prominently labeled with the weight of the object and lift limitation (e.g., mechanical, two-person lift, three-person lift). Where mechanical or power lift is required, hoist and lift points shall be provided and clearly labeled (see 5.4.10.4).

5.20.5 Load assistance devices. Good design of the workplace in areas where two-wheeled hand trucks and four-wheeled dollies will be used to move loads will reduce user's risk of injury. Points to consider when designing workspaces for load assistance devices include the following elements:

a. The coefficient of friction appropriate for the task (i.e., coefficient of static friction, coefficient of dynamic friction, and coefficient of rolling friction).

b. The smoothness of the surface to allow travel of the load assistance devices (see 5.20.5.2.1).

c. The distance of a push or pull.

5.20.5.1 When to use. Points to consider when designing for as well as selecting load assistance devices for use include the following elements:

a. The worker's body weight and strength

b. The height of the force application.

c. The direction of the force application.

d. The distance of the force application from the body.

e. The worker's posture (bending forward or leaning backward).

f. The duration and distance of the push or pull.

g. The expected load (weight, size, and shape).

h. The type of wheels or casters.

i. Pushing tasks are ergonomically preferable compared with pulling tasks.

j. Equipment including casters must be properly maintained to facilitate moving.

5.20.5.2 Hand trucks and wheeled dollies.

5.20.5.2.1 Maximum incline. Dollies and hand trucks shall not be used to move loads up and down stairs or ramps with an angle of inclination greater than 7 degrees.

5.20.5.2.2 Hand trucks turning radius. The turning radius for hand trucks shall be not greater than 120 cm (48 in).

5.20.5.2.3 Casters for dollies. Dollies shall have casters with swivel casters at the handle end of the dolly. Larger diameter wheels are ergonomically easier to push.

5.20.5.2.4 Space required. When dollies or hand trucks are required, clear space shall be provided within the area of their use.

5.20.5.3 Exoskeletons and industrial human augmentation.

5.20.5.3.1 General. Exoskeletons (which may also be referred to as exosuits, exosystems, industrial human augmentation, or simply exos) are mechanical devices worn by a user that provide passive or powered assistance to support or augment human performance. An exoskeleton may include rigid or soft components, or both. The augmented activity may be static or dynamic. Use cases include, but are not limited to, combat and combat support duties. Each use case has unique requirements that should be analyzed via a detailed risk analysis conducted on both the environment and the user.

5.20.5.3.2 Use, characteristics, and handling. The use, characteristics, and handling of exoskeletons shall be in accordance with the following standards:

a. ASTM F3323

b. ASTM F3444/F3444M

c. ASTM F3358

d. ASTM F3392

e. ASTM F3427

5.20.5.4 Patient or person movement devices.

5.20.5.4.1 General. The healthcare industry records the highest rates of work-related injuries causing employees to miss work. Over half of these injuries result from manual patient handling and repositioning of patients. Patient or person movement device design guidelines are the same as for load assistance devices (see 5.20.5.1 and 5.20.5.2). Below are specific recommendations for the use of patient movement devices.

5.20.5.4.2 Wheelchairs, gurneys, and other equipment designed to assist with movement of patients. Best practices for the use of wheelchairs, gurneys, and other equipment designed to assist with the movement of patients include the following elements:

a. Push equipment, rather than pull, and use two hands when possible.

b. Do not exceed weight capacity limits of the equipment.

c. Keep arms close to the body and push with the whole body instead of just the arms.

d. Remove unnecessary objects to minimize weight.

e. Avoid obstacles that could cause abrupt stops.

f. Consider path of movement to minimize maneuvering equipment around furniture, through doorways, around sharp turns, and over thresholds, sloped, or uneven surfaces.

g. When possible and practical, powered devices should be used (e.g., power-drive beds, wheelchair movers, and powered patient handling devices like floor-based lifts and ceiling lifts).

h. Take defective equipment out of service.

i. Perform routine maintenance on all equipment.

j. Ensure wheels and wheel locks are functioning properly.

5.20.6 Push and pull forces.

5.20.6.1 General. Pushing and pulling equipment can place high force demands on shoulder, back muscles, and joints. These high forces may lead to work-related musculoskeletal disorders. Pushing and pulling tasks should be assessed to determine whether they are safe to perform manually; recommendations based on scientific evidence should be used to determine whether assistive technology is needed to perform the task.

5.20.6.2 Horizontal. Manual horizontal push and pull forces required to be applied initially to an object to set it in motion or to be sustained over a short period of time shall not exceed the values of table XLVIII, as applicable, or those given in table XLIX if more appropriate to the force and movement characteristics of the task.

TABLE XLVIII. Horizontal push and pull forces exertable intermittently or for short periods of time.

Horizontal Force [1/]	**Applied With [2/]**	**Condition (μ = Coefficient of Friction) [3/]**
66 N (15 lb) push or pull	Both hands or one shoulder or the back	Low traction: $0.2 < \mu < 0.3$
130 N (30 lb) push or pull	Both hands or one shoulder or the back	Medium traction: $\mu \sim 0.6$
160 N (36 lb) push	One hand	If braced against a vertical wall, 50 to 150 cm (20 to 60 in) from and parallel to the push panel
200 N (45 lb) push or pull	Both hands or one shoulder or the back	High traction: $\mu > 0.9$
330 N (75 lb) push or pull	Both hands or one shoulder or the back	If braced against a vertical wall, 50 to 175 cm (20 to 70 in) from and parallel to the panel or if anchoring the feet on a perfectly non-slip ground (like a footrest)
500 N (110 lb) push	The back	If braced against a vertical wall, 50 to 175 cm (20 to 70 in) from and parallel to the panel or if anchoring the feet on a perfectly non-slip ground (like a footrest)

FOOTNOTES:

1/ May be doubled for two and tripled for three users pushing simultaneously. For the fourth and each additional user, not more than 75% of their push capability shall be added.

2/ See figure 100 for examples.

3/ The appropriate coefficient of friction must be selected; to go from a stationary position to a moving load would be coefficient of static friction, but once the load is in motion, a dynamic coefficient of friction is needed for keeping it in motion.

NOTE: Values are predicated upon a surface (as illustrated on figure 100) the user may use to aid in force exertion (i.e., a vertical rough surface that is approximately 40 cm [16 in] wide and 50 to 125 cm [20 to 50 in] above the floor to allow force application with the hands, the shoulder, or the back).

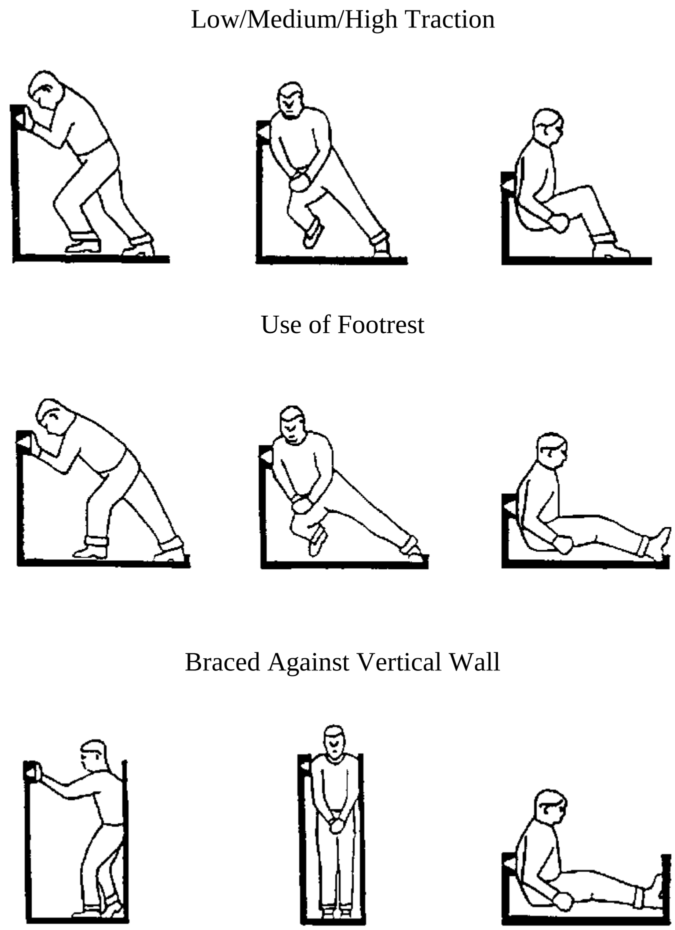
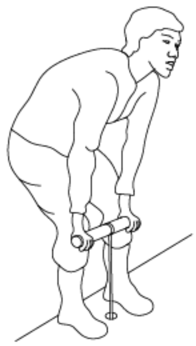


FIGURE 100. Examples of push forces.

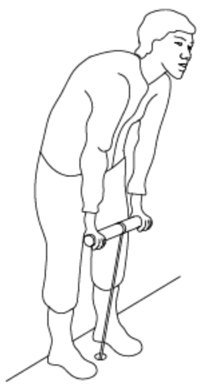
TABLE XLIX. Static muscle strength.

Strength Measurements			Values in N (lb)			
			5th Percentile		95th Percentile	
			Male	Female	Male	Female
A. Standing two-handed pull	38 cm (15 in) level	Mean force	738 (166)	331 (74)	1354 (304)	818 (184)
		Peak force	845 (190)	397 (89)	1437 (323)	888 (200)
B. Standing two-handed pull	50 cm (20 in) level	Mean force	758 (170)	326 (73)	1342 (302)	841 (189)
		Peak force	831 (187)	374 (84)	1442 (324)	905 (203)
C. Standing two-handed pull	100 cm (40 in) level	Mean force	444 (100)	185 (42)	921 (209)	443 (100)
		Peak force	504 (113)	218 (49)	988 (222)	493 (111)
D. Standing two-handed push	150 cm (60 in) level	Mean force	409 (92)	153 (34)	1017 (229)	380 (85)
		Peak force	473 (106)	188 (42)	1094 (246)	430 (97)
E. Standing one-handed pull	100 cm (40 in) level	Mean force	215 (48)	103 (23)	628 (141)	284 (64)
		Peak force	259 (58)	132 (30)	724 (163)	322 (72)
F. Seated one-handed pull	Centerline, 45 cm (18 in) level	Mean force	227 (51)	106 (24)	678 (152)	392 (88)
		Peak force	273 (61)	126 (29)	758 (170)	451 (101)
G. Seated one-handed pull	Side, 45 cm (18 in) level	Mean force	240 (54)	109 (25)	604 (136)	337 (76)
		Peak force	273 (61)	134 (30)	659 (148)	395 (89)
H. Seated two-handed pull	Centerline, 38 cm (15 in) level	Mean force	595 (134)	242 (54)	1221 (274)	770 (173)
		Peak force	699 (157)	285 (64)	1324 (298)	842 (189)
I. Seated two-handed pull	Centerline, 50 cm (20 in) level	Mean force	525 (118)	204 (46)	1052 (237)	632 (142)
		Peak force	596 (134)	237 (53)	1189 (267)	697 (157)

TABLE XLIX. Static muscle strength – Continued.



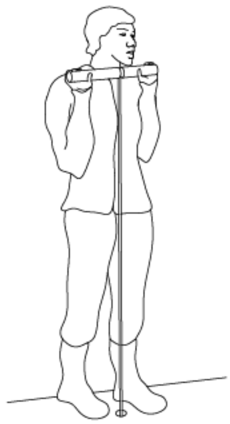
A. Standing Two-Handed Pull: 38-cm (15-in) Level
Standing with feet 45 cm (18 in) apart and knees bent. Bending at waist, grasping both sides of a 45-cm (18-in) long handle located directly in front, 38 cm (15 in) above standing surface, and pulling using primarily arms, shoulders, and legs.



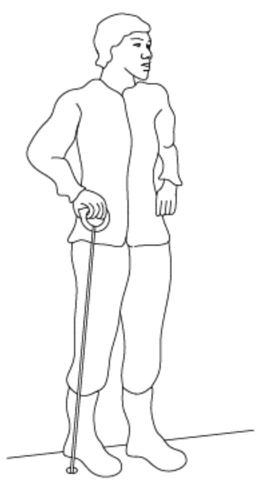
B. Standing Two-Handed Pull: 50-cm (20-in) Level
Standing with feet 45 cm (18 in) apart and knees straight, bending at waist, grasping both sides of a 45-cm (18-in) long handle located directly in front, 50 cm (20 in) above standing surface, and pulling using primarily arms and shoulders.

C. Standing Two-Handed Pull: 100-cm (39-in) Level
Standing erect with feet 45 cm (18 in) apart, grasping both sides of a 45-cm (18-in) long handle located directly in front, 100 cm (39 in) above standing surface, and pulling using the arms.

TABLE XLIX. Static muscle strength – Continued.



D. Standing Two-Handed Push: 150-cm (59-in) Level
Standing erect with feet 45 cm (18 in) apart, grasping from below, both sides of 45-cm (8-in) long handle located directly in front, 150 cm (59 in) above standing surface, pushing upward using arms and shoulders.

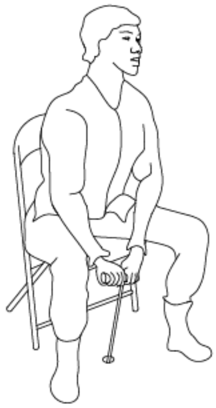


E. Standing One-Handed Pull: 100-cm (39-in) Level
Standing erect with feet 15 cm (6 in) apart, dominant hand grasping underside of a D-ring located directly to the side, 100 cm (39 in) above standing surface, pulling upward while keeping shoulder square and other arm relaxed at side.

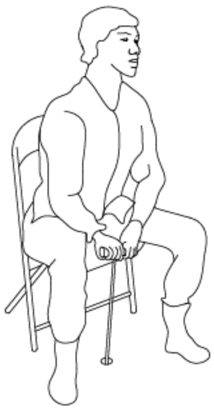
F. Seated One-Handed Pull: Seat Centerline 45-cm (18-in) Level
Sitting erect with feet 55 cm (22 in) apart, dominant hand grasping underside of a D-ring located directly to the front, 45 cm (18 in) above the floor, pulling upward while keeping shoulders square and other arm resting in lap.

TABLE XLIX. Static muscle strength – Continued.

G. Seated One-Handed Pull: Side of Seat, 45-cm (18-in) Level
Sitting erect with feet 55 cm (22 in) apart, dominant hand grasping underside of a D-ring located a short distance to side, 45 cm (18 in) above the floor, pulling upward while keeping shoulders square and other arm resting in lap.



H. Seated Two-Handed Pull: Centerline of Seat, 38-cm (15-in) Level
Sitting erect with feet 55 cm (22 in) apart, bending slightly at waist, grasping both sides of 15-cm (6-in) long handle located directly to the front, 38 cm (15 in) above the floor, pulling upward, using arms and shoulders, keeping arms off thighs.



I. Seated Two-Handed Pull: Centerline of Seat, 50-cm (20-in) Level
Sitting erect with feet 55 cm (22 in) apart, bending slightly at the waist, grasping both sides of a 15-cm (6-in) long handle located directly to the front, 50 cm (20 in) above the floor, pulling upward, using arms and shoulders, keeping arms off thighs.

5.20.6.3 Vertical. Manual vertical push and pull forces required shall not exceed the applicable 5th percentile peak or mean force values of table XLIX or those given on figure 23 if more appropriate to the force and movement characteristics of the task.

5.20.7 Handles and grasp areas. Handles and grasp areas shall meet the criteria of 5.20.7.1 through 5.20.7.8.

5.20.7.1 Means for handling. All items designed to be carried or removed and replaced shall be provided with handles or other means for grasping, handling, and carrying, and where appropriate, by a gloved or mittened hand.

5.20.7.1.1 Two handles. Items requiring handling shall be provided with not less than two handles or one handle and one grasp area.

5.20.7.1.2 Light items. Unless otherwise specified (see 6.2), items weighing less than 4.5 kg (10 lb) whose form factor permits them to be handled easily are exempt from this requirement.

5.20.7.2 Location. Handles, grasp areas, or hoist points shall be located above the center of gravity and in a manner to preclude uncontrolled swinging or tilting when lifted.

5.20.7.2.1 Clearance. Handles, grasp areas, or hoist points shall be located to provide at least 5 cm (2 in) of clearance from obstructions during handling.

5.20.7.2.2 Interference. The location of handles shall not interfere with installing, removing, operating, or maintaining the equipment.

5.20.7.3 Non-fixed handles.

5.20.7.3.1 Stop position. Non-fixed handles (e.g., hinged or foldout) shall have a stop position for holding the handle perpendicular to the surface on which it is mounted.

5.20.7.3.2 Place into carrying position. Non-fixed handles shall be capable of being placed into carrying position by one hand, and where appropriate, by a gloved or mittened hand.

5.20.7.4 Grasp surface. Where an item's installation requires that its bottom surface be used as a handhold during removal or installation, a non-slip grasp surface (e.g., grooved, knurled, or frictional) shall be provided.

5.20.7.5 Handle dimensions. Handles that are to be used with mittened, gloved, or ungloved hands shall meet the minimum applicable dimensions shown on figure 101.

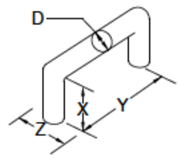
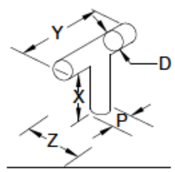
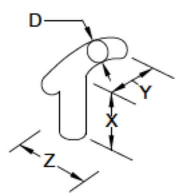
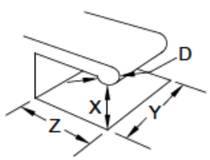
Illustration	Type of Handle	Dimensions mm (inches)								
		(Bare Hand)			(Gloved Hand)			(Mittened Hand)		
		X	Y	Z	X	Y	Z	X	Y	Z
	Two-finger bar	32 (1.25)	65 (2.5)	75 (3)	38 (1.5)	75 (3)	75 (3)	Not applicable		
	One-hand bar	48 (1 9)	111 (4.4)	75 (3)	50 (2)	125 (5)	100 (4)	75 (3)	135 (5.25)	150 (6)
	Two-hand bar	48 (1 9)	215 (8.5)	75 (3)	50 (2)	270 (10.6)	100 (4)	75 (3)	280 (11)	150 (6)
	T-bar	38 (1.5)	100 (4)	75 (3)	50 (2)	115 (4.5)	100 (4)	Not applicable		
	J-bar	50 (2)	100 (4)	75 (3)	50 (2)	115 (4.5)	100 (4)	75 (3)	125 (5)	150 (6)

FIGURE 101. Minimum handle dimensions.

Illustration	**Type of Handle**	**Dimensions mm (inches)**								
		(Bare Hand)			**(Gloved Hand)**			**(Mittened Hand)**		
		X	**Y**	**Z**	**X**	**Y**	**Z**	**X**	**Y**	**Z**
	Two-finger recess	32 (1.25)	65 (2.5)	50 (2)	38 (1.4)	75 (3)	50 (2)	Not applicable		
	One-hand recess	50 (2)	110 (4.25)	90 (3.5)	90 (3.5)	135 (5.25)	100 (4)	90 (3.5)	135 (5.25)	125 (5)

Curvature of Handle or Edge	Weight of item	Minimum Diameter	
	Up to 15 lb (6.8 kg)	D – 6 mm (0.25 in)	Gripping efficiency is best if finger can curl around handle or edge to any angle of 120° (2 rad) or more
	15 to 20 lb (6.8 to 9.0 kg)	D – 13 mm (0.5 in)	
	20 to 40 lb (9.0 to 18 kg)	D – 19 mm (0.75 in)	
(DOES NOT PRECLUDE	Over 40 lb (over 18 kg)	D – 25 mm (1 in)	
USE OF OVAL HANDLES)	T-bar Post	T – 13 mm (0.5 in)	

FIGURE 101. Minimum handle dimensions – Continued.

5.20.7.6 Handle and grasp area force requirements. Force requirements to operate handle and grasp areas other than the controls covered by 5.1 shall not exceed the values on figure 23.

5.20.7.7 Handle material.

5.20.7.7.1 Thermally or electrically conductive. Handles or grasp areas used with bare hands shall have surfaces that are not thermally (see 5.7.5.9) or electrically conductive.

5.20.7.7.2 Prevent grit and grime. The surface shall be sufficiently hard to prevent embedding of grit and grime during normal use.

5.20.7.8 Handle shape. Handles that are shaped to facilitate being held by the hand (e.g., one-hand bar or T-bar) shall be used when items must be carried frequently or for long periods.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. This standard is intended for use as design criteria for military systems, equipment, and facilities cited contractually in system specifications and elsewhere and for use as a basis for structuring that part of human factors testing where design characteristics are assessed for purposes of acceptance. It is not intended for use to express binding requirements in conceptual and other early acquisition phases. This standard may be applied to traditional as well as non-developmental item acquisitions.

6.2 Acquisition requirements. Acquisition documents should specify the following:

a. Title, number, and date of this standard.

b. Specialized terms and definitions that vary from this standard and MIL-HDBK-1908 (see 3.2).

c. Target user population accommodation (see 4.5.3).

d. Remote and local protocol for transfer of control (see 4.6.2).

e. Individual PPE for the CBRNE or other mission environments in which the system will be operated and maintained (see 4.11).

f. Survival periods and CBRNE environmental for mission-essential operation equipment (see 4.11.2).

g. Aircrew system design (see 4.15).

h. The type of control selected and the location of the motion envelopes (see 5.1.1.1.1.1).

i. Operationally acceptable response times for teleoperated systems (see 5.1.2.1.6.4).

j. Functional group coding for non-critical functional groups (see 5.1.2.2.1.4.2).

k. Touchscreen accessibility (see 5.1.3.1.13.1).

l. Barriers for critical switches and on switches likely to be inadvertently actuated (see 5.1.4.2.1.5.4.2).

m. Acceptable false alarm rate (see 5.3.1.10).

n. Thermal environments for selected materials (see 5.3.8.4).

o. Full range of environmental extremes to which the system is required to be subjected (see 5.5.1).

p. Target audience population that will interact with the system or facility and their clothing and gear that the design needs to accommodate (see 5.5.1.1).

q. Design environmental conditions and extremes (see 5.5.1.2).

r. Any spaces that will not require HVAC (see 5.5.2.1).

s. The number of people to be accommodated for enclosures less than 4.25 cubic meters per person (see 5.5.2.1.3.2).

t. Personal hearing protection to be worn within the context of mission performance (see 5.5.4.4.3.1).

u. Target audience population for ground vehicle system (see 5.6.1.1).

v. User population for user interfaces and workspaces (see 5.6.1.2).

w. Seat clearances to accommodate required gear (see 5.6.2.2.5).

x. Thermal environments for padding materials (see 5.6.2.3.3).

y. Low latency and high resolution for driver's horizontal field of regard (see 5.6.5.6.3).

z. Number of people to be accommodated in hot climate operation (see 5.6.6.2.2).

aa. Duration of extended lighting time (see 5.6.7.3.1).

bb. Level of unacceptable compromise to vehicle's reserve buoyancy (see 5.6.7.3.3).

cc. Underwater visibility requirements for amphibious vehicles (see 5.6.7.3.7).

dd. G-loading and duration of amphibious vehicles (see 5.6.7.3.8).

ee. Color coding for glad hands (see 5.6.11.8.6.6.c).

ff. Ceiling height when occupants seldom stand to perform normal operations (see 5.6.11.13.2).

gg. Alternate access dimensions for construction machinery (see 5.6.11.14.8).

hh. Maximum weight for the smallest female in the user population (see 5.7.2.6.3).

ii. Sub-population accommodation (see 5.8.2.3 through 5.8.2.3.4).

jj. Design of DoD systems, equipment, and facilities accommodations if other than specified (see 5.8.3.1, 5.8.3.2, and 5.10.1).

kk. Anthropometric database(s) (see 5.8.4.2.2).

ll. Spacing for clamps or plates that mount lines and cables (see 5.9.13.2.2).

mm. Boot measurements combined with PPE (see 5.10.2.4.2.1 and 5.10.2.4.2.2).

nn. Height of work surfaces to support documents (see 5.10.3.8.2.6.3).

oo. Height of work benches, desktops, and writing tables (see 5.10.3.9.2.2).

pp. Armrest design and adjustability range (see 5.10.3.12.11).

qq. Physical space within equipment and systems to accommodate target user population (see 5.11.2.7.1).

rr. Surface color guidance (see 5.11.9.1).

ss. Navy surface colors (see 5.11.9.2).

tt. Reflected light from remote work areas requirements if other than specified (see 5.12.2.6.1).

uu. If system tanks are associated with greater uncertainty and risk (see 5.12.3.3.2).

vv. Decision aid usage (see 5.12.3.4.16.1 and 5.12.3.4.16.2).

ww. Autonomous weapon system interface (see 5.12.3.6.1.3).

xx. UAV primary flight symbology (see 5.12.4.6.2).

yy. Additional mission phases for manual handling design (see 5.12.4.8).

zz. Period of time for "return home" capability to activate when communication is lost between system and users (see 5.12.4.10).

aaa. Period of time for neutralize capability to activate when communication is lost between system and users (see 5.12.4.11).

bbb. Requirements for telemedicine devices (see 5.12.6.2).

ccc. Mitigations and indications for Service security regulation differences (see 5.12.6.3.2).

ddd. Thermal insulation for weapon parts (see 5.13.1.4.1.4).

eee. Other reticle shapes that may be used (see 5.13.2.9.4).

fff. Helmets, protective masks, and other clothing for use with eyecups and headrests (see 5.13.2.12.3).

ggg. Quick-release mechanisms operated by gloved hand(s) (see 5.13.2.16.4).

hhh. If an access by stair may be used for category 1 valves (see 5.14.2.2.1).

iii. If an alternative means of assessing category 2 valves for maintenance purposes may be used (see 5.14.2.2.2.1).

jjj. If the airborne sound pressure levels on the bridge are to meet the A-3 requirement in accordance with MIL-STD-1474 (see 5.18.4.2).

kkk. The locations external to the bridge that critical navigational information is to be provided (see 5.18.6.2.2).

lll. Levels of vibration on the bridge (see 5.18.11.3).

mmm. Conditions in which PEDs are intended to operate (see 5.19.1.2).

nnn. Any strength and handling requirements that apply to user population-specific or other strength data (see 5.20.1).

ooo. Typical load for the mission, climate, and occupational specialty for the system being acquired (see 5.20.2.3.3).

ppp. Lifting limits if other than specified (see 5.20.3.1) and carrying weight limits if other than specified (see 5.20.4.1).

qqq. If items weighing less than 4.5 kg (10 lbs) are not exempt from the handle and grasp requirements (see 5.20.7.1.2).

6.3 Subject term (key word) listing.

Anthropometry

Controls

Cybersecurity

Design for maintainability

Environment

Ground vehicles

Habitability

Handheld devices

Human factors

Human performance

Human systems integration

Information systems

Labeling and marking

Optics

Physical environment

Safety

Ship bridge design

Shock

Small equipment

Speech and audio systems

Strength and handling

Valves

Vibration

Virtual environments

Visual displays

Warnings and hazards

Weapons

Workstation design

6.4 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extent of the changes.

CONCLUDING MATERIAL

Custodians:
Army – MI
Navy – SH
Air Force – 11

Preparing activity:
Navy – SH
(Project HFAC-2020-006)

Review activities:
Army – AR, AT, AV, CR, EA, GL, MD, MR, PT, TE, TM
Navy – AS, CG, EC, MC, ND, OS, PE
Air Force – 01, 10, 19, 40, 84
DLA – DH
DISA – DC2
NGA – MP
NSA – NS
OSD – SE

Industry associations:
AAMI
AIA
ASTM
EIA
HFES
SAE

NOTE: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at https://assist.dla.mil.