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RECOMMENDED MODIFICATIONS TO MIL-STD-1472B; SELECTED SECTIONS ON CONTROLS, DISPLAYS AND RELATED HARDWARE

ADDENDUM TO
TECHNICAL REPORT RS-CR-80-2

HUMAN ENGINEERING DESIGN CRITERIA FOR MODERN CONTROL/DISPLAY COMPONENTS AND STANDARD PARTS

FINAL REPORT

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For

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US Army Missile Laboratory

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Notes to Reviewers:

1. This workbook has been set up so that original materials from MIL-STD-1472B are printed on white pages, with recommended modifications for each white page section printed on yellow. This allows one to first review the original material, along with recommended modifications section by section.

2. Although the primary objective has been to minimize reorganizing the order of original materials, it has been necessary in some cases to do some reorganizing in order to add new materials.

3. It should be noted that there have been a few slight modifications with respect to specific criterion values that were in the original (i.e., in terms of dimensions, rates, times, forces, etc.), in order to minimize some of the conflicts that have occurred between MIL-STD-1472 and other military standards and specifications. Such changes were based on judgment that such changes do not materially affect human performance.

4. Many of the new materials recommended for addition to MIL-STD-1472 have been based on best judgment of various experts based on experience and consensus (since specific research data was not available). Your critical review of these are solicited, especially if you have knowledge of research information to suggest that such recommendations are not correct.

5. Note that tables and figures in yellow sections have not been numbered purposely, since until decisions have been made as to which recommendations might be used for revising MIL-STD-1472B, such numbering might confuse the reviewer. Hopefully such tables and figures have been placed appropriately so you can relate them with text references.

ORIGINAL REQUIREMENT	MFI COMMENTS
1.1 SCOPE - This standard establishes general human engineering criteria for development of military systems, subsystems, equipment and facilities. 1.2 PURPOSE - The purpose of this standard is to present human engineering design criteria, principles, and practices to achieve mission success through integration of the human into the system, subsystem, equipment, and facility, and achieve effectiveness, simplicity, efficiency, reliability, and safety of system operation, training, and maintenance. 1.3 APPLICATION - This standard shall be applied to the design of all systems, subsystems, equipment and facilities. Nothing in this standard shall be construed as limiting the selection of hardware, materials, or processes to the specific items described herein.	Some of the statements in this Section could be improved by minor revision as indicated. The matter of conflicts with other standards would be appropriate to include in this Section as indicated in the MFI Recommended Modifications and Rationale.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
1.1 SCOPE -	
This standard defines human engineering criteria for utilization in developing, procuring, and evaluating systems, subsystems, equipment, and facilities for military use.	
1.2 PURPOSE -	
The purpose of this standard is to ensure that all military systems, subsystems, equipment, and facilities will be designed for proper interface with their operators and maintainers, to enhance human-system performance capability, and to reduce manning and training requirements, and insure adequate safety.	More specific to "interface" design.
1.3 APPLICATION -	
This standard shall be applied to the design of all systems, subsystems, equipment and facilities for military use, subject to the following limitations.	
1.3.1 <u>Aircraft Flight Control Stations</u> - Only those provisions which specifically cite applicability to aircraft flight control stations shall apply to such stations.	
1.3.2 <u>Design Limits</u> - Design limits are generally presented in the text or in tables referenced to the text or keyed to illustrations. Some illustrations include a specification of limits or characteristics directly on the illustration. In the absence of limiting specifications the illustrations should be construed as examples only, and do not provide design limits with respect to approach, hardware, materials, or range of acceptable values.	To avoid implication that 1472 is a design specification.
1.3.3 <u>Conflicts With Other Standards</u> - Some provisions in this Standard may be in conflict with provisions in other standards and specifications which are called out in development contracts. When a conflict occurs, the procuring activity shall determine which provisions of the respective documents shall govern.	Although we have tried to eliminate as many conflicts as possible, some will remain until "other" documents are revised.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
2.1 SPECIFICATIONS AND STANDARDS -	
<u>Specifications</u>	
Add the following:	
MIL-C-81774 Control Panel, Aircraft, General Requirements For.	This very comprehensive specification has considerable human engineering content.

ORIGINAL REQUIREMENT	MFI COMMENTS
5. DETAILED REQUIREMENTS 5.1 CONTROL/DISPLAY INTEGRATION - 5.1.1 General Criteria - 5.1.1.1 Compatibility - Controls shall be compatible with their associated displays. The control-display relationships shall be functionally effective and require a minimum of decoding or mental involvement on the part of the operator. 5.1.1.2 Relationship - The relationships of a control to its associated display and the display to the control shall be immediately apparent and unambiguous to the operator. Controls shall normally be located adjacent to (preferably under or to the right of) their associated displays and positioned so that neither the control nor the hand normally used for setting the control will obscure the display. 5.1.1.3 Design - Control-display relationships shall be apparent through design considerations of proximity, similarity of groupings, coding, framing, labeling, and similar tecnniques. 5.1.1.4 Precision - The precision required of control manipulation shall be consistent with the precision required by the system. The precision of display presentation shall be consistent with the range of control movements required for adequate system performance. 5.1.1.5 Feedback - Feedback on control response adequacy shall be provided.	Titles do not convey purpose of paragraph content Paragraph sentences tend to obscure primary objective. Feedback requirement is too simplistic -- needs clarification.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5. DETAILED REQUIREMENTS	No change
5.1 CONTROL/DISPLAY INTEGRATION	
5.1.1 <u>General Criteria</u>	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.1.1.1 Compatibility - Control-display relationships shall be functionally effective and require a minimum of decoding or mental involvement on the part of the operator. This shall include relationships between a control and specific display hardware (e.g., meters, instruments, labeled control escutcheon plates, etc.), and/or external devices or visual elements that are used as visual reference while operating particular controls. A control shall not be used in any application in which its movement is likely to be ambiguously interpreted. (Example--the manipulation required is opposite to that anticipated or expected by the typical operator.)	Expanded to cover other feedback relationships.
5.1.1.2 Physical Relationships - The physical relationships of a control to its associated visual display and/or the display to the control shall be immediately apparent and unambiguous to the operator (i.e., in terms of adjacency). Controls shall normally be placed beneath or to the right of a related display except under conditions as follows:	Re-titled to differentiate from 5.1.1.1.
a. The display would be obscured by the operator's hand.	Expanded to clarify "unambiguous" and to include awkwardness.
b. Panel space limitations requires use of an array of displays that would be selectively operated by means of a "ganged" control device, wherein separate knobs would be associated with individual displays within the array.	
c. The control operation would be inefficient or awkward if the control were placed next to the display, and/or vice-versa (i.e., placement of the display next to the control would make for awkward or inefficient visual access to the display). Typical applications include such relationships as steering wheel, joystick or foot-operated controls relative to displays on an instrument panel.	
5.1.1.3 Organization - Controls and displays shall be organized in a manner that will minimize operator effort, confusion and error, by means of functional grouping, sequential arrangement, accessibility to the nominal using limb or hand, and/or nominal viewing axis of the operator.	Added as a "general" requirement.
5.1.1.4 Design Detail - Control-display relationships shall be apparent from the configurational and graphic details of the hardware elements, i.e., size, shape, format, labeling, etc.	Modified since proximity is in 5.1.1.2, and to emphasize other visual factors.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.1.1.5 Simplicity - The complexity and/or precision required of control manipulation and display monitoring shall be consistent with the precision required of the system and shall not exceed the capability of the operator (in terms of discrimination of display detail) and/or exceed the operator's manipulative capability under the dynamic conditions expected (in terms of manual dexterity, coordination or reaction time).	Simplicity is made a general concept, with an explanation.
5.1.1.6 Feedback - Control-display systems shall be designed to provide feedback on control input and system state as related to control input. Feedback shall be considered at three levels as follows: a. Control Actuation - (1) Discrete State Selectors - Controls of this type (toggle switches, push button switches, rotary selectors, etc.) shall provide positive indication of control actuation to the operator under all operational conditions. Control displacement sufficient to be unambiguously recognized may provide adequate feedback at this level for most functions. (2) Continuous Adjustment Controls - Controllers such as continuous-adjustment knobs, cranks, joysticks, etc., shall provide feedback as to where the control is positioned with respect to its entire range of variability. Ordinarily this is by means of visual indication viz; the control's moving pointer against a fixed scale. b. Transient System Response - Feedback at this level is used to provide an indication of system response to the control input between the time of control actuation and that of arriving at system steady-state condition in response to that input. (When the transient response is short, e.g., less than two seconds duration, feedback at this level for non-critical functions may not be required.) Usually a single positive feedback indication at this level is sufficient (i.e., there is one clear visual or auditory indication that the system is in the process of responding). For especially critical functions,	Expanded because this is perhaps the most important general requirement that applies across the board. This material is a collation of basic precepts from numerous authors found in references such as the following: Van Cott, Human Engineering Guide to Equipment Design, 1972 McCormick, Human Factors in Engineering and Design, 1976 Poulton, Tracking Skill and Manual Control, 1974 Kelley, Manual and Automatic Control, 1968 AFSC DH 1-3, Design Handbook, plus comments from our reviewers.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
however, transient system response shall be indicated by one of the following: (1) Direct positive feedback from the mechanism being driven viz; for example, a strong auditory signal directly from a drive motor, or direct visual indication of the orientation of the driven unit. (2) Redundant positive feedback from two different points in the system (e.g., a meter indication and a pilot light, which sense the system's transient state). (3) Both positive and negative feedback, so that one or the other will always be activated, whether or not the system responds to the control input viz; the positive feedback indicates the system <u>is</u> in the process of responding when it should; the negative feedback indicates that the system <u>is not</u> responding when it should; and/or one or the other of the indications would always be present during the transient period. c. <u>System Steady State</u> - Feedback shall be provided to indicate: (1) completion of the system's response to the control input and (2) current system operating state. Usually a single positive feedback indication at this level is sufficient. (The onset of the indication signals completion of the response and the continuing indication constantly inform of system state.) Where the original control input is by some type of discrete state selector, a discrete state indicator for feedback is sufficient. Where the original control input was by a continuous adjustment control, an analog or digital indication of system state is usually required to indicate that the system has indeed responded fully to the control input. Exceptions to this may be allowed where provision is made to automatically compare the completed system response with the magnitude of the control input	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
and to indicate that the system has responded within satisfactory tolerance. For critical functions, a warning indication shall be provided to signal at all times following the system transient response when the system state mis-matches the ordered state as set by the input control(s).	
5.1.1.7 <u>Illumination</u> - Visual displays, including display control and panel labels and critical markings, that must be read at night or under darkened conditions shall be illuminated.	Added because without illumination visual feedback will not occur. Too many arbitrary decisions are made with regard to providing light or unlighted components. This requirement should be "up front"

ORIGINAL REQUIREMENT

5.1.2 Position Relationships -

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

5.1.2.1.1 Functional Group Arrangement -

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

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

5.1.2.1.1.3 Functional Group Marking - Functional groups may be set apart by outlining with contrasting lines. Where such coding is specified by the procuring activity, and where gray panels are used, noncritical functional groups (i.e., those not associated with emergency operations) shall be outlined with a 1/16-inch (1.6mm) black border (27038 of FED-STD-595), and those involving emergency or extremely critical operations shall be outlined with a 3/16-inch (4.8mm) red border (21136 of FED-STD-595). As an alternate method, contrasting color pads or patches may be used to designate both critical and noncritical functional areas, subject to prior approval by the procuring activity. When red compartment lighting is used, an orange-yellow (23538 of FED-STD-595) and black (27038 of FED-STD-595) striped border shall be used to outline functional groups involving emergency or extremely critical operations. Critical and noncritical control-display areas in aircraft crew stations shall be delineated in accordance with MIL-M-18012.

Note: Above 5.1.2.1.1.3 moved to new paragraph under "Control-Display Identification"

MFI COMMENTS

A key issue in locating controls and displays is the appropriate definition of the basic operator position and his/her orientation.

For years we have also set forth at least four basic principles of control-display positioning, i.e., grouping by function, by sequence of operation, by frequency of use, and by emergency need. Although these are treated variously within the original, we believe these principles are important to expose as clearly as possible.

Allowing for these two issues, remaining material should be reorganized to follow.

The main title does not fully reflect what is to follow.

Some subtitles also do not reflect what follows.

Some of the requirement statements are not complete with respect to the topic.

Additional topics germane to the to the section title should be added.

ORIGINAL REQUIREMENT	MFI COMMENTS
5.1.2.1.1.4 Consistency - Location of recurring functional groups and individual items shall be similar from panel to panel.	Too limited.
5.1.2.2 Location and Arrangement - Whenever an operator must use a large number of controls and displays, their location and arrangement shall be designed to aid him in determining which controls are used with which displays, which equipment component each control affects, and which equipment component each display describes. 5.1.2.3 Arrangement Within Groups - Controls and displays within functional groups shall be located according to operational sequence or function, or both. 5.1.2.3.1 Left-to-Right Arrangement - If controls must be arranged in fewer rows than displays, controls affecting the top row of displays shall be positioned at the far left; controls affecting the second row of displays shall be placed immediately to the right of these, etc. 5.1.2.3.2 Vertical and Horizontal Arrays - If a horizontal row of displays must be associated with a vertical column of controls or vice versa, the farthest left item in the horizontal array shall correspond to the top item in the vertical array, etc. However, this type of arrangement shall be avoided whenever possible. 5.1.2.3.3 Multiple Displays - When the manipulation of one control requires the reading of several displays, the control shall be placed as near as possible to the related displays and preferably beneath the middle of the displays. 5.1.2.3.4 Combined Control - When separate displays are affected by a combined control (e.g., concentrically ganged knobs), the display shall be arranged from left to right with the combined control underneath the center of the displays.	This is part of same topic addressed in 5.1.2.1 and other of the following paragraphs. The reader has difficulty understanding topic hierarchy. Some modification of subtitles and order could help clarify this by bringing "like" topics together.

ORIGINAL REQUIREMENT	MFI COMMENTS
5.1.2.3.5 <u>Separate Panels</u> - When related controls and displays must be located on separate panels and both panels are mounted at approximately the same angle relative to the operator, the control positions on one panel shall correspond to the associated display positions on the other panel. The two panels shall not be mounted facing each other.	It took several passes to understand what was said here!
5.1.2.3.6 <u>Component Groups</u> - When a group of equipment components has the same function, the related control and display positions shall be oriented to correspond to those of the controlled and monitored components. (For example, the position of aircraft engine controls shall be oriented as if the operator faces the normal direction of vehicle movement.)	Same here.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.1.2 General Arrangement Factors - Arrangement of controls and displays at work stations shall be in accordance with those arrangement factors most likely to ensure effective operator performance. Care shall be exercised to obtain the best balance of these factors when they may be in conflict or may vary in significance with mode of operation at the work station. The following arrangement factors shall be considered.	Title changed to more clearly represent all that follows. An introductory statement introduces concept of proper compromise.
5.1.2.1 Operator Orientation - Controls and displays associated with a given control/monitoring task(s) shall be located and positioned with reference to a specified operator position or positions, including requirements for visual monitoring beyond the immediate control-display interface, and shall not impose difficult mobility problems for the operator (i.e., sitting or standing in an awkward position, frequent extreme reaching and body or head turning requirements, or constant changes in body position in order to accommodate to various control manipulation or visual monitoring tasks). Controls and displays that may be used concurrently and/or alternately by more than one person shall be positioned so that neither operator is inconvenienced for the advantage of the other except where it can be determined that one of the operator's tasks is more critical and of higher priority, and spatial constraints actually require compromise of one operator's convenience over the other.	First issue of arrangement is operator position, missing from original section. The following are somewhat reorganized but include all of previous topics plus additional ones considered important to cover in this section.
5.1.2.2 Functional Grouping - Functionally related controls and displays shall be located in groups and physically or visually separated from other control-display elements or groups whenever suoh grouping enhances operator capability to locate related functions and observe inter-relationships among related functions. No non-related control or display function shall be located within the apparent confines of a functionally-related group of controls or displays.	This topic needed to be more explicit.
5.1.2.3 Sequence of Operation - Whenever a frequently recurring sequence of operation (i.e., instrument scan or sequential series of control operations) can be defined, control-display elements shall be arranged for convenient left-to-right, or top-to-bottom eye/hand movements. Such sequential arrangement shall be observed both for individual items or group-to-group sequences, and "within functional groups".	Same.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.1.2.4 Frequency of Use - Controls and/or displays that are used continuously and/or most frequently should be located and positioned as convenient to the operator as practicable relative to related physical and environmental constraints. Displays should be positioned to minimize excess reaching and/or awkward hand/arm and/or foot/leg movements.	Same.
5.1.2.5 Importance of Use - Controls and displays which are most critical to operation should be placed in preferential positions. Refer to appropriate sections of 5.2 VISUAL DISPLAYS and 5.4 CONTROLS.	This and next topic were omitted in original, but are critical factors in arrangement.
5.1.2.6 Simultaneous Use - Visual displays that must be monitored concurrently with manipulation of a related control shall be located sufficiently close to the control so that the operator is not required to observe the display from an extreme visual angle and thus introduce the possibility of parallax error.	
5.1.2.7 Emergency Use - Emergency displays and controls shall be located where they can be seen and reached with minimum delay (e.g., warning lights within a 30-degree cone about the operator's nominal line of sight; emergency control close to the nearest, available hand in its nominal operating position).	This topic needed to be more explicit.
5.1.3 Design Factors	A new title was needed to collate following topics at an appropriate level.
5.1.3.1 Control-Display Identification - Except for controls whose function and appearance is obvious (e.g., steering wheel, joystick, etc.), all operator and maintainer controls and displays shall have appropriate labels to aid in their identification. This shall apply not only to individual items, but also to functional groups of controls and displays. Functional groups may be set apart by means of spatial separation, outlines around the group, and/or contrasting panel backgrounds. When outline borders are used they shall not be wider than the character stroke width in the associated function labels, except for panels containing emergency or extremely critical functions where the border width may be twice the character stroke width. Borders on gray panels should be marked in black (FED-STD-595, color #27038); or for emergency panels, the border should be red (FED-STD-595, color #21136) unless red illumination is used, in which case it	Note: 5.1.3.1 picks up detailed material from original 5.1.2.1.1.3.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
should be striped in yellow and black (FED-STD-595 yellow #23538 and black #27038). Background pads may be used subject to approval by the procuring activity. Critical and noncritical control-display areas in aircraft crew stations shall be delineated in accordance with MIL-M-18012 and MIL-C-81774). For other display-control labeling and marking, see 5.5.	Add new aircrew station "Control Panel" specification.
5.1.3.2 <u>Consistency</u> - Like control-display functions shall be consistent from one operator workstation to another when it is likely that the same operator may be called upon to change workstations. The following are examples:	Makes topic more explicit. These "standardization" concepts are based on recent automotive driver station studies by MFI for U.S. DOT plus some refinement of the material presently contained in 1472.
a. <u>Left-Right Arrangements</u> - When a group of control-display elements normally have a left-to-right and/or numbered relationship to other equipment components (e.g., aircraft engines numbered from left to right), the operator control-display arrangement shall remain the same with respect to the operator's orientation within the work station (i.e., facing forward, right, left, or aft).	
b. <u>Related But Separated Control-Display Arrays</u> - When an array of controls on one panel correspond to displays mounted on another panel (i.e., due to special space limitations), the control and display arrays should be similarly arranged. That is, the left-most control of a horizontal array shall correspond to the left-most display mounted on the other panel, or a top-most control of a vertical array shall correspond to the top-most display on the other panel. The two horizontal panels shall not be mounted so that they "face" each other and thus create the opportunity to confuse the right-to-left relationships.	
c. <u>Vertical vs Horizontal Control-Display Arrangements</u> - When displays are arranged in a row or column the associated controls should be similarly arranged and spaced (and vice versa), except as follows:	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
(1) Fewer Rows of Controls Than Displays - Controls affecting the top row of displays shall be positioned at the far left; controls affecting a second row of displays shall be placed immediately to the right of these, with an appropriate space between the two control arrays.	Ref: Van Cott, Human Engineering Guide to Equipment Design, 1972, Ch 9
(2) Vertical vs Horizontal Association - If a horizontal row of displays must be related to a vertical row of controls or vice versa, the farthest left item in the horizontal array shall correspond to the top item in the vertical array, etc. Note: The above exceptions often lead to errors in spite of the recommended spatial associations. Therefore they should be avoided whenever possible.	
(3) Multiple Displays vs Single Control - When the manipulation of one control requires reading of several displays, it shall be "centered" as near as possible below the display group.	
(3) Multiple Display vs Ganged Control - When up to three displays are to be individually-affected by a three-layer, ganged rotary control switch, the switch should be centered below a horizontal display group, or to the right of a vertical display group. The knob-display associations should be as follows: (a) Top Knob - Left Display or Upper Display (b) Middle Knob - Middle Display (c) Bottom Knob - Right Display or Lower Display	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.1.3 <u>Movement Relationships</u> - 5.1.3.1 <u>Lack of Ambiguity</u> - Display indicators shall clearly and unambiguously direct and guide the appropriate control response. The response of a display to control movements shall be consistent, predictable, and compatible with the operator's expectations.	This section needs to address the independent control motion expectancies as well as the control vs display motions.
5.1.3.2 <u>Time Lag</u> - The time lag between the response of a system to a control input and the display presentation of the response shall be kept to a minimum, consistent with safe and efficient system operation. The display indicator shall normally cease to move after the control movement has ceased.	
5.1.3.3 <u>Moving Pointer Circular Scales</u> - Clockwise movement of a rotary control or movement of a linear control forward, up, or to the right shall produce a clockwise movement of circular scale pointers and an increase in the magnitude of the setting. 5.1.3.4 <u>Moving Pointer Linear Scales</u> - Clockwise movement of a rotary control or movement of a linear control forward, up, or to the right shall produce a movement up or to the right for horizontal and vertical scale pointers and an increase in the magnitude of the reading.	The universal use of CW vs CCW to describe motions breaks down under certain cases, especially when left vs right hand use is considered. To clarify these differences, it seems desirable to use illustrations since it is hard to describe all variables in words.
5.1.3.5 <u>Fixed Pointer Circular Scale</u> - Displays with moving scales and fixed pointers or cursors should be avoided. When circular fixed-pointer, moving-scale indicators are necessary, clockwise movement of a rotary control or movement of a linear control forward, up, or to the right shall normally produce a counterclockwise movement of the scale and an increase in the magnitude of the reading.	
5.1.3.6 <u>Fixed Pointer Linear Scale</u> - When vertical or horizontal fixed-pointer, moving-scale indicators are necessary, clockwise movement of an associated rotary control or movement of a linear control forward, up, or to the right shall normally produce a movement of the scale down or to the left and an increase in the magnitude of the reading.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.1.3.7 Direct Linkage - When there is a direct linkage between control and display (e.g., radio frequency selector and station pointer), a rotary control shall be used if the indicator moves through an arc of more than 180°. If the indicator moves through an arc of less than 180°, a linear control may be used, provided the path of control movement parallels the average path of the indicator movement and the indicator and control move in the same relative direction.	
5.1.3.8 Common Plane - Controls shall be selected so that the direction of movement of the control will be consistent with the related movement of an associated display, equipment component, or vehicle.	This "breaks down" for certain applications (e.g., aircraft, submersibles).
5.1.3.9 Parallel Movement - Direction-of-movement relationships shall be strictly adhered to when control and display are parallel in line of movement.	
5.1.3.10 Labeling - When control-display relationships specified herein cannot be adhered to, controls shall be clearly labeled (see para 5.5) to indicate the direction of control movement required.	
5.1.3.11 Movement Direction - When a rotary control and a linear display are in the same plane, the part of the control adjacent to the display shall move in the same direction as the moving part of the display.	There is some confusion between this and paragraph 5.1.3.9.
5.1.3.12 Thumbwheels - If a thumbwheel is used as a continuous control which affects vehicle movement, movement of the thumbwheel forward or up should cause the vehicle to move down or forward.	Upward motion of thumbwheel for downward vehicle motion would apply only to specific vehicles. Suggest be deleted since its limited application will be covered by pertinent engineering documents.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.1.3.3 Control-Display Movement Relationships	Title clarified.
5.1.3.3.1 Change in Value - When control manipulation results in a change in value, the direction of control movement shall conform to criteria in Figure____.	
5.1.3.3.2 Change in Displayed Element - When control manipulation results in a change in the position of displayed elements (e.g., display pointers, cross-hairs, or other controlled markers), the direction of control movement shall conform to criteria in Figure_______.	
5.1.3.3.3 Change in Vehicle/Component Movement or Position - Direction-of-motion conventions for various types of operational systems (i.e., automotive, aircraft, marinecraft, etc.) shall be followed unless express approval has been granted by the procuring activity. The following conventions shall apply:	New topic - omitted in original.
A. Automotive	Although these are obvious, such conventions need to be stated to avoid "odd design inventions".
(1) Steering Wheels: Clockwise rotation = right turn; counterclockwise rotation = left turn.	
(2) Service Brake, Clutch and Accelerator Pedals: Forward pedal motion applies braking, disengages clutch and increases engine R.P.M. respectively.	
(3) Automatic Gear Shift: Floor/Console-mounted; PARK = foremost position of lever, followed by successive aft positions of REVERSE, NEUTRAL, DRIVE and LOW; Column-mounted; same positional order.	
(4) Turn Signals: (Column-mounted lever, left-hand-operated) Clockwise movement about column axis = RIGHT TURN; counterclockwise movement = LEFT TURN.	
(5) Automotive Manual Throttle: "Pull" = Increasing R.P.M.	

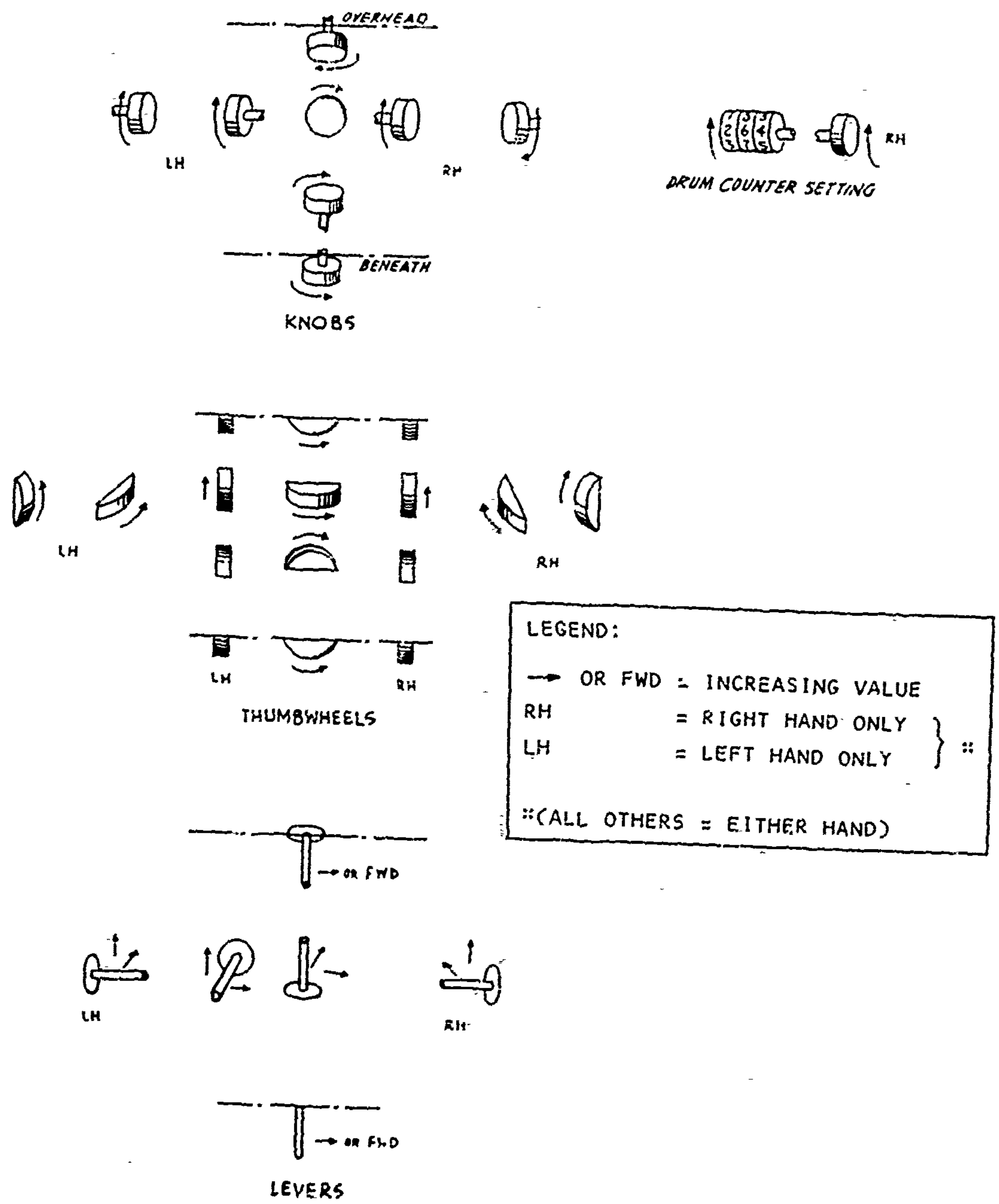


FIGURE_____ - CONTROL MOVEMENT FOR VALUE CHANGE

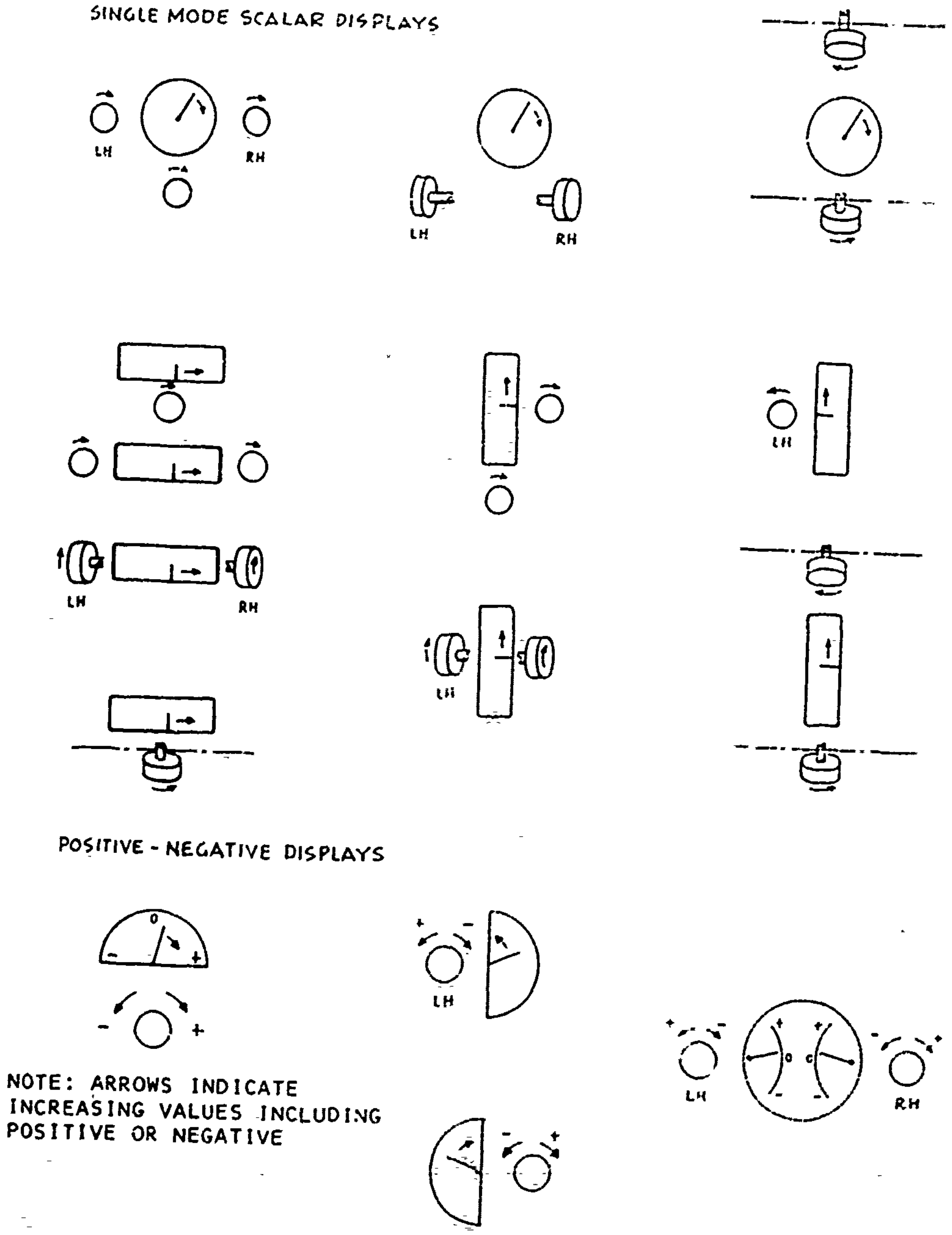
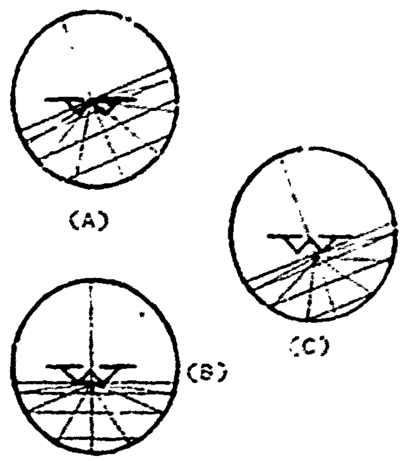


FIGURE_____ - CONTROL VS DISPLAY MOTION

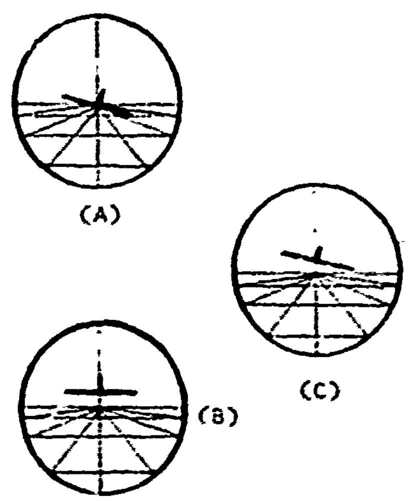
MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
B. Aircraft	
(1) Rudder Pedals: Forward movement of right pedal = right turn; forward movement of left pedal = left turn.	
(2) Control Stick/Wheel: Aft motion = nose-up; forward motion = nose down; Movement to the right and/or clockwise wheel motion = right wing down; left movement and/or counterclockwise wheel motion = left wing down.	
(3) Throttle(s): Forward motion = increase in aircraft speed, e.g., increased thrust. When reverser systems are present, aft motion of throttle lever(s) = increased thrust (a separate "lift" movement of throttle lever shall be required to prevent inadvertent operation of reverser system).	Ref: AFSCM, Handbook of Instructions for Aircraft Design (HIAD), 1967, p c.2-1.
(4) Other: As a general rule, forward or upward lever movement = increased vehicle performance. Rotary controls shall conform to criteria in Figure_____.	
C. Submersibles	
(1) Direction and Attitude: Clockwise motion of a rotary control = right turn, counterclockwise motion = left turn; forward motion of lever or rotary control = bow down, aft motion of lever or rotary control = bow up.	
(2) Propulsion System Control: Forward lever motion = increasing forward motion of vessel, aft lever motion = decreasing forward motion/increasing rearward motion of vessel (i.e., to provide corollary control/vessel motions).	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.1.3.3.4 Control-Display Geometric Compatibility - Where applicable and/or practical, the shape of a control should correspond geometrically to that of the display it affects viz; (1) a round knob corresponds geometrically to a round dial with a rotating pointer, (2) a lever corresponds geometrically to a rectilinear display with linear pointer or cross-hair movements.	Recent automotive research shows control shape to influence operator expectations re; function and manipulation. (MFI study for DOT, e.g., DOT-HS-803-456)
5.1.3.3.5 Inside-Out vs Outside-In Principle - Instruments or displays that utilize semi-pictorial elements, along with fixed, scalar or indexing elements to allow the operator to quickly see positional relationships between himself and related features of the operating environment, may utilize either the "Inside-Out" or "Outside-In" principle. The "Outside-In" principle should normally be used when the operator will not have external cues, i.e., reliance throughout the mission will be completely on the artifical display. When the operation may involve alternate reference to the display and external references (viz; flying an airplane), the "Inside-Out" principle shall be used, i.e., so that the movement relationships between moving and fixed elements of the display are equivalent to the comparable elements in the external visual world. (See Figure_____).	Topic omitted in original - very germane to this section. Ref: Woodson and Conover, Human Engineering Guide for Equipment Designers, 1966, p 2-26.
5.1.3.3.6 Display Lag - The time lag between system/display response to control input should be kept to a minimum, consistent with safe and efficient system operation.	From 5.1.3.2, simplified since we cannot define "normally" in last sentence.
5.1.3.3.7 Fixed Scale/Moving Pointer vs Moving Scale/Fixed Pointer - When skirted, rotary knob controls are used, a fixed scale/moving pointer format is preferred, because both scale progression and control movement are compatible with operator expectancies. The moving scale/fixed pointer (i.e., the scale is imprinted on the knob skirt, and moves against a fixed index on the adjacent panel surface) shall only be used when operator time and error probability is not critical, and/or there is special benefit in having the scale value to be readout appear in a constant position (i.e., for check-reading several knob/dial devices).	Combines 5.1.3.5 & 5.1.3.6 since the "decision" is critical.



INSIDE-OUT DISPLAY

WHEN AN OPERATOR CONTROLS "OWN VEHICLE" FROM WITHIN THE COCKPIT, AN "INSIDE-OUT" DISPLAY FORMAT SHOULD BE USED. THIS FORMAT PROVIDES A ONE-TO-ONE MOTION RELATIONSHIP BETWEEN THE MOVING ELEMENT IN THE DISPLAY AND THE MOVING FEATURES OF THE OUTSIDE WORLD AS VIEWED THROUGH THE VEHICLE WINDSCREEN. IN (A) THE AIRCRAFT IS SHOWN BANKING TO THE RIGHT; IN (B) THE AIRCRAFT IS NOSE-HIGH; IN (C) THE AIRCRAFT IS NOSE-HIGH AND BANKING TO THE RIGHT. TO LEVEL THE WINGS, THE OPERATOR MOVES THE JOYSTICK IN THE DIRECTION OF THE ARTIFICIAL HORIZON DISCREPANCY. TO LOWER THE NOSE THE OPERATOR PUSHES THE STICK FORWARD. THIS TYPE OF DISPLAY OFTEN REFERRED TO AS A "CONTACT ANALOG" DISPLAY TENDS TO CONFUSE NAIVE OPERATORS SINCE THEY EXPECT TO MOVE THE CONTROL IN RELATION TO THE AIRCRAFT SYMBOL (WHICH UNFORTUNATELY DOES NOT MOVE).



OUTSIDE-IN DISPLAY

WHEN AN OPERATOR CONTROLS A "DRONE" VEHICLE (I.E., THE OPERATOR IS LOCATED OTHER THAN IN THE COCKPIT OF THE VEHICLE BEING CONTROLLED, AN "OUTSIDE-IN" FORMAT SHOULD BE USED SINCE IT WILL PRODUCE FEWER "CONTROL-REVERSAL" ERRORS BY NON PILOT-TRAINED OPERATORS. THE ACCOMPANYING ILLUSTRATIONS SHOW (A) A RIGHT BANK, (B) NOSE-HIGH, AND (C) COMBINATION NOSE-HIGH/RIGHT BANK. TO CORRECT THESE DISCREPANCIES THE OPERATOR "FLYS" THE AIRCRAFT SYMBOL "TO" THE FIXED HORIZON.

WHEN A PILOT FLYS A DRONE FROM THE COCKPIT OF AN AIRCRAFT, "INSIDE-OUT" DISPLAYS SHOULD BE USED FOR BOTH "OWN AIRCRAFT" AND "DRONE" CONTROL.

FIGURE_____ - INSIDE-OUT VS OUTSIDE-IN CONTROL-DISPLAY PRINCIPLES

ORIGINAL REQUIREMENT	MFI COMMENTS
5.1.4 Control Display Ratio -	Add the word "movement".
5.1.4.1 Minimization of Time - Control display ratio shall be selected for continuous adjustment controls so as to minimize the total time required to make the desired control movement (i.e., slewing time plus fine adjusting time), taking into consideration display size, tolerance requirements, viewing distance, and time delays.	Needs general, introductory par. to clarify the need to consider gross and precision adjustment requirements, operator limitations, and general principles relating to control-display ratio determination.
5.1.4.2 Range of Display Movement - When a wide range of display element movement is required, small movement of the control shall generally yield a large movement of the display element. When a small range of display movement is required, a large movement of the control shall result in small movement of the display.	Need to reorganize rest of the requirements so they are more compatible with the way a designer would expect to see the information categorized.
5.1.4.3 Knob, Coarse Setting - When a knob is provided for making coarse display element settings on linear scales -- 0.016 to 0.100 inch (0.4 to 0.25mm) tolerance -- approximately 6 inches (150 mm) display element movement shall be provided for one complete turn of the knob.	Suggest adding steering ratio criteria.
5.1.4.5 Bracketing - When bracketing is used to locate a visual or auditory null position (e.g., tuning a transmitter), the knob shall move through an arc of 30 to 60 on either side of the null position in order for a misalignment to be just noticeable.	
5.1.4.6 Foot-Operated Controls - Foot-operated controls shall be provided only for gross settings.	Suggest slight expansion here in order to make it more comprehensive.
5.1.4.7 Lever, Coarse Setting - When a lever is provided for coarse settings -- 0.016 to 0.100 inch (0.4 to 2.5 mm) tolerance -- one unit of display element movement shall be used to three units of lever movement.	Suggest removing tolerances - these are not only confusing, but questionable criteria.
5.1.4.8 Lever, Two-Dimensional Setting - When a lever is provided to make settings in two dimensions to coarse tolerances -- 0.1 inch (2.5 mm) -- one unit of display element movement shall be used to two and one-half units of lever movement.	
5.1.4.9 Counters - When counters are provided, the control-display ratio shall be such that one revolution of the knob equals approximately 50 counts (i.e., the right hand drum rotates five times).	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.1.4 Control-Display Movement Ratio	
5.1.4.1 General - Control-display movement ratios for continuous-adjustment controller tasks shall be selected so as to minimize the total time required for the operator to work the desired control movement, i.e., to accommodate both response time and precision-setting requirements.	Conceptual elements are gathered under general head, followed by details. This should make requirements easier to follow.
5.1.4.1.1 Coarse vs Fine Setting - The amount of control and/or display movement shall be compatible with the operator's inherent capacity to discriminate visual and tactile inputs from displayed elements and/or control movement feedback. For coarse setting tasks, control movement should be less than display movement; for fine setting tasks, display movement should be greater than control movement. When a task may include requirements for both coarse and fine setting the control/display ratio should be chosen to minimize the time to make control settings. At operator stations where some tasks require only coarse settings, but others require fine settings, the operator should be provided with two selectable ratios, normal and "fine."	Ref: Van Cott, Human Engineering Guide for Equipment Design, 1972, p 348-49.
5.1.4.1.2 Hand vs Foot Controls - Foot controls shall be used only for coarse adjustments or settings. Hand/arm-operated controls may be used for both coarse and fine adjustment. The more precision required, the less arm movement should be involved in control operation.	
5.1.4.2 Coarse Setting - The following criteria shall apply: a. Knob/Linear Scale - 1 full knob rotation = approximately 6-inches of display element movement. b. Lever/Linear Scale - 1 to 2 units of lever movement = 1 unit of display element movement. c. Steering Wheel - Approximately 3 $\pm$1/2 turns of the wheel = lock-to-lock.	Have removed tolerance definitions. They are not in proper terms (e.g., %) and if they were, are not applicable across the board.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.1.4.3 Fine Setting - The following criteria shall apply:	
a. Knob/Linear Scale - 1 full knob rotation = 1 to 2 inches of display element movement.	
b. Lever/Linear Scale - 3 to 4 units of lever movement = 1 unit of display element movement.	
5.1.4.4 Bracketing for Determining Maximum or Minimum Values - When bracketing is to be used to locate a maximum or minimum rather than a specific value (e.g., as in tuning a transmitter), the control knob shall swing through an arc of at least plus or minus 10 degrees but not more than plus or minus 30 degrees either side of the target value in order to make the peak or dip associated with that value clearly noticeable.	
5.1.4.5 Counter-Setting - The following criteria shall apply:	Broadened coverage.
a. Multi-Digit, Mechanical Drum Counters - One revolution of a knob should equal approximately 50 counts (i.e., the right-hand drum rotates five times).	Ref: Woodson and Conover, Human Engineering Guide for Equipment Designers, 1966, p. 2-33.
b. Multi-Digit Electronically-Displayed Counters - A momentary switch type control shall be used. Both slow and fast speed (slew) operation should be provided so the operator can either slew through the digits rapidly (about 2 digits per second for the cell being read) or step through, one digit at a time. In the latter case, the system should preclude the operator advancing more than one character in the event the control is not released. However, it is preferred to have a system in which both forward and reverse display changes can be made (i.e., so that the operator can "backup" one or two digits rather than having to "cycle-through" the series to obtain the desired setting.	
c. Single-Digit Electronically-Displayed Counter - A momentary-contact step advance may be sufficient unless frequent setting is required in which case a two-speed switch should be provided as for the multi-digit counter.	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.1.4.6 Foot-Operated Controls - Foot-operated controls should not be used to adjust a visual display directly, i.e., other than indirect display of vehicle changes in direction, acceleration, etc.). If a directly-coupled display adjustment is to be made by foot-operated control movements, it should be only for gross, relatively slow settings. Foot-operated controls, when used to control the direction of vehicle movement (as in small submersibles) should be instrumented to indicate the direction and magnitude of control surface actuation as well as the heading of the vehicle.	First sentence is believed necessary to preclude use of foot control "just" to adjust a display.

ORIGINAL REQUIREMENT	MFI COMMENTS
5.2 VISUAL DISPLAYS -	
5.2.1 General - Visual displays should be utilized to provide the operator with a clear indication of equipment or system conditions for operation under any eventuality commensurate with the operational and maintenance philosophy of the system under design.	
5.2.1.1 Display Illumination - When the degree of dark adaptation required is not maximum, low brightness white light (preferably integral), adjustable as appropriate, shall be used; however, when the maximum degree of dark adaptation is required, low brightness red light (greater than 620 nm) shall be provided. Where multiple displays are grouped together, the displays shall have brightness uniformity so that all appear of equal brightness across the range of full ON to full OFF.	
5.2.1.2 Information -	5.2.1.2 This section is about information requirements.
5.2.1.2.1 Content - The information displayed to an operator shall be limited to that which is necessary to perform specific actions or to make decisions.	5.2.1.2.1 Although strictly speaking this may be correct there are other considerations which should be brought out.
5.2.1.2.2 Precision - Information shall be displayed only to the degree of specificity and precision required for a specific operator action or decision.	5.2.1.2.2 This statement as written might conceivably give the wrong idea about scale design in relation to information granularity.
5.2.1.2.3 Format - Information shall be presented to the operator in a directly useable form. (Requirements for transposing, computing, interpolating, or mental translation into other units shall be avoided.)	5.2.1.2.3 Minor revision.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2 VISUAL DISPLAYS -	
5.2.1 General - Visual displays are used for a wide variety of purposes such as sensing, detection, tracking identification, monitoring, decision making, system or process control, and pattern recognition. They may be without memory and present only transient, real-time data, or may have memories and present data accumulated over a period of time. A direct reading meter is an example of a transient display and a status board is an example of a memory display. Visual displays without memory should be used whenever the visual channel is superior for sensing and perceiving transient information as compared with other sensory channels. Visual displays with memory should be used whenever it is desirable to allow the user to have random access to information accumulated over a period of time.	Feel this amplification helps set stage for following detailed requirements.
5.2.1.1 Display Illumination - The full range of operational conditions shall be taken into account in designing display illumination. A display which must be operable under conditions varying from night blackout conditions to full daylight shall incorporate the necessary illumination features to allow proper use under all these widely varying conditions. A display which will always be used in a controlled lighting environment, e.g., a command control center may need to satisfy illumination requirements only for the ambient conditions of that task environment. When complete dark adaptation is required, the illumination shall be low-brightness red light (greater than 620 nm); when only partial adaptation is required low brightness white illumination may be used as appropriate for specific applications.	Increases scope and definition requirement.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.1.2 <u>Information Requirements</u>	
5.2.1.2.1 <u>Content</u> - The information displayed to an operator shall be limited to that which is necessary for performing specific actions, monitoring a situation, or making decisions or assessments. Extraneous information which can be of no use either in normal or emergency operation shall not be displayed.	5.2.1.2.1 Much more information may be presented for monitoring a situation than might be obviously needed for specific actions or decisions. Also information may need to be presented which would not normally be used but which would be essential for an operator in order to quickly assume emergency or fall back duties.
5.2.1.2.2 <u>Precision</u> - Information shall be displayed only to the level of precision which is operationally meaningful and useful to the operator, except that scale designs should be based on logical numerical progressions as specified in 5.2.3.1.5.1. (E.g., in a system in which antenna position is known only to the nearest 7^{o}, the best scale to use would be graduated in 5^{o} intervals.)	5.2.1.2.2 Relates information granularity to scale progression.
5.2.1.2.3 <u>Format</u> - Information shall be presented to the operator in a directly usable form whenever practical so as to minimize the requirements for transposing, computing, interpolating, conversion of units, etc.	5.2.1.2.3 Practicability clause added.

ORIGINAL REQUIREMENT	MFI COMMENTS
5.2.1.2.4 Redundancy - Redundancy in the display of information to a single operator shall be avoided unless it is required to achieve specified reliability. 5.2.1.2.5 Combined Information - Information necessary for performing different activities (e.g., operation and troubleshooting) shall not simultaneously appear in a single display unless they are comparable functions requiring the same information. 5.2.1.2.6 Display Failure Clarity - Displays shall be so designed that failure of the display or display circuit will be immediately apparent to the operator. 5.2.1.2.7 Display Circuit Failure - Failure of the display circuit shall not cause a failure in the equipment associated with the display. 5.2.1.2.8 Unrelated Markings - Trademarks and company names or other similar markings not related to the panel function shall not be displayed on the panel face.	This statement leaves the user with the impression that redundancy is generally undesirable and should be avoided unless it can be related to a "specified" reliability. Paragraphs 5.2.1.2.5 and 5.2.1.2.8 require minor revision. Paragraph 5.2.1.2.7 should be deleted because it is really an engineering design matter rather than a human engineering matter. Paragraph 5.2.1.2.6 needs amplification.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.1.2.4 Redundancy - Redundancy of information appears in systems by presenting the same information in two or more different places, at two or more different times, or under two or more different encoding techniques. Redundancy may be constructively utilized to facilitate pattern recognition, enhance detectability, provide back-up capability, speed up information retrieval, and increase reliability in information processing. Redundancy shall be avoided, however, if it simply increases the volume of information which must be displayed and processed without obvious constructive purpose.	The revision indicates that redundancy may be constructively utilized in several ways, but it should be avoided if not purposeful.
5.2.1.2.5 Combining Operator/Maintainer Information - Operator and maintainer information shall not be combined in a single display unless the information content and format are well suited to, and time compatible for both users.	5.2.1.2.5 It is not important that the functions be comparable, but it is essential that both the operator and maintainer get the information they need, and get it in a timely manner.
5.2.1.2.6 Display Failure Indication - Displays shall be so designed that failure of the display itself or of the associated display circuitry will be readily apparent to the operator by a suitable technique such as one or more of the following. a. The display illumination is extinguished b. The display sweep stops scanning c. A failure indicator is energized	5.2.1.2.6 This revision provides greater specificity than the original.
5.2.1.2.7 Unrelated Markings - Trademarks and company names or other similar markings not related to panel function shall not be displayed on the panel face, or if displayed, shall be clearly differentiable from panel labels and markings having to do with function. If the unrelated markings are displayed at all, they should be displayed with reduced character size and diminished contrast so as to reduce their conspicuity in comparison with the other markings.	5.2.1.2.7 (5.2.1.2.8 in the original). Some standards call for identifying markings to appear on instruments. This should be acceptable provided the markings are not obvious and would not be confused with function labels.

ORIGINAL REQUIREMENT	MFI COMMENTS
5.2.1.3 Location and Arrangement - 5.2.1.3.1 Accuracy - Displays shall be located and designed so that they may be read to the degree of accuracy required by personnel in the normal operating or servicing positions. 5.2.1.3.2 Access - Ladders, supplementary lighting, or other special equipment should not be required in order to gain access to or to read a display. 5.2.1.3.3 Orientation - Display faces shall be perpendicular to the operator's normal line of sight whenever feasible and shall not be less than 45° from the normal line of sight (see Figure 1). Parallax shall be minimized. 5.2.1.3.4 Reflection - Displays shall be constructed, arranged, and mounted to prevent reduction of information transfer due to the reflection of the ambient illumination from the display cover. Reflection of instruments and consoles in windshields and other enclosures shall be avoided. If necessary, techniques (such as shields and filters) shall be employed to insure that system performance will not be degraded. 5.2.1.3.5 Vibration - Vibration of visual displays shall not degrade user performance below the level required for mission accomplishment (see para 5.8.4.2).	
5.2.1.3.6 Grouping - All displays necessary to support an operator activity or sequence of activities shall be grouped together 5.2.1.3.7 Function and Sequence - Displays shall be arranged in relation to one another according to their sequence of use or the functional relations of the components they represent. They shall be arranged in sequence within functional groups whenever possible to provide a viewing flow from left to right or top to bottom.	5.2.1.2.6 through 5.2.1.3.10 The material in these paragraphs should be moved to the control-display integration section, (new 5.1.2) except for 5.2.1.3.5, "Vibration"--because all of these requirements apply to controls as well as displays.

ORIGINAL REQUIREMENT	MFI COMMENTS
5.2.1.3.8 Frequency of Use - Displays used most frequently should be grouped together and placed in the optimum visual zone (see Figure 2). 5.2.1.3.9 Importance - Very important or critical displays shall be placed in a privileged position in the optimum projected visual zone or otherwise highlighted. 5.2.1.3.10 Consistency - The arrangement of displays shall be consistent in principle from application to application, within the limits specified herein. 5.2.1.3.11 Maximum Viewing Distance - The viewing distance from the eye reference point to displays located close to their associated controls shall not exceed 28 inches (710 mm). Otherwise, there is no maximum limit other than that imposed by legibility limitations, which shall be compensated for by proper design. NOTE: A 30-inch (760 mm) clearance is required when using ejection seats. 5.2.1.3.12 Minimum Viewing Distance - The effective viewing distance to displays, with the exception of cathode ray tube displays (see 5.2.4.2) and collimated displays, shall never be less than 13 inches (330 mm) and preferably not less than 20 inches (510 mm). 5.2.1.3.13 Aircrew Station Signals - Signals for aircrew stations shall be in accordance with MIL-STD-411. Human Engineering design for other members of the crew who occupy positions in the air vehicle other than on the flight deck (such as in multi-engined specialized aircraft) shall be in accordance with the criteria in this standard. (See 5.14.2.1.)	

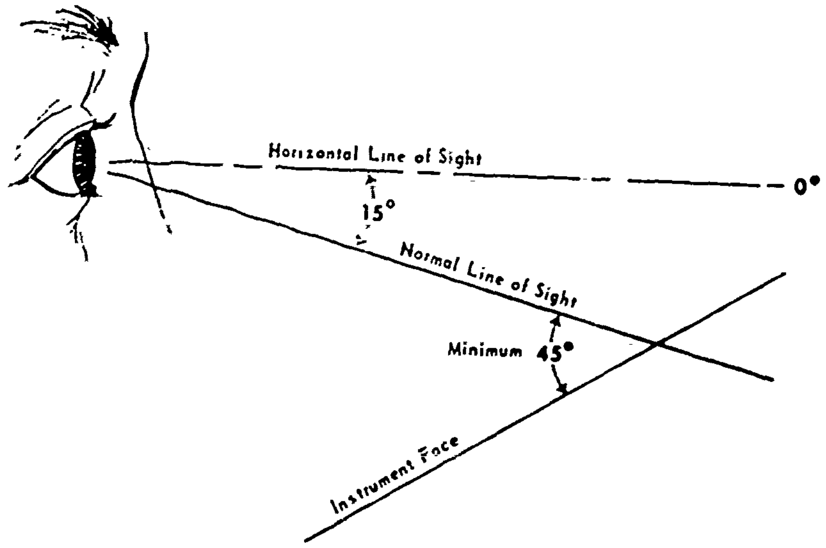


Figure 1. LINES OF SIGHT

ORIGINAL

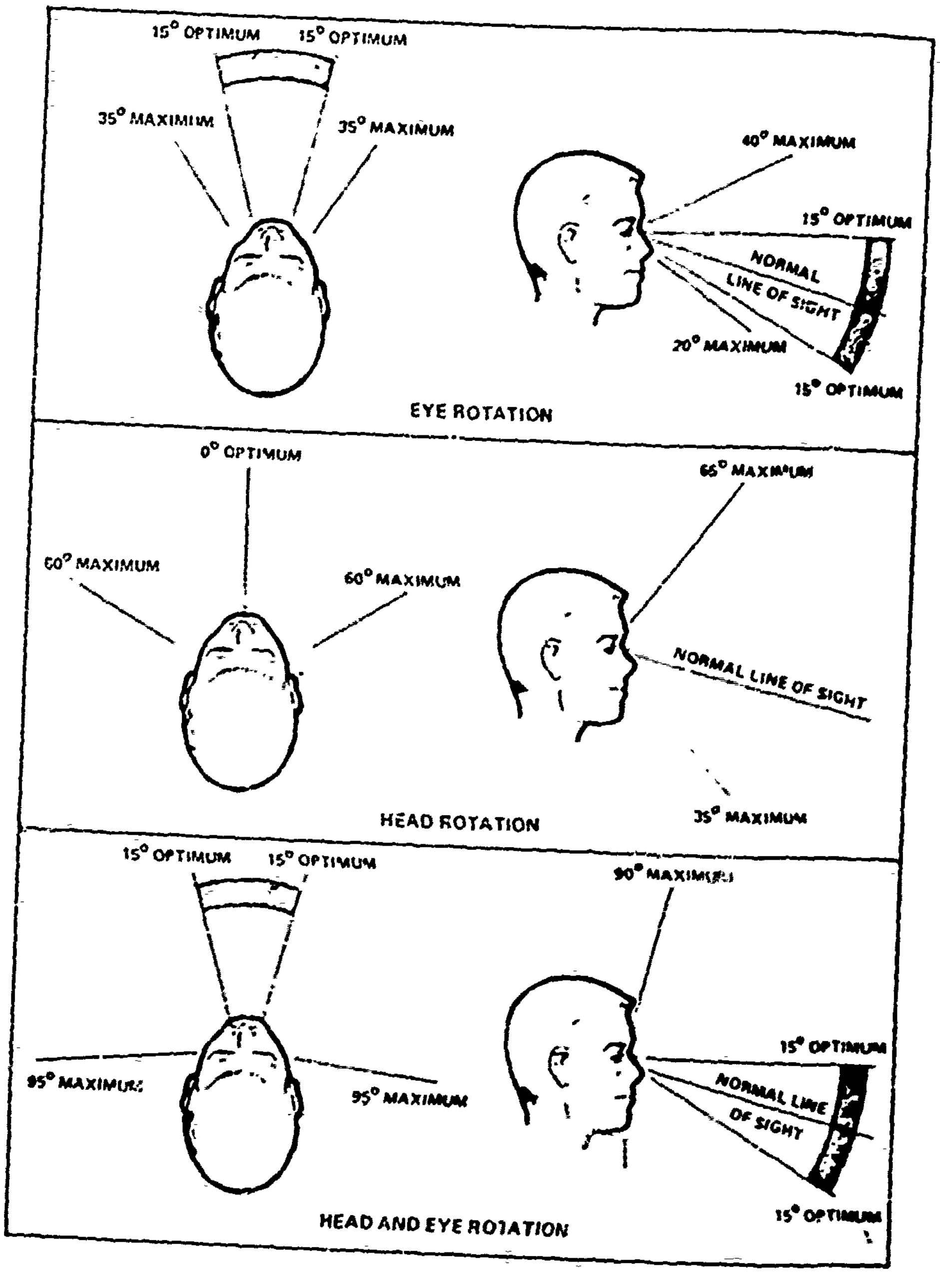


Figure 2 - Vertical and Horizontal Visual Field

ORIGINAL

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.1.3 Display Location and Arrangement - Display location and arrangement shall be in accordance with the factors identified in section 5.1.2, General Arrangement Factors, and the following additional r irements specific to displays. Limits on display location are lso defined in Figures 1 and 2.	A new Fig 2 is provided.
5.2.1.3.1 Accuracy - Displays shall be located and designed so that they may be read to the degree of accuracy required by operating and servicing personnel when they occupy expected nominal working positions. Consideration shall be given to viewing distance, viewing angle, illumination and possible intervening obstacles.	The constraining variable are identified.
5.2.1.3.2 Access - Visual displays should be visually accessible without resorting to use of ladders, flashlight or other special equipment in order to read the display.	Broader and more explicit.
5.2.1.3.3 Orientation - Reading errors due to parallax shall be minimized by positioning display faces perpendicular to the operator's normal line of sight (see Figure 1), or not less than 45° from the normal line of sight.	Identifies intent first.
5.2.1.3.4 Reflection - Displays shall be constructed, arranged, positioned, shielded, and/or cover glass treated to minimize loss of information transfer due to reflections (ambient light, reflection of the oeprator or other objects within the viewing envelope). Reflection of instrument faces in windshields or other critical viewing windows shall be avoided. If necessary, special display/illumination filtering techniques shall be used to insure that system performance will not be degraded.	Needed pointer added.
5.2.1.3.5 Vibration - [Use original material from 5.2.1.3.5.]	

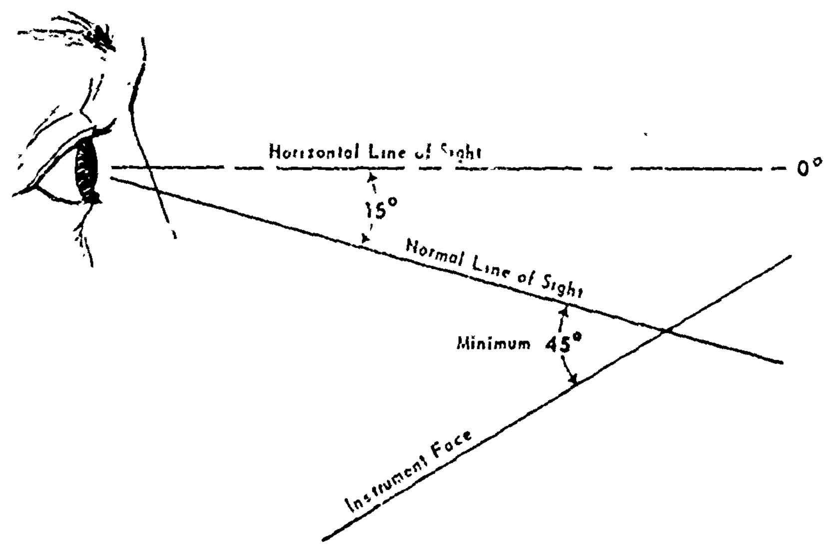
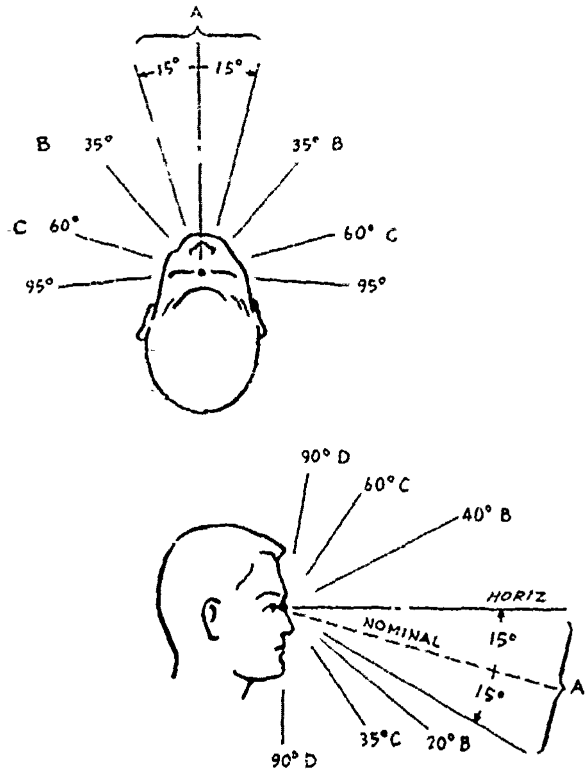


Figure 1. LINES OF SIGHT



A – Optimum envelope when operator must concentrate on primary visual object yet needs to pick up peripheral signal.

B – Maximum envelope within which peripheral signals may be detected without eye movement.

C – Maximum envelope when head is fixed but eyes are free to rotate.

D – Maximum envelope when both head and eyes are free to rotate.

Note: Normally the nominal eye reference axis is about 15 degrees down from the horizontal as shown above. However, the nominal axis may be different depending on the position of a primary display that may have to be located other than according to the normal relaxed eye reference (i.e., due to other physical constraints such as the dash board of a vehicle).

Figure 2 - Visual Field Design Reference Criteria (Revised)

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.1.3.6 Viewing Distance - Display location relative to the operator depends on several factors, i.e., display detail, size, and illumination vs nominal viewing distance, and whether the operator must have manual contact with the display. Displays shall not be located so far from the operator that displayed detail cannot be recognized or read, nor shall the display be placed so close to the operator that visual accommodation becomes difficult and tiring. The following criteria shall apply:	Expanded preparatory information so the criterion statements will be more clearly understood.
a. Viewing distance from the eye reference point of displays located close to associated controls shall not exceed 28 inches (71.1 cm).	Ref: Woodson and Conover, Human Engineering Guide for Equipment Designers, 1966, p. 2-129.
b. Minimum viewing distance should not be less than 13 inches (33.0 cm) and preferably not less than 16 inches (40.6 cm).	Professional Judgment; Ref: NAVSHIPS Display Illumination Design Guide (NELC TD 223), 1973, Sect. 2.
5.2.1.3.7 Aircrew Station Signals - [Use original material in 5.2.1.3.13]	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.2.1.4 Coding -	
5.2.1.4.1 Objectives - Coding techniques shall be used to facilitate: a. Discrimination between individual displays b. Identification of functionally related displays c. Indication of relationship between displays d. Identification of critical information within a display.	General information transfer enhancement occurs when internal instrument coding is used.
5.2.1.4.2 Techniques - Displays shall be coded by color, size, location, shape, or flash coding, as applicable.	
5.2.1.4.3 Standardization - All coding within the system shall be uniform and shall be established by agreement with the procuring activity.	Important that designer utilize already-established codes too!

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.1.4 Coding of Visual Displays	
5.2.1.4.1 Objectives -	
[Add -]	
e. General ease with which display features can be discriminated within a single display.	
5.2.1.4.2 Techniques -[Displays may (instead of shall)...]	Should not be mandatory.
5.2.1.4.3 Standardization - Display coding within a system should be uniform. Previously established coding standards shall be followed, and any variations from these, and/or newly-proposed codes shall be established by agreement with the procuring activity.	Inserts necessary caution to recognize and follow current coding standards.

ORIGINAL REQUIREMENT	MFI COMMENTS
5.2.2 Transilluminated Displays -	Although term "transilluminated" may be useful, it is not sufficiently recognized to be used as a title.
5.2.2.1 General - The following three general types of transilluminated displays should be considered:	
a. Single- and multiple-legend lights, which present information in the form of meaningful words, numbers, symbols, and abbreviations.	
b. Simple indicator lights, such as pilot, bull's-eye, and jewel lights.	Signal lights?
c. Transilluminated panel assemblies, which present qualitative status or system readiness information.	
5.2.2.1.1 Use - Transilluminated indicators should be used to display qualitative information to the operator (primarily, information that requires either an immediate reaction on the part of the operator, or that his attention be called to an important system status). Such indicators may also be used occasionally for maintenance and adjustment functions.	Minimally informative.
5.2.2.1.2 Equipment Response - Lights, including those used in illuminated push buttons, shall display equipment response and not merely control position.	Too simplistic to address broad range of applications.
5.2.2.1.3 Information - Lights and related indicators shall be used sparingly and shall display only that information necessary for effective system operation.	Really needs to emphasize point of "too many lights".
5.2.2.1.4 Positive Feedback - The absence or extinguishment of a signal or visual indication shall not be used to denote a "go-ahead", "ready", "in-tolerance", or completion condition, nor shall such absence be used to denote a "malfunction", "no-go", or "out-of-tolerance" condition; however, the absence of a "Power On" signal or visual indication shall be acceptable to indicate a "Power Off" condition. Changes in display status shall signify changes in functional status rather than results of control actuation alone.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.2.2.1.5 Grouping - Master caution, master warning, master advisory and summation lights used to indicate the condition of an entire subsystem shall be set apart from the lights which show the status of the subsystem components, except as required under paragraph 5.2.2.1.8.	This is not universally so. Also the title should reflect main subject, i.e., "Master" warning lights.
5.2.2.1.6 Location - When a transilluminated indicator is associated with a control, the indicator light shall be so located as to be immediately and unambiguously associated with the control and visible to the operator during control operation.	Inadequate coverage.
5.2.2.1.7 Location, Critical Functions - For critical functions, indicators shall be located within 15° of the operator's normal line of sight (see Figure 2). Warning lights shall be an integral part of, or located adjacent to, the lever, switch, or other control device by which the operator is to take action.	This should be combined with 5.2.2.1.6.
5.2.2.1.8 Maintenance Displays - Indicator lights used solely for maintenance and adjustment, and referred to infrequently, shall be covered or non-visible during normal equipment operation, but shall be readily accessible when required.	"Non visible" not always necessary, or practical.
5.2.2.1.9 Luminance - The luminance (brightness) of transilluminated displays shall be compatible with the expected ambient illuminance level, and shall be at least 10% greater than the surround luminance.	This needs expansion to make sure designer recognizes all variables that also have to be considered. Otherwise he will not be prepared for ensuing set of requirements.
5.2.2.1.10 Luminance Control - When displays will be used under varied ambient illuminance, a dimming control shall be provided. The range of the control shall permit the displays to be legible under all expected ambient illuminance. The control shall be capable of dimming the display from full ON to full OFF.	
5.2.2.1.11 Reflection - Provision shall be made to prevent direct and/or reflected sunlight from making indicators appear illuminated when they are not, or to appear extinguished when they are illuminated.	Omits problem of "self reflection".
5.2.2.1.12 Contrast Within the Indicator - The luminance contrast within the indicator shall be at least 50% (See 3.18). For aircraft or other low ambient illumination applications (e.g., MIL-L-25467), this ratio should be at least 90% (see 3.18), with the background luminance less than the figure luminance.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.2.2.1.13 Lamp Redundancy - For incandescent displays or for other than airborne applications, lamps shall be provided that incorporate filament redundancy or dual bulbs, so that when one filament or bulb fails, the intensity of the light shall decrease sufficiently to indicate the need for lamp replacement, but not so much as to degrade operator performance. 5.2.2.1.14 Lamp Testing - When indicator lights using incandescent bulbs are installed on a control panel, a master light test control shall be incorporated. When applicable, design shall allow testing of all control panels at one time. Panels containing three or fewer lights may be designed for individual press-to-test bulb testing. Circuitry should be designed to test the operation of the total indicator circuit. If dark adaptation is a factor, a means for reducing total indicator light brightness during test operation shall be provided. 5.2.2.1.15 Lamp Removal, Method - Where possible, provisions shall be made for lamp removal from the front of the display panel without the use of tools, or by some other equally rapid and convenient means. 5.2.2.1.16 Lamp Removal, Safety - Display circuits shall be designed so that bulbs may be removed and replaced while power is applied without causing failure of indicator circuit components or imposing personnel safety hazards. 5.2.2.1.17 Indicator Covers - Legend screen or indicator covers shall be designed to prevent inadvertent interchange or a means shall be provided for checking the covers after installation to insure they are properly installed. 5.2.2.1.18 Color Coding - With the exception of aircrew station signals which shall conform to MIL-STD-411, and training equipment which shall conform to MIL-T-23991, transilluminated light emitting diode (LED) and incandescent displays shall conform to the following color coding scheme, in accordance with Type I - Aviation colors of MIL-C-25050. a. RED shall be used to alert an operator that the system or any portion of the system is inoperative, or that a successful mission is not possible until appropriate corrective or override action is taken. Examples of indicators which should be coded RED are those which display such information as "no-go", "error", "failure", "malfunction", etc.	

ORIGINAL REQUIREMENT	MFI COMMENTS
b. FLASHING RED shall be used only to denote emergency conditions which require operator action to be taken without undue delay, to avert impending personnel injury, equipment damage, or both. c. YELLOW shall be used to advise an operator that a condition exists which is marginal. YELLOW shall also be used to alert the operator to situations where caution, recheck, or unexpected delay is necessary. d. GREEN shall be used to indicate that the monitored equipment is in tolerance or a condition is satisfactory and that it is all right to proceed (e.g., "go-ahead", "in-tolerance", "ready", "function activated", "power on", etc.). e. WHITE shall be used to indicate system conditions that do not have "right" or "wrong" implications, such as alternative functions (e.g., Missile No. 1 selected for launch, etc.) or transitory conditions (e.g., action or test in progress, function available), provided such indication does not imply success or failure of operations. f. BLUE may be used for an advisory light, but preferential use of BLUE should be avoided.	
5.2.2.1.19 Flashing Lights - The use of flashing lights shall be minimized. Flashing lights may be used only when it is necessary to call the operator's attention to some condition requiring action. The flash rate shall be within 3 to 5 flashes per second with approximately equal amounts of ON and OFF time. The indicator shall be so designed that, if it is energized and the flasher device fails, the light will illuminate and burn steadily (see 5.3.2.4).	There are numerous conflicts with this flash rate. We suggest modification except when "attention-getting" is critical. Should ref other standards re; signal lights.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.2 Light-Generated Displays	
5.2.2.1 General - Light-generated displays (hereinafter referred to as "transilluminated displays") may be used to indicate system, equipment and/or control condition. The following general types should be considered: a. Single- and multiple-legend lights, which present information in the form of meaningful words, numbers, symbols, and abbreviations. b. Simple indicator lights, such as pilot lights, bull's-eye or jewel lights, and exterior signal lights. c. Transilluminated panel assemblies, which present qualitative status or system readiness information.	This more adequately describes the scope.
5.2.2.1.1 Application - Transilluminated displays should be used when the "attention-getting" value of an illuminated vs non-illuminated display is needed to increase the liklihood that the operator will attend to the conditional or functional information in a timely fashion. Except for certain cases (i.e., equipment Power-ON pilot light), an "illuminated" display shall indicate a positive system response, i.e., the absence or extinguishment of a light shall not be used to denote "go-ahead", "ready", "in-tolerance","condition completion", and/or "no-go" or "out-of-tolerance" condition.	This clarifies the purpose and establishes application objectives and limitations.
5.2.2.1.2 Equipment Response - Generally, equipment state rather than control position or condition shall be displayed, considering the following: a. Equipment state should always be continually displayed. b. Control actuation should be transiently displayed. c. Control setting should be continuously displayed if it can be at variance with equipment state, e.g., an "in-transit" condition should remain ON until the system state is consistent with the control state (except for in-transit durations shorter than the operator's response time.)	This broadens the conditions to be addressed.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.2.1.3 Number of Displays - Due to the distracting characteristics of light-generated displays, such displays should be used sparingly and shall display only that information necessary for effective system operation.	Title change more to the point.
5.2.2.1.4 Master Warning, Caution and Advisory Lights - Master warning, caution and/or advisory lights may be used to indicate the condition of an entire subsystem, i.e., when space limitations preclude location of an entire set of condition indicators in the preferred viewing area, a master light indicator should be located in the preferred viewing position, to indicate to the operator that one or more of the "condition" indicators has been activated (the latter being grouped in a less critical area of the workspace or control panel), except as required in 5.2.2.1.6.	Original was unnecessarily limiting, and couldn't be justified in all applications. This expands the concept so it is more universally applicable.
5.2.2.1.5 Location of Transilluminated Displays	
a. When an indicator is associated with a control, the indicator light shall be so located as to be immediately and unambiguously associated with the control and visible to the operator during control operation (except when the light is in an integral part of special control handles viz; aircraft flight controls).	Brings in exceptions. Otherwise we would have unnecessary conflicts with AFSCM 80-1 (HIAD).
b. Critical function indicators (e.g., safety-related Master Warning Lights) shall be located within 15° of the operator's normal line of sight (see Figure 2), except as indicated in (a) above.	This key point was not in the original.
5.2.2.1.6 Maintenance Displays - Indicator lights used solely for maintenance (not required by the operator) shall be covered or made less conspicuous during normal operation (i.e., they are not illuminated except when actual maintenance is being performed). Covered elements shall be easily accessible when required.	Slightly broadened.
5.2.2.1.7 Display Luminance and Visibility	
5.2.2.1.7.1 Luminance - The luminance (brightness) of transilluminated displays shall be compatible with the expected range of ambient illuminances associated with mission operation and/or servicing and maintenance of the system and equipment. The following factors shall be considered in determining luminance levels:	This clarifies the total picture of luminance.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
a. Within-display contrast, i.e., contrast between light ON vs OFF modes; two-level contrast if display requires a dormant luminance to read an identifying label, plus an active luminance increase to indicate functioning mode.	
b. Display/Surround contrast, i.e., contrast between the illuminated indicator and its immediate panel surface, in which case effects of ambient reflection on either the display or surround shall be compensated for (i.e., by increased display luminance, surround surface modification, use of filters or shields, etc.).	
c. Operator visual-adaptation requirements, i.e., display brightness shall be compatible with the operator's requirement to detect low-level signals or targets in the external visual environment, and/or perceive faint signals on a CRT or read red-lighted instruments provided for night time operation.	
d. Conspicuity and attention-demand requirements, i.e., luminances shall provide the required alerting to insure that the operator will not miss a critical warning, caution or advisory message.	
e. Distraction, i.e., luminance levels shall not dazzle or otherwise distract the operator in a manner that could be detrimental to safe, efficient system operation.	
5.2.2.1.7.2 <u>Brightness Level</u> - Brightness of the illuminated indicator shall be at least 10% greater than the immediate mounting surface. When a two-level indicator is used, the difference between the dormant and illuminated brightnesses shall be approximately 2:1, considering always the factors noted in 5.2.2.1.7.1.	Ref: Van Cott, <u>Human Engineering Guide to Equipment Design</u>, 1972, p. 62.
5.2.2.1.7.3 <u>Brightness Control</u> - When displays will be used under varied ambient illuminance, a dimming control shall be provided. The range of control shall permit the displays to be legible under all expected ambient illuminance. Dimming from "full-ON" to "full-OFF" may be provided in certain non-critical operations, but shall not be used if inadvertent failure to turn on an indicator(s) would lead to critical operator failures, i.e., failure to detect or perform a critical step in an operation.	This adds the requirement need to prevent operator from turning off critical displays.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.2.2 Legend Lights	
5.2.2.2.1 Application - Transilluminated displays containing legends shall be used in preference to simple indicator lights except in certain applications such as Power pilot lights, and/or vehicular and other external signalling lights.	Clarifies exceptions.
5.2.2.2.2 Visibility and Legibility - Legends shall be visible to the operator whether or not the indicator is energized. except in warning and caution indicators, and flight crew stations. The size and other characteristics of lettering used for legends shall conform to 5.5 herein, or as otherwise specified by the procuring activity.	To eliminate conflict with other specs. Also encompasses lettering to eliminate separate par. 5.2.2.2.3. See MIL-STD-411 and MIL-T-23991.
5.2.2.2.3 Color Coding - Legend lights may be color coded. If used, colors shall conform to the following criteria:	
a. Use of RED, YELLOW, GREEN or BLUE shall conform to requirements in 5.2.2.1.8 [originally 5.2.2.1.18] .	
b. Other, "pale" colors may be used as a means of providing visual differentiation between and among single and grouped indicators. Such coding colors shall not conflict with colors in (a), nor materially reduce the legibility of legends. Approval for such coding shall be obtained from the procuring activity.	An acceptable practice.
5.2.2.2.4 Display Size - Choice of legend indicator size and shape shall be determined on the basis of legend legibility, i.e., the maximum number and size of letters or symbols required for a given application. There shall be at least a minimum border around each legend equalling the width of the letter 'H' of the selected type font. Display size may be used sparingly as a coding device, i.e., legend lights that denote personnel or equipment disaster may be discriminably larger than other indicators. Typically these should also be color coded and where appropriate, brighter than other indicators.	This is an important addition based on current experience working with designers. Mainly because of current fad to operate everything by push buttons and legend lights.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.2.2.5 <u>Multi-Function Legends</u> - Indicators designed to provide alternately-presented legends shall present only one legend at a time, i.e., the legend not in use shall not be visible. If the indicator device utilizes "stacked" legends, it shall be designed so that (1) when the rear legend is energized, it shall not be obscured by the front legend(s), (2) rear legend plates are so positioned as to minimize parallax, and (3) rear legends have approximately equal brightness to front legends, and the contrast between rear legends and background is equal to that of front legend and its background.	This replaces "Matrix" par. 5.2.2.2. because this type of display was not covered originally, and the original 5.2.2.2.6 is useless, i.e., it is not clear what is meant by "matrix" or "symbol ambiguity".

ORIGINAL REQUIREMENT	MFI COMMENTS
5.2.2.3 Simple Indicator Lights -	
5.2.2.3.1 Use - Simple indicator lights should be used when design considerations preclude the use of legend lights.	Too limited!
5.2.2.3.2 Spacing - The spacing between adjacent edges of simple round indicator light fixtures shall be sufficient to permit unambiguous labeling, indicator interpretation, and convenient bulb removal.	
5.2.2.3.3 Coding - Simple indicator lights shall be coded in conformance with Table II; however, the different sizes shown are intended only for the attention-getting value that larger lights of at least equal luminance provide in relation to indicator lights of lesser importance.	Should not be mandated!

TABLE II. CODING OF SIMPLE INDICATOR LIGHTS

SIZE/TYPE	COLOR			
	RED	YELLOW	GREEN	WHITE
1/2-INCH (13mm) DIAMETER or SMALLER/STEADY	Malfunction; action stopped; failure; stop action.	Delay; check; recheck.	Go ahead; in tolerance; acceptable; ready.	Functional or physical position; action in progress.
1-INCH (25mm) DIAMETER or LARGER/STEADY	Master summatic (system or subsystem).	Extreme caution (impending danger).	Master summation (system or subsystem).	
1-INCH (25mm) DIAMETER or LARGER/FLASHING (3 to 5/sec.)	Emergency condition (impending personnel or equipment disaster).			

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.2.3 Simple Indicator, Signal and Identification Lights	Title expansion considered desirable.
5.2.2.3.1 Application - Simple, non-legend light displays may be used when design considerations make legend light displays impractical, e.g.: a. Small size of pilot light precludes legend or symbol imprint on display surface. Application primarily for Power-ON-OFF indication. b. Small equipment indicator, e.g., light to indicate radio is in AM vs FM mode. c. Vehicular panel indicator, e.g.: "high beam" headlight mode, left/right "turn signal indication", etc. d. External vehicle identification/mode lights, e.g.: rear caution/stop/backup/turn lights, vehicle perimeter warning lights, and "blackout" lights, aircraft position lights, navigation lights, anti-collision lights. e. Ground-based beacons, airport runway, taxiway, obstacle warning and roadway signal lights. f. Marinecraft position, navigation and signalling lights.	This expansion is more representative of the applications scope.
5.2.2.3.2 International Conventions and Standards - International conventions and standards for aircraft, highway vehicle, and marinecraft shall be followed in design, location and luminance characteristics of all military systems utilizing public roadways, airways, or navigable streams, rivers and seaways.	This is a key point not recognized in original.
5.2.2.3.3 Other - Simple light displays used on operator control panels shall conform to the following:	
a. Location and Spacing shall be such that lights are visible (i.e., not obscured by an intervening control, operator's hand, or at an angle that causes the indicator bezel to diminish the effectiveness of the light). They shall also be far enough apart so that lamp replacement is convenient.	Added conditions.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
b. Brightness shall be sufficient for the operator to easily differentiate between an ON and OFF condition. The indicator shall also be designed and/or otherwise positioned or shielded so that bright ambient light will not cause the indicator to appear lighted when it is not, and/or so that the lighted indicator will not reflect on other critical viewing surfaces and thus diminish viewing effectiveness of a display or window. Brightness of simple light indicators shall not be so high as to create "dazzle", and/or destroy required operator dark adaptation where required.	
c. Size coding, if used shall conform to criteria presented in Table II. Note: The different sizes indicated in Table II 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.	Clarification.
d. Shape coding may be used to aid the operator in quickly identifying a function, and/or to provide additional information, e.g.: "arrow-shaped", vehicle turn indicator lights identify the direction of turn (left or right).	

TABLE II. CODING OF SIMPLE INDICATOR LIGHTS

SIZE/TYPE	COLOR			
	RED	YELLOW	GREEN	WHITE
1/2-INCH (13mm) DIAMETER or SMALLER/STEADY	Malfunction; action stopped; failure; stop action.	Delay; check; recheck.	Go ahead; in tolerance; acceptable; ready.	Functional or physical position; action in progress.
1-INCH (25mm) DIAMETER or LARGER/STEADY	Master summation (system or subsystem).	Extreme caution (impending danger).	Master summation (system or subsystem).	
1-INCH (25mm) DIAMETER or LARGER/FLASHING (3 to 5/sec.)	Emergency condition (impending personnel or equipment disaster).			
Note: See also 5.2.2.1.14				

ORIGINAL REQUIREMENT	MFI COMMENTS
5.2.2.4 <u>Transilluminated Panel Assemblies</u> - Transilluminated panel assemblies, which present whole patterns of information, should be considered for presentation of data flow and complicated data organization.	This is too important to treat so lightly!

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.2.4 Transilluminated Panel Assemblies - Transilluminated (integrally-lighted) panel assemblies should be considered for the following: a. To provide illuminated labels for a control panel. b. To provide a light source for illuminating transilluminated control knobs. c. To provide illuminated association markings on a control panel, e.g., connecting lines between controls, outlines around a functionally-related group of controls and/or displays, etc. d. To create a "pictorialized" representation of a system process, communication network, or other information/ component organization.	Rationale for this expansion should be clear from the material presented.
5.2.2.4.1 Integrally-Lighted Sub Panels - Integrally-lighted subpanels shall be designed so that all panel markings are equally visible throughout the range of panel light level adjustment; and brightness variation among separate sub panels on the same lighting circuit shall not exceed 1:7.	See MIL-P-7788, MIL-L-25467 and and MIL-C-25050. Also: Van Cott, Human Engineering Guide to Equipment Design, 1972, p. 65.
5.2.2.4.2 Large, Single Pictorial Graphic Panels - Large, single pictorial graphic panels used to display system processing, communications networks, etc. shall comply with requirements for visibility, legibility, color and illumination as specified herein.	
5.2.2.4.3 Re-Lamping - When incandescent lamps are used as the source for integral lighting of panel assemblies, lamps shall be readily accessible without removing the panel(s). There shall be a sufficient number of lamps provided so that failure of one lamp will not cause the display to be unreadable.	
5.2.2.4.4 Brightness - Brightness of illuminated panel markings and/or transilluminated controls shall be compatible with the ambient environment and/or the operating conditions (e.g., dark adaptation requirements). Brightness control by the operator (dimming) shall be provided where applicable to maintain appropriate visibility and/or operator dark adaptation level.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.2.3 Scale Indicators -	
5.2.3.1 General	
5.2.3.1.1 Types of Scale Indicators - The types of scale indicators that should be considered are:	This is not useful. Should start with "Applications".
a. Moving-pointer, fixed-scale, circular, curved (arc), horizontal straight, and vertical straight.	
b. Fixed-pointer, moving-scale, circular, curved (arc), horizontal straight, and vertical straight.	
5.2.3.1.2 Applications - The selection of scale indicators for various applications should be based on the criteria in Table III as well as the specific criteria contained in this section. Moving-pointer, fixed-scale indicators shall be selected in preference to fixed-pointer, moving-scale indicators. The latter should be used only when necessitated by operational requirements or other conditions, and when approved by the procuring activity.	Table III needs expansion and updating This whole section is too "terse" an non-informative. It needs illustrative clarification since, in some instances words become too complicated to clarify the basic intent.
5.2.3.1.3 Quantitative Information - Scale indicators should be used to display quantitative information in combination with qualitative information (such as trend and direction-of-motion) and where only quantitative information is to be displayed and there is no requirement (such as speed and accuracy of response) which demands the use of printers or counters.	
5.2.3.1.4 Linear Scales - Except where system requirements clearly dictate nonlinearity to satisfy operator information requirements, linear scales shall be used in preference to nonlinear scales.	
5.2.3.1.5 Scale Markings -	
5.2.3.1.5.1 Graduations - Scale graduations shall progress by 1, 2, or 5 units or decimal multiples thereof.	
5.2.3.1.5.2 Intermediate Marks - The number of minor or intermediate marks between numbered scale pointers shall not exceed nine.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.2.3.1.6 Numerals - 5.2.3.1.6.1 Major Marks - Except for measurements that are normally expressed in decimals, whole numbers shall be used for major graduation marks. 5.2.3.1.6.2 Starting Point - Display scale shall start at zero, except where this would be inappropriate for the function involved. 5.2.3.1.7 Pointers - 5.2.3.1.7.1 Length - The display shall be designed so that the control or display pointer will extend to, but not obscure, the shortest scale graduation marks.	

ORIGINAL REQUIREMENT	MFI COMMENTS

TABLE III. APPLICATION OF VARIOUS TYPES OF MECHANICAL DISPLAYS

USE	SCALES		COUNTERS	PRINTERS	FLAGS
	Moving Pointer	Fixed Pointer			
QUANTITATIVE INFORMATION	FAIR May be difficult to read while pointer is in motion.	FAIR May be difficult to read while scale is in motion.	GOOD Minimum time and error for exact numerical value.	GOOD Minimum time and error for exact numerical value.	N/A
QUALITATIVE INFORMATION	GOOD Location of pointer easy. Numbers and scale need not be read. Position change easily detected.	POOR Difficult to judge direction and magnitude of deviation without reading numbers and scale.	POOR Numbers must be read. Position changes not easily detected.	POOR Numbers must be read. Position changes not easily detected.	GOOD Easily detected. Economical of space.
SETTING	GOOD Simple and direct relation of motion of pointer to motion of setting knob. Position change aids monitoring.	FAIR Relation to motion of setting knob may be ambiguous. No pointer position change to aid monitoring. Not readable during rapid setting.	GOOD Most accurate monitoring of numerical setting. Relation to motion of setting knob less direct than for moving pointer. Not readable during rapid setting.	N/A	N/A
TRACKING	GOOD Pointer position readily controlled and monitored. Simplest relation to manual control motion.	FAIR No position changes to aid monitoring. Relation to control motion somewhat ambiguous.	POOR No gross position changes to aid monitoring	N/A	N/A
GENERAL	Requires largest exposed and illuminated area on panel. Scale length limited unless multiple pointers used.	Saves panel space. Only small section of scale need be exposed and illuminated. Use of tape allows long scale.	Most economical of space and illumination. Scale length limited only by number of counter drums.	Limited application.	Limited application

MFI COMMENTS:

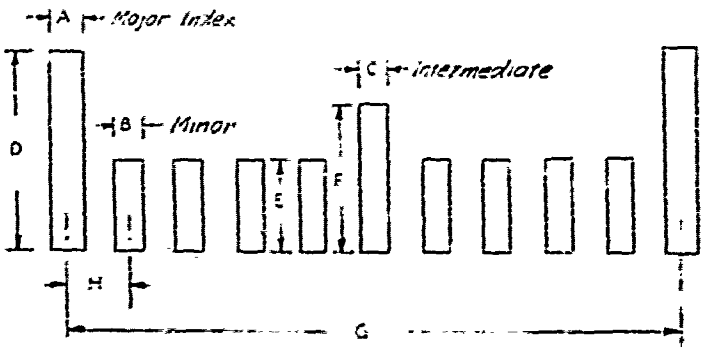
This table does not address a typical display area (pictorial instruments); it needs to address another use area (e.g., pre-estimation); and the "General" section lacks purpose, i.e., it does not seem to be applications oriented.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.3 Scalar Indicators 5.2.3.1 General 5.2.3.1.1 Applications - (See Table III.) Scalar indicators should be used in preference to digital readouts when the data displayed are of qualitative as well as quantitative value (e.g., when trends, direction of movement, more-than/less-than relationships are of value as well as the specific numerical value), or of qualitative value only. Scalar indicators should not be used when the primary purpose is read out of precise quantitative information.	We believe the following revisions and additions make this section more complete, definitive and broadly applicable than the original. Ref: Van Cott, Human Engineering Guide to Equipment Design, 1972, Ch. 3.
5.2.3.1.2 Preferred Type - The preferred type of scalar indicator for most applications has a moving pointer and a fixed scale. (The scale may be circular, curved (arc), horizontal, straight or vertical straight.) With this type of scale both the scale progression and control movement are compatible with operator expectancies hence it can be used effectively wherever a scalar indicator is required. The other major type of scalar indicator has a fixed pointer and a moving scale. Because there is always compromise to one or another human engineering principles in use of this design, its use should be limited to the following applications: (a) where multiple scales can be lined up and read in a row or column (with the readout values always appearing in the same position--preferably in the center of window openings) and/or (b) where speed and accuracy of setting is not critical.	The preferred format idea is brought up front. Exception guidance is provided.
5.2.3.1.3 Scale Linearity - Scales should be graduated linearly even if the function being controlled is non-linear. If the non-linearity of the function causes too much scale compression making difficulty in readout or adjustment, another type of device such as a moving tape indicator would be preferred over use of a non-linear scale.	Our professional judgment is that non-linear scales should be avoided in military equipment because of susceptability to misinterpretation.
5.2.3.1.4 Scale Marking and Numbering	

TABLE III. APPLICATION OF VARIOUS TYPES OF MECHANICAL DISPLAYS

USE	SCALAR INDICATORS		MECHANICAL COUNTERS	PICTORIAL INSTRUMENTS	PRINTERS	FLAGS
	MOVING POINTER	MOVING POINTER				
QUANTITATIVE INFORMATION	FAIR Difficult to read while pointer is in motion.	FAIR Difficult to read while scale is in motion.	GOOD Minimum time and error for exact numerical value, but, difficult to read when moving.	FAIR Direction of motion/scale relations sometimes conflict, causing ambiguity in interpretation.	GOOD Minimum time and error for exact numerical value.	N/A
QUALITATIVE INFORMATION	GOOD Location of pointer easy. Numbers and scale need not be read. Position change easily detected.	POOR Difficult to judge direction and magnitude of deviation without reading numbers and scale.	POOR Numbers must be read. Position changes not easily detected.	GOOD Real world situation more quickly assimilated.	POOR Numbers must be read. Position changes not easily detected.	GOOD Easily detected. Economical of space.
SETTING	GOOD Simple and direct relation of motion of pointer to motion of setting knob. Position change aids monitoring.	FAIR Relation to motion of setting knob may be ambiguous. No pointer position change to aid monitoring. Not readable during rapid setting.	GOOD Most accurate monitoring of numerical setting. Relation to motion of setting knob less direct than for moving pointer. Not readable during rapid setting.	GOOD Generally direct control-display relationship easy to observe.	N/A	N/A
TRACKING	GOOD Pointer position readily controlled and monitored. Simplest relation to manual control motion.	FAIR No position changes to aid monitoring. Relation to control motion somewhat ambiguous.	POOR No gross position changes to aid monitoring.	GOOD Same as above.	N/A	N/A
DIFFERENCE ESTIMATION	GOOD Easy to calculate positively or negatively by scanning scale.	FAIR Subject to reversal errors.	POOR Requires mental calculation.	GOOD Easy to calculate either quantitatively or qualitatively by visual inspection.	FAIR Can predict possible future pattern of pen trace.	N/A
PERMANENT RECORD	N/A	N/A	N/A	N/A	GOOD Provides hard copy.	N/A
GENERAL	Limited scale length for dials. Moving tape provides best method for scale extension.		Specific numeric values only; poor dynamic situations.	Both quantitative & situational or positional info are required.	Hard copy reference anticipated.	Use in conjunction with scalar, quasi-pictorial or other instrument. Use to indicate instrument condition.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.3.1.4.1 Graduation Markings - Scale graduations shall be in increments of 1, 2, or 5 units or decimal multiples thereof (except as noted in 5.2.3.1.4.2). No more than three sizes of marks shall be used on any scale. The scales which require three sizes of marks include: (1) those which have numbered values in multiples of 10 but are graduated in units (multiples of 5 receive the intermediate size), and (2) azimuth scales numbered in multiples of 30° but graduated in 5° and 10° intervals. The number of graduation marks between numbered marks shall not exceed nine. The sizes of graduation marks which should be used are presented in Table_____, and illustrations of scales graduated in various ways are provided in Figure_____.	Ref: McCormick, Human Factors in Engineering and Design, 1976, p. 73. Van Cott, Human Engineering Guide to Equipment Design, 1972, p. 85.
5.2.3.1.4.2 Scale Numerals - Except for measurements that are normally expressed in decimal fractions, whole numbers shall be used for major graduation marks. Intermediate marks should ordinarily not be numbered. On fixed-scales numerals shall be vertically oriented, and on rotating scales numerals shall be radially oriented and positioned so as to be upright when read against the pointer. Bearing dials shall have numerals (and major graduation marks) at either 10° or 30° as shown in Figure_____.	
5.2.3.1.4.3 Scale Length - Scales shall start and end on a major graduation mark even if this puts either or both ends beyond the usable range of the scale. (e.g., if the maximum voltage which can be read on an instrument is 23 volts, the scale shall go at least to 25 volts where there could be a major graduation mark.)	Professional judgment.
5.2.3.1.5 Pointers	
5.2.3.1.5.1 Length - On fixed-scale indicators with outward-projecting marks the pointer shall extend almost to the inboard end of the graduation markings but shall leave a short gap (e.g., 1/32") so as to provide for better vernier acuity. On fixed scale indicators with inward-projecting marks the ends of the different sizes of marks are at different distances from the center; on indicators of this type the pointer should extend almost to the inboard end of the shortest (minor) graduation marks. The pointer	Ref: Woodson and Conover, Human Engineering Guide for Equipment Designers, 1966, p. 2-16.



Scale Mark Dimensions for 28-Inch Viewing Distance

Dimension	Black on White (cm)	Black on White (in.)	White on Black (cm)	White on Black (in.)
A Width	0.089	(0.035)	0.318	(0.125)
B Width	0.064	(0.025)	0.318	(0.125)
C Width	0.076	(0.030)	0.318	(0.125)
D Length	0.558	(0.22)	0.559	(0.22)
E Length	0.254	(0.10)	0.254	(0.10)
F Length	0.406	(0.16)	0.406	(0.16)

(G = Minimum 1.27 cm (0.5 in.))
(H = Minimum 0.1778 cm (0.07 in.))

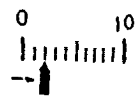
Notes: (1) For other viewing distances, the proportions should be maintained by using the following formula.

$$\text{Dimension at 28-in} \times \frac{x\text{-in}}{28}$$

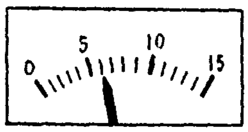
(2) The pointer tip width should be the same as the width of the minor index.

(3) The above marking dimensions are for "light marks" on a dark background. When "dark" marks are used on a light background, the stroke width dimensions should be increased by 20 percent.

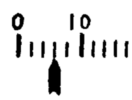
Table____ - Sizes of Graduation Marks



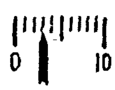
A - Fixed scale-moving pointer preferred; Three-level marking, numbered at each major mark. Pointer adjacent to graduation marks to preclude obscuration of either marks or numbers.



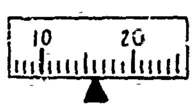
B - For short, finite scale, every 5th graduation is marked; using only two-level marking.



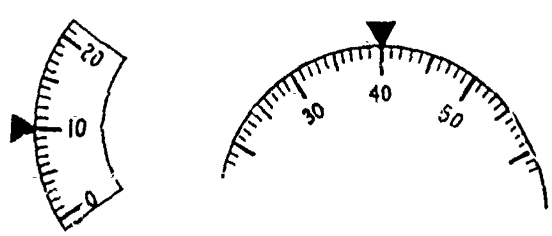
C - When scale crowding makes pointer-mark association difficult, scale may be graduated in units of two, with two-level scale marking and numbering at each major marking.



D - When dial face is deeply inset within instrument case and visibility of numbers is more important than scale mark-pointer association, pointer may be located inside the graduations along with numbers at major markings. Pointer width should be narrowed at point in which it passes numbers.



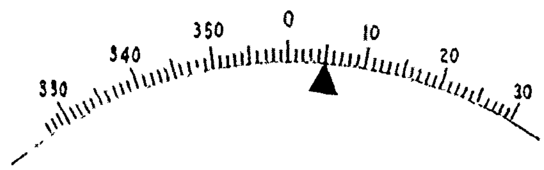
E - Moving scale against an index mark or pointer may be used when scale length precludes the fixed scale format (i.e., graduation marks would be too close together). Open window configuration helps operator focus on significant scale area.



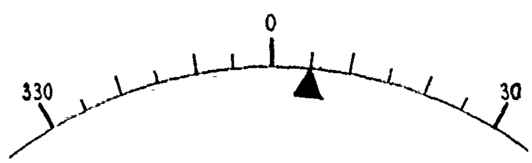
F - When open window configuration is oriented in vertical position, numbers should appear upright as each number passes the index mark or pointer.

Total scale exposure is desirable when operator needs to refer to other portions of the scale.

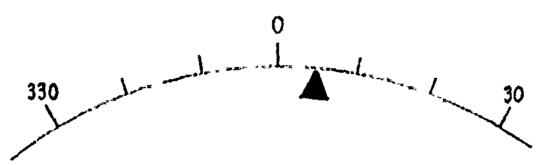
Figure ____ - Scale Graduation, Pointer Position and Scale Numbering Alternatives



Graduated in 1^{o} increments



Graduated in 5^{o} increments



Graduated in 10^{o} increments

Small Dial Diameters ——— Large Dial Diameters

*Note: The above general scale marking concepts also apply to displays in which measure is in mils.

Figure____ - Fixed-Scale Azimuth Dials

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
or index on moving scale indicators should always approach the rim of the scale from the outside, not from the center. See Figure_____.	
5.2.3.1.5.2 Width - The width of the pointer, where it intercepts the graduation marks, shall not exceed the width of the intermediate marks.	Professional Judgment (but based on study performed at NEL about 1950 - report not located)
5.2.3.1.5.3 Mounting - The pointer shall be mounted as close as possible to the face of the dial to minimize parallax.	
5.2.3.1.6 Luminance Contrast - Luminance contrast of at least 50 percent shall be provided between the scale face and the markings and pointer.	
5.2.3.1.7 Calibration Information - Operator tasks should normally be designed so that calibration as a part of operation is unnecessary. When calibration is required as part of the operating procedure it shall be presented in a legible but inconspicuous manner so as not to interfere with dial legibility.	
5.2.3.1.8 Coding - When certain operating conditions (such as normal operating temperature or dangerous pressure level) always fall within a limited range of the total scale, these ranges should be made readily identifiable by means of pattern, color, or shape coding applied to the face of the instrument. Use of red color coding should be limited to caution situations. Operating zones may be shape coded when the indicator must be viewed in very low-light-level work environments (e.g., 0.02-0.1 Ft-L) or where the illuminant color will cause difficulty in discrimination of colors. See Figure _____.	Ref: Van Cott, Human Engineering Guide for Equipment Design, 1972, p. 90.

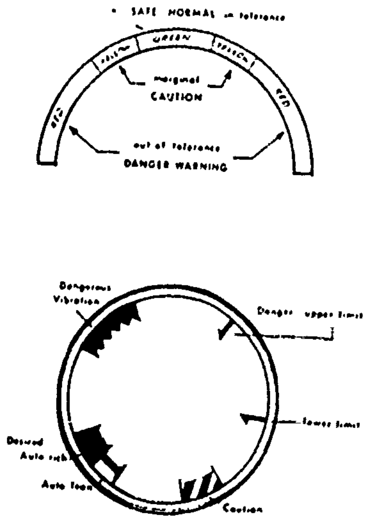
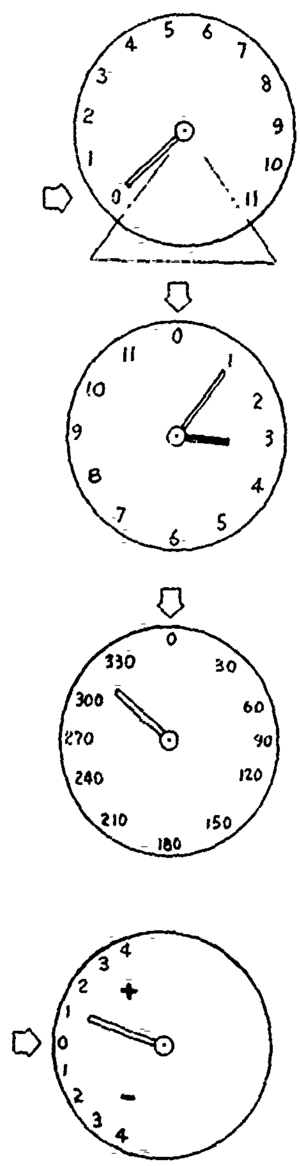


Figure ____ Shape/Color Coding Operating Ranges

ORIGINAL REQUIREMENT	MFI COMMENTS
5.2.3.2 Moving-Pointer, Fixed-Scale Indicators -	
5.2.3.2.1 Numerical Progression - The increase of numerical progression on fixed scales shall read clockwise, from left to right, or from the bottom up, depending on display design and orientation.	Misses "left-to-right".
5.2.3.2.2 Orientation - Numbers on stationary scales shall be oriented in the upright position.	
5.2.3.2.3 Circular Scales -	
5.2.3.2.3.1 Scale Reading and Pointer Movement - The magnitude of the scale reading shall increase with clockwise movement of the pointer.	
5.2.3.2.3.2 Zero Position and Direction of Movement - When positive and negative values are displayed around a zero or a null position, the zero or null point shall be located at either 12 o'clock or the 9 o'clock position. Positive values shall increase with clockwise movement of the pointer, and negative values shall increase with counterclockwise movement.	Other zero position considerations should be addressed.
5.2.3.2.3.3 Scale Break - There shall be an obvious break of at least 10° of arc between the two ends of the scale, except on multi-revolution instruments such as clocks.	
5.2.3.2.3.4 Number of Pointers - Whenever precise readings are required not more than two coaxial pointers shall be mounted on one indicator face.	Clocks are exception.
5.2.3.2.3.5 Pointer Alignment - When a stable value exists for given operating conditions in a group of circular-scale indicators, they shall be arranged either in rows so that all pointers line up horizontally on the 9 o'clock position under normal operating conditions or in columns so that all pointers line up vertically in the 12 o'clock position under normal operating conditions. If a matrix of indicators is needed, preference shall be given to the 9 o'clock position.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.2.3.2.3.6 Placement of Numerals - Numerals shall be placed outside of graduation marks to avoid having numbers covered by the pointer. Numerals may be placed inside of graduation marks when it is necessary to avoid constriction of the scale. In any case, the pointer shall extend to, but not obscure, the shortest graduation marks.	and/or scale marks! Solution to scale constriction is not poor format but rather a change in dial size!
5.2.3.2.4 Curved (Arc), Horizontal Straight, and Vertical Straight Scales	
5.2.3.2.4.1 Scale Reading and Pointer Movement - The magnitude of the scale reading shall increase with movement of the pointer up or to the right.	
5.2.3.2.4.2 Zero Position and Direction of Movements - When positive and negative values are displayed around a zero point, the positive values shall increase with movement of the pointer up or to the right, and negative values shall increase with movement of the pointer down or to the left.	
5.2.3.2.4.3 Placement of Pointers - Pointers shall be located to the right of vertical scales and at the bottom of horizontal scales.	
5.2.3.2.4.4 Placement of Numerals - Numerals shall be placed on the side of 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.	Same comment as above.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.3.2 Moving-Pointer, Fixed-Scale Indicators	
5.2.3.2.1 Numerical Progression - Numbered scales shall increase clockwise, from left to right, or from bottom to top depending on scale layout (e.g., circumferential, or linear in horizontal or vertical axis).	Ref: Woodson and Conover, Human Engineering Guide for Equipment Designers, 1966, p. 2-13.
5.2.3.2.2 Orientation of Numerals - Numbers on fixed scales shall appear vertical (upright) to the observer.	
5.2.3.2.3 Circular Scales	
5.2.3.2.3.1 Scale reading and Pointer Movement - [Same as the original.]	
5.2.3.2.3.2 Zero Position and Pointer Movement - The position of the zero value on a numbered scale, and the relative pointer movement shall conform to criteria in Figure_____.	Illustration is used to clarify alternate concepts.
5.2.3.2.3.3 Scale Break - There shall be an obvious break between the two ends of non-continuous scales of at least 10° of arc.	
5.2.3.2.3.4 Number of Pointers - Except for clocks or watches (which often have three hands), not more than two coaxial pointers shall be used on a single dial indicator.	We feel strongly about this in spite of conflicts with some aircraft specs.
5.2.3.2.3.5 Aligned Pointers for Check-Reading - [Although title change is recommended, material should be same as original. But add (see Figure______).]	Precision has little to do with requirement. Illustration is added since typical reader will not know what we are talking about.
5.2.3.2.3.6 Relative Position of Scale Marks and Numbers - When reading time and accuracy are critical, circular scale markings and location of associated numbers shall be arranged to prevent pointers from covering any portion of scale marks or numerals, and scale marks/numbers shall be on, or close to the plane of the pointer tip (i.e., to avoid visual parallax - see Fig_____). However, if readout accuracy is not critical (i.e., gross relationship between the pointer and the numeral is all that is required), an arrangement of numerals "inside" the scale annulus is acceptable. (See examples in Figure_____).	Collates and illustrates all variables. Professional Judgment



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

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

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

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

Figure_____ - Zero Position and Pointer Movement for Circular Dial Displays

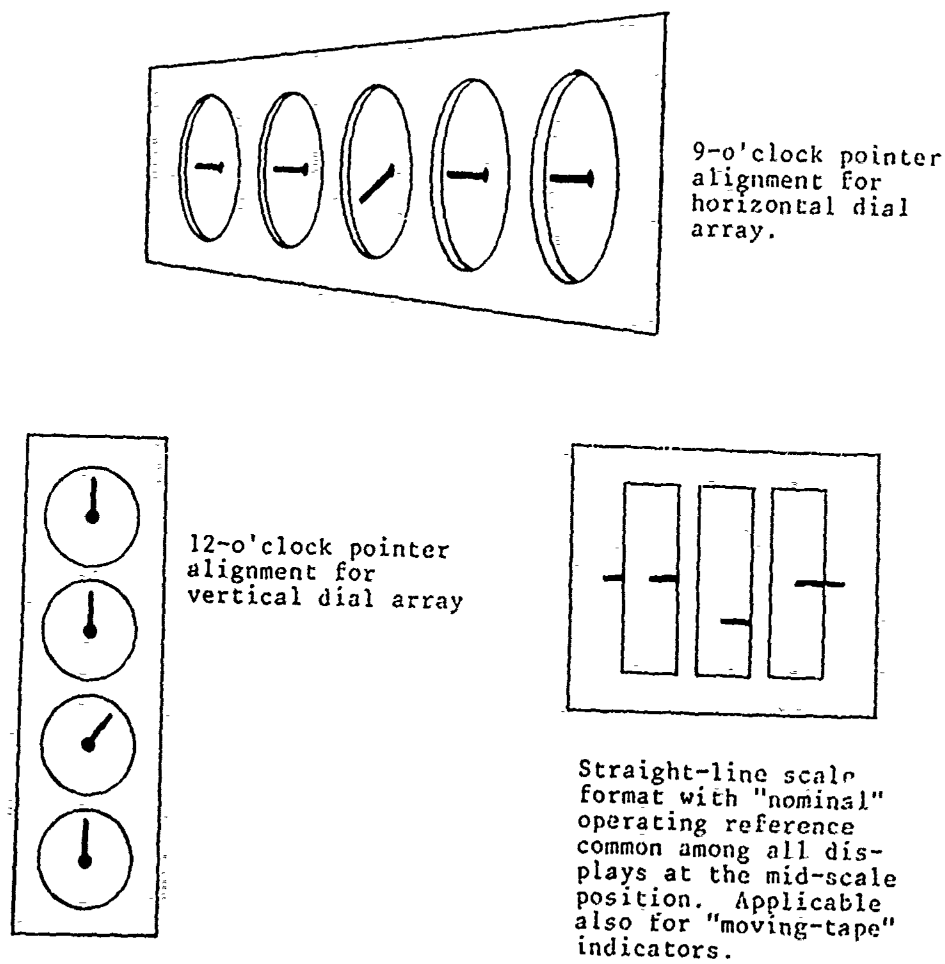
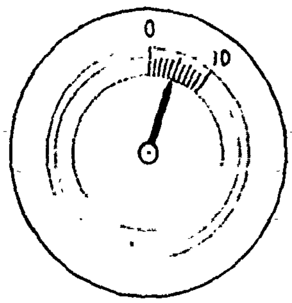
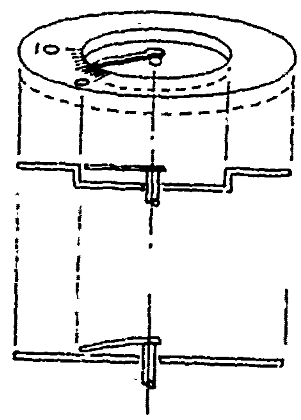


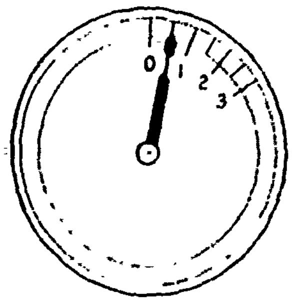
Figure____ - Aligned Pointers for Rapid Check-Reading



For maximum reading accuracy, numerals shall be placed outside the scale, and the inner annulus of scales marks provides an "even" border, against which the pointer tip rides, i.e., the pointer is an equal distance (nominal 0.0312-0.0625-inches - 0.079-0.159 cm) from all scale marks, never overlapping any mark or numeral.



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

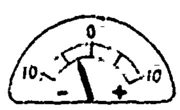


Alternate format when the instrument face is surrounded with a deep bezel, i.e., numerals are inside the scale, since gross reading of numbers is paramount.

Figure_____ - Relative Position of Scale Marks, Numerals and Pointers on Circular Dials

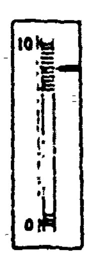
MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.3.2.4 Curved (Arc), Horizontal or Vertical Straight Scales	
5.2.3.2.4.1 Scale Reading and Pointer Movement - [Same as the original.]	
5.2.3.2.4.2 Zero Position and Pointer Movement - The position of the zero value on curved or straight scales shall conform to criteria in Figure_____.	Illustrations to clarify statements.
5.2.3.2.4.3 Relative Position of Pointers, Scales and Numerals - The relative position of pointers, scales and numerals shall conform to criteria in Figure_____.	

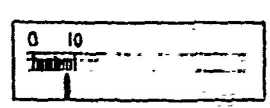
Numerals should be located outside scale marks, and pointer should ride against the inner scale annulus just short of the markings. The zero reference should be to the left so that increasing numbers and pointer motion is clockwise.



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

Relative location of numerals, scale and pointer on "straight-line" display formats should be as shown, i.e., pointer should not cover either the scale marks nor the numerals. The pointer should eminate from the right side of the vertical format; from the bottom of the horizontal format.





Note: Zero reference for straight-line scales should be centered.

Figure_____ - Relative Position of Scale Marks, Numerals and Pointers on Arc and Straight-Line Scales

ORIGINAL REQUIREMENT	MFI COMMENTS
5.2.3.3 Fixed-Pointer, Moving-Scale Indicators -	
5.2.3.3.1 Numerical Progression - On fixed-pointer, moving scale indicators, numbers shall progress in magnitude in clockwise direction around the faces of circular dials (counter-clockwise dial movement for numerical increase). On vertical or horizontal straight moving scales, numbers shall increase from bottom to top or from left to right.	
5.2.3.3.2 Orientation - Numerals on moving scales shall be upright when in the reading position.	
5.2.3.3.3 Alignment of Pointer or Fixed Reference Line - Alignment of pointer or fixed reference line shall be in the 12 o'clock position for right-left directional information and in the 9 o'clock position for up-down information. For purely quantitative information, either position may be used.	
5.2.3.3.4 Setting - If the display will be used for setting in a value (e.g., tuning in a desired wavelength), the unused portion of the dial face shall be covered, and the open window shall be large enough to permit at least one numbered graduation to appear at each side of any setting.	Believe "Open Window" in title would improve its reference value.
5.2.3.3.5 Tracking - If the display will be used for tracking, as in the case of a directional indicator, the whole face of the dial shall be exposed.	Without a specific example this requirement is probably confusing.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.3.3 Fixed-Pointer, Moving-Scale Indicators	
5.2.3.3.1 Numerical Progression - [Same as original.]	
5.2.3.3.2 Orientation - [Same as original.]	
5.2.3.3.3 Alignment of Pointer or Fixed Reference Line - [Same as original.]	
5.2.3.3.4 Open Window Display - When the display will be used primarily for "setting in a value" (e.g., tuning to a desired wavelength), only the portion of the scale of interest should be exposed, i.e., the rest of the scale is covered to reduce visual clutter and confusion. The open window shall be of sufficient size to permit view of at least one numbered graduation either side of the desired setting, i.e., at least two number values shall appear within the window at all times unless the scale is finite and the dial cannot be rotated continuously through successive rotations in the same direction. If the display will be used for tracking (as in the same of a directional indicator), the entire face of the dial shall be exposed.	Slight modification to insure that two numbers appear in window. Also picks up tracking requirement. Van Cott, Human Engineering Guide to Equipment Design, 1972, p. 83.
[5.2.3.3.5 Tracking - This requirement has been incorporated in 5.2.3.3.4, with slight modification.]	Deleted.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
NEW SECTIONS	
5.2.3.4 Moving Tape Displays - When the scale length required for acceptable readout accuracy exceeds the limits of the capacity of the display package, i.e., compaction of scale marking would make the display illegible and/or subject to readout error, moving-tape scale format shall be considered.	These requirements represent updating recommendations.
5.2.3.5 Composite Scalar/Pictorial Displays - Combinations of scales, pointers, and/or pictorialized symbols may be used to combine functionally-related information into a single instrument or display (e.g., artificial horizon/command heading, true/relative bearing and other similar combinations). Design of significant reference features (aircraft or ship symbols, horizon/altitude or pitch scales, etc.) shall conform to the general criteria herein relative to direction-of-motion, scale-pointer relationships, legibility, etc. Color contrast shall be used to aid the operator in differentiating among various elements of the combined or composite display (i.e., dark "land" vs light "sky", etc.). See also 5.2.6.5, "Flags".	Ref: Woodson and Conover, Human Engineering Guide for Equipment Designers, 1966, p. 224.
5.2.3.6 Head-Up Display - The "head-up" display (a positional/command type of display typically projected on the primary windscreen of an aircraft cockpit, to provide the pilot with flight direction information without his or her having to look down into the cockpit at instrument panel displays), may be considered with the approval of the procuring agency. The head-up display concept shall not be used for ground-borne or sea-borne vehicles or other operator control-display installations without express approval of the procuring agency.	
5.2.3.6.1 Display/External Viewing Interference - Markings projected on the windshield shall be designed and illuminated in a manner that will not create confusion with external visual details required by the pilot for safe flight. Brightness control shall be provided the operator, with sufficient latitude to set the brightness appropriately for the expected visual environment variations.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.2.4 Cathode Ray Tube (CRT) Displays -	
5.2.4.1 Signal Size - When a target of complex shape is to be distinguished from a nontarget shape that is also complex, the target signal should subtend not less than 20 minutes of visual angle and should subtend not less than 10 lines or resolution elements. Image quality shall be consistent with the operator's needs.	Considering the widespread use and variety of applications for CRT displays, the present section is entirely inadequate because of deficiency in scope and content.
5.2.4.2 Viewing Distance - A 16-inch (410 mm) viewing distance shall be provided whenever practicable. When periods of scope observation will be short, or when dim signals must be detected, the viewing distance may be reduced to 10 inches (250 mm). Design should permit the observer to view the scope from as close as he may wish. Displays which must be placed at viewing distances greater than 16 inches (410 mm) due to other considerations shall be appropriately modified in aspects such as display size, symbol size, brightness ranges, line-pair spacing and resolution.	
5.2.4.3 Screen Luminance - The ambient illuminance shall not contribute more than 25% of screen brightness through diffuse reflection and phosphor excitation.	
5.2.4.4 Faint Signals - When the detection of faint signals is required and when the ambient illuminance may be above 0.25 FT-C (2.7 lux), scopes shall be hooded, shielded, or recessed. (In some instances, a suitable filter system may be employed, subject to approval by the procuring activity.)	
5.2.4.5 Luminance Range - The luminance range of surfaces immediately adjacent to scopes shall be between 10% and 100% of screen background luminance. With the exception of emergency indicators, no light source in the immediate surround shall be brighter than scope signals.	
5.2.4.6 Ambient Illuminance - The ambient illuminance in the CRT area shall be appropriate for other visual functions (e.g., setting controls, reading instruments, maintenance, etc.) but shall not interfere with the visibility of signals on the CRT display.	
5.2.4.7 Reflected Glare - Reflected glare shall be minimized by proper placement of the scope relative to the light source, use of a hood or shield, optical coatings or filter control over the li[illegible] source.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.2.4.8 Adjacent Surfaces - Surfaces adjacent to the scope shall have a dull matte finish. The reflectances of these surfaces shall be such that the resultant luminances will be consistent with the criteria established above.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.2.4.9 Electronically or Optically Generated Displays - Electronically or optically generated displays shall conform to MIL-STD-884.	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.4 Cathode-Ray Tube (CRT) Displays 5.2.4.1 Applications - Cathode ray tubes may be used for a wide variety of display purposes such as presentation of: sensor data from radar, sonar, electronic-warfare systems, etc.; computer-generated data such as processed sensory data, target tracks, computer graphics, status data, and simulated exercises; aircraft system status; caution and warning indications; and presentation of television pictures. A cathode ray tube may also be employed for multiple uses in which case it shall at least minimally satisfy the criteria for each use. 5.2.4.2 General Requirements - The following general requirements are applicable to CRT selection and design regardless of specific use. 5.2.4.2.1 Screen Luminance - The screen luminance shall be within a range which satifies all the following requirements. a. Operating Range - The luminance used shall be compatible with the CRT's operating characteristics and life expectancy. That is, for example, the CRT shall not be driven beyond its normal value in order to gain greater screen luminance since this could result in burning of the screen or in reduced life. b. Ambient Illumination - CRT luminance shall be compatible with the ambient illumination otherwise required in the work area, except that shielding, filtering or use of a hood may allow lower CRT luminance if the technique employed is compatible with the operator's task. c. Operator Visual Capabilities and Task Requirements - Luminance of the faintest information displayed for operator response shall be well above the operator's threshold considering target size and presentation rate, clutter, phosphor color, and ambient illumination conditions.	This very much expanded section introduces needed material in many areas concerned with CRT display, including applications, phosphors, use of color, persistence, dynamic range, flicker and jitter, spot size and resolution, burning of screen, distortion, screen shape and size, viewer protection, "housekeeping" controls, TV displays, sensor displays, and computer-generated displays.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.4.2.2 Finish and Luminance of Surrounding Area - Panel surfaces adjacent to the CRT shall have a dull matte finish which under ambient operational conditions shall have a luminance range between 10% and 100% of the screen background luminance. Some means of adjusting the surround luminance should be provided if necessary to ensure operation within this range.	
5.2.4.2.3 Daylight Viewing - CRTs which must be viewed under daylight conditions such as on the bridge of a ship or in an aircraft cockpit shall utilize one or more appropriate means such as the following to bring viewing conditions within an acceptable range: (1) a deep shield or hood to reduce the amount of incident light, (2) scan conversion for continuous presentation at high luminance levels, (3) a high-output burn-resistant phosphor such as the P-1 compatible with the higher ambient light levels, (4) a circularly-polarized filter for cancellation of light reflected off the face plate, (5) negative image polarity to present dark traces on a light background, (6) a filter/phosphor combination which will minimize screen flourescence, and (7) a fiber-optic or mesh type filter which tends to reject incident light and pass screen-emitted light.	Ref: Skolnik, Radar Handbook, Ch. 6.
5.2.4.2.4 Reflection and Glare - Reflection and glare off CRT faceplates and cover plates shall be minimized by one or more appropriate techniques such as: (1) shielding the CRT or the light sources to prevent direct illumination from striking the CRT, (2) positioning light sources so they do not reflect off the CRT face plate into the operator's eyes, (3) use of a circularly-polarized filter for cancellation of light reflected off the CRT face plate, (4) use of a cross-polarized lighting system (a polarizing filter over the CRT rotated 90° with respect to polarizing filters over the light sources), (5) use of a controlled white light system which delivers light only to the necessary work areas and baffles it from the CRT, (6) use of a selective spectrum lighting system wherein the spectral output of the CRT is substantially outside the spectrum of the ambient illumination, and (7) application of an anti-reflective coating on the CRT face plate and non-bonded filter surfaces to reduce the proportion of reflected light.	Ref: Skolnik, Radar Handbook, Ch. 6. Also: A. Cakir, Hart, and Stewart, The VDT Manual, 1979, pp. 84-92.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.4.2.5 Phosphors - CRT phosphors shall be selected on the basis of color, persistence, resolution capability, and durability as appropriate to the operator's task in utilizing the CRT. Characteristics of commonly-used phosphors currently available are presented in Table_____.	Ref: Skolnik, Radar Handbook, Ch. 6.
5.2.4.2.6 Use of Color - Color is inherently a good coding dimension, but it should be utilized only when: (1) any loss of CRT resolution resulting from the use of color is acceptable, (2) color codes are compatible with color stereotypes and conventional usage, and (3) all users will be able to perceive the code. (Because there are some color deficient personnel in the Armed Forces, it cannot be assumed that any random operator will be able to differentiate the color codes reliably. Use of some other code redundantly along with the color code is the best way to ensure that the codes will be differentiable by all personnel. Thus, if friendly and hostile tracks are to be differentiated by color, they should also be differentiable by some other means such as shape coding.)	
5.2.4.2.7 Persistence - Transient signals of very short duration such as those derived from radar and active sonar systems shall be displayed with sufficient persistence for the operator to perform whatever operations are needed with respect to the signals. Persistence beyond signal duration on the display may be accomplished through use of persistent phosphors, periodic re-painting (refreshing) of the image from processor memory, or utilization of scan converters or direct view storage tubes as appropriate to the application. With rotating sweep indicators, the persistence should be at least such as to display even faint signals above threshold for a period equal to one-quarter of a sweep rotation. Short to medium persistence is adequate for scan rates such as those used for television.	Professional Judgment
5.2.4.2.8 Dynamic Range - A dynamic range of at least 7 db should be provided for detection of targets on a plan-type (PPI) indicator, and 20 db or more is desirable for detection on an A-scan presentation or other deflection display. A dynamic range of at least 7 db should be provided for TV images, and applications where fine-grain detail is important, such as high-resolution reconnaisance sensors should provide the maximum attainable with the state of the art.	Ref: Boeing Co., Design Handbook for Imagery Interpretation Equipment, 1975, Ch. 4.

Table____

CRT Phosphor Applications and Characteristics

Application	Phosphor I.D.	CIE Coordinates X	Y	Persistence	Flourescence	Phosphorescence	Decay Time (m sec)	*Notes
Radar	P-1	.218	.712	Med.	Yellow Green	Yellow Green	24	*
Sonar,	P-2	.279	.534	Med.	Yellow Green	Yellow Green	35-100	*
and	P-7	.357	.537	Long	Yellow	Yellow Green		*
Oscilloscope	P-10			Very Long	Dark Trace Screen			
	P-12	.605	.394	Med. Short	Orange	Orange		
	P-14	.504	.443	Med.	Yellow Orange	Orange		
		.150	.093	Med. Short	Blue	Orange		
	P-17	.302	.390	Long	Blue	Yellow		
	P-19	.572	.422	Long	Orange	Orange		*
	P-21	.539	.373	Med.	Red Orange	Red Orange		
	P-25	.557	.430	Med.	Orange	Orange		*
	P-26	.582	.416	Very Long	Orange	Orange		*
	P-28	.370	.540	Long	Yellow Green	Yellow Green	500	
	P-29	(P-2 + P-25)		Med.	Green	Green		
	P-31	.193	.420	Med. Short	Green	Green	4	*
	P-32			Long	Purple Blue	Yellow Green		
	P-33	.559	.440	Very Long	Orange	Orange		*
	P-34	.235	.364	Very Long	Blue Green	Yellow Green	40 sec	*
	P-35	.286	.420	Med. Short	Green	Blue		*
	P-38	.561	.437	Very Long	Orange	Orange	1040	
	P-39	.223	.698	Long	Yellow Green	Yellow Green	150	*
	P-40	.276	.3117	Med.	White/Blue	Yellow Green		
Monochrome TV	P-4	.270	.300	Med. Short	White	White	25	*
	P-23	.375	.390					
Color TV	P-22	.155	.060	Med.	Blue	Blue	25	
		.285	.600	Med.	Yellow Green	Yellow Green	60	
		.675	.325	Med.	Orange Red	Orange Red	0.9	

CRT Phosphor Applications and Characteristics (con't.)

Application	Phosphor I.D.	CIE Coordinates X	CIE Coordinates Y	Persistence	Flourescence	Phosphorescence	Decay Time (m sec)	*Notes
Projection TV	P-18	.333	.347	Med.				
Storage Tubes	P-20	.444	.536	Med. Short	Yellow Green	Yellow Green		

Persistence:

VL = Very long, 1-second or over
L = Long, 100 msec-1.0 sec
M = Medium, 1 msec to 100 msec
M/S = Medium short, 10µ sec to 1.0 msec
S = Short, 1µ sec to 10µ sec
VS = Very short, less than 1µ sec

*Notes

P-1 - High efficiency, resolution and resistance to burn.
P-2 - Decrease in decay with increase in beam current.
P-4 - Sulfide version.
P-7 - High efficiency and resistance to burn.
P-19 - Slow refresh rate for flickerless display; low light output; low burn resistance.
P-25 - Desired low-level persistence, high resistance to burn; low light output.
P-26 - Slow refresh rate for flickerless display; low light output and burn resistance.
P-31 - Curve has blue peak at 450 nanometers; high efficiency, resolution and resistance to burn.
P-33 - Decay decreases with beam current decreases; burns rapidly when used with stationary or slow-moving beam.
P-34 - IR stimulatable; Y-phosphor.
P-35 - Resists burning compared to P-11.
P-39 - Similar to P-1 but with longer decay.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.4.2.9 Jitter - Erratic movement of sweep traces on CRT displays shall be diminished to the point where it is not detectable by the operator.	
5.2.4.2.10 Flicker - The refresh (re-paint) rate of signals or data displayed on a CRT shall not be between the rates of 7 Hz and 28 Hz except in applications requiring sensor scanning at these rates and as noted in paragraph 5.2.4.5.1.3. Rates between 1 and 7 Hz shall be utilized only when it is desired to capitalize on the conspicuity value of such rates, such as for warning signals or in the rare circumstances when flash rate coding might be utilized. Refresh rates for data which are to be perceived as continuously presented shall be adjusted upward from 28 Hz as necessary to reduce flicker to a non-detectable level over entire range of display luminance.	Professional judgment based on data from many sources including: (1) Cakir, Hart, & Stewart, The VDT Manual (2) Boeing Co., Design Handbook for Imagery Interpretation Equipment, Ch. 4. (3) S.S. Stevens, Handbook of Experimental Psychology.
5.2.4.2.11 Spot Size and Resolution - The spot size (diameter to 10% luminance) on a CRT shall be compatible with the signal characteristics and type of scan to be utilized. For radar the spot size preferably should be smaller than the minimum size of a returned pulse as presented on the slowest sweep (longest range scale) in order to avoid loss of resolving power inherent in the radar system. For most CRT display applications spot diameter at all parts of the screen should subtend no more than 1 minute of arc from the normal viewing position. Alphanumeric characters should be scaled to subtend at least 15 minutes of arc; other complex shapes should subtend at least 20 minutes of arc.	Ref: Van Cott, Human Engineering Guide to Equipment Design, 1972, p. 58. NAV SHIPS Display Illumination Design Guide (NELC TD 223), 1973, III-5.
5.2.4.2.12 Hand Capacitance Effects - For applications where the operator's hand normally comes close to the screen, such as in plotting on the faceplate or in using a light pencil for data pickoff, aluminized backing of the screen shall be utilized, so as to minimize the effect of hand capacitance which tends to add uncontrolled deflection to the CRT beam.	Ref: Skolnik, Radar Handbook, 6-9.
5.2.4.2.13 Burning of Screen - The display design shall minimize the likelihood of burning of long persistence phosphor screens such as the P19, P25 and P33, since it cannot be assumed that burn-damaged CRTs will always be properly replaced under operational conditions, and the presence of burned areas seriously degrades display legibility. (Anti-burn techniques include use of aluminized backings and protective circuits for automatic intensity reduction whenever the beam remains stationary.	Ref: Skolnik, Radar Handbook, 6-9/

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.4.2.14 Distortion - Sweep non-linearity with raster on PPI-type scans shall be less than 2%. CRTs displaying only alphanumeric or graphics data shall show no obvious distortion in any column or row of characters, and the character aspect ratio shall appear to be constant at all parts of the screen.	Ref: NAVSHIPS Display Illumination Design Guide (NELC TD 223), 1973, p. III-7.
5.2.4.2.15 Screen Shape - CRT display surfaces used exclusively for data presentation or computer graphics shall be rectangular in shape. CRT displays used exclusively for TV image presentation shall also be rectangular and should normally follow the standard practice of having a 3:4 aspect ratio (height to width). Those CRTs used exclusively for polar plots of sensor data shall be round. The preferred display surface shape for A-scan presentations is rectangular. CRTs used simultaneously or sequentially for two or more different display functions may have round, square or rectangular display surfaces as best fit the combined purposes.	Professional Judgment; also MIL-HDBK-759, p. 190.
5.2.4.2.16 Useful Screen Diameter - The diameter of direct-viewing console-mounted CRTs should normally be within the following limits. (Smaller CRTs than those listed for detection, detection and tracking, and situation display may be used where there are severe space constraints such as in aircraft or submarines or hand-held units.) a. For detection of signals from sensor systems: 21.5 cm (8.5 in.) ± 3½ cm (1.5 in.). b. For both detection and tracking: 30 cm (12 in.) ± 5 cm (2 in.). c. Tactical or situation displays: at least 38 cm (15 in.); maximum 76 cm (30 in.). d. Alphanumeric displays: size these by considering the largest format which will be required and the recommended character size. (See 5.5.5.) e. TV: minimum 12 cm (5"; maximum 60 cm (24 in.). f. Single character display: 1.9 cm (0.75 in.) minimum. g. Display of single pulse or short sweep segment for qualitative monitoring only: 1.9 cm (0.75 in.) minimum.	Professional Judgment, based on operational experience and references such as MIL-HDBK-759, p. 190.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.4.2.17 Viewer Protection - A transparent safety screen which may be integral with the CRT faceplate shall be provided to prevent implosion injury. Protection as needed shall also be provided against low-intensity X-radiation as prescribed by current regulations of the Bureau of Radiological Health of the Food and Drug Administration.	Ref: Cakir, Hart & Stewart, The VDT Manual, 1979, p. 23
5.2.4.2.18 "Housekeeping" Controls - The number of "housekeeping" controls (e.g., focus, intensity, and centering) to be used by the operator for adjustment of the CRT shall be kept to a minimum. Such controls which are to be used by the operator (as opposed to a maintenance technician) shall be finger-operated and available from the front panel but recessed and preferably covered when not in use.	
5.2.4.2.19 Display Composition Features - Convenient controls shall be provided for structuring the display format and content in accordance with user requirements. Display capability shall be provided to present both the current settings of all controls relating to display composition, and the total range of settings available.	
5.2.4.2.20 Viewing Angle - CRT screens should be perpendicular to the operator's line of sight (i.e., have a 90° viewing angle at screen center) whenever feasible and no part of any screen including secondary CRTs shall offer a viewing angle of less than 45° from the operator's normal position.	
5.2.4.3 Special Requirements for TV Displays	
5.2.4.3.1 Resolution - Resolution shall be 400 lines or greater both horizontally and vertically except that for low-resolution applications, line spacing need not be closer than needed to subtend 1 minute of arc from the normal viewing position.	Ref: Boeing Co., Design Handbook for Imagery Interpretation Equipment, 1975, Ch. 4.
5.2.4.3.2 Frame Rate and Interlacing - Except for slow-scan systems for reproduction of static images, the frame rate for sampling of video material shall be a minimum of 30 per second. There shall be two display scans (fields) per frame period (or a minimum of 60 per second) with the lines of the second scan in the frame period interlaced with the lines of the first scan.	Standard practice provides satisfactory results.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.4.3.3 Phosphors - The phosphors for TV screens shall have short or medium persistence and high output (e.g., the P-4 or P-23 for black and white monitors, and the P-22 or P-27 for color monitors).	
5.2.4.3.4 Distortion - Spot diameter shall not vary by more than a ratio of 1.5 to 1.0 at any two points on the screen. Distortion shall not be sufficient to cause obvious non-linearity anywhere on the screen when viewing alphanumeric formats or picture images.	Professional judgment
5.2.4.3.5 Gray Scale - There shall be a minimum of at least 5 distinguishable gray scale levels. When the requirements include interpretation of handwriting, resolution of fine detail, or complex image interpretation, up to 8 gray scale levels should be provided.	Ref: Boeing Co., Design Handbook for Image Interpretation Equipment, 1975, Ch. 4.
5.2.4.4 Special Requirements for Sensor Displays	
5.2.4.4.1 Types of Scans - The type of scan selected shall be appropriate to the operator's task in utilizing the sensor data. Commonly-used scan types shall be selected in preference to novel or experimental scan types except as approved by the procuring activity.	
5.2.4.4.2 Display Scale Sizes and Range Ring Values - Display scale shall be selected on the basis of the following criteria. a. If range rings are to be used the display scales selected should be compatible with use of a constant number of range rings regardless of scale, as follows: **3 Range Rings** — Any decimal multiples of: 15 unit scale, 30 unit scale, 60 unit scale **4 Range Rings** — Any decimal multiples of: 4 unit scale, 8 unit scale, 20 unit scale **5 Range Rings** — Any decimal multiples of: 5 unit scale, 10 unit scale, 25 unit scale Display systems capable of presenting alphanumerics should present range ring values on the CRT.	Professional judgment, based on the Van Cott HE Guide and other sources.

3 Range Rings	4 Range Rings	5 Range Rings
Any decimal multiples of:	Any decimal multiples of:	Any decimal multiples of:
15 unit scale	4 unit scale	5 unit scale
30 unit scale	8 unit scale	10 unit scale
60 unit scale	20 unit scale	25 unit scale

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
b. Appropriate scale limits considering sensor characteristics such as minimum range, range resolution, bearing resolution, and maximum range of detection. (Also see 5.2.4.4.4.) For example, the display scales for use with a shipboard surface search radar having a minimum range of 200 years and a maximum range of 36 miles might be as follows: (1) Minimum - one mile (not more than 10 times the minimum range value, to capitalize on range determination at close-in ranges as in station keeping). (2) Maximum - 40 miles (accommodates maximum range of the radar and is a good scale for estimation and interpolation). c. Area and scaling limits suggested by representative operational situations including warfare operations, search patterns, maneuvers, flight operations, etc. For example, an aircraft carrier which may have a number of missions involving close-in aircraft operations at ranges from 10 to 20 miles should have a 20 mile display scale for monitoring and control of aircraft on such missions. 5.2.4.4.3 Offset - Provision for offsetting display center should be made if it is expected that operators may find it advantageous to sometimes confine their attention to an expanded portion of the display which would not be centered on the sensory location. The preferred way to offsetting is through positioning of a CRT marker on the desired new display center by means of a two-coordinate controller and activation by means of an entry switch. If the amount of offset is sufficient to display the original display center off the scope, then some simple means of recapturing the original center shall be provided.	Professional judgment.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.4.4.4 Resolution, Signal Size, and Viewing Distance - In general, the display should present sensor signals with sufficient display resolution to match the resolution of the system (e.g., a precision radar needs a high resolution display but a mosaic of infrared detectors can suffice with a much lower display resolution). The signal size should be sufficient to provide a subtended visual angle for the target of at least 12 minutes of arc for the normal position of the viewer. When the target is of complex shape and recognition is required, it should subtend no less than 20 minutes of visual angle and at least 10 lines or resolution elements (25 minutes in presence of heavy noise or clutter).	Ref: NAVSHIPS Display Illumination Design Guide (NELC TD 223) 1973, Sect. III.
5.2.4.4.5 Reference and Boundary Marks - Provision may be made for range rings, grid marks, azimuth markings, map outlines, operational boundaries, velocity vectors, etc., as appropriate for the intended operational situation. When such aids are provided they shall be selected as needed, parallax-free, and controllable in intensity. There should be no more than 5 range rings on a PPI.	
5.2.4.4.6 Operator Loading - In planning the number of detection and tracking displays which may be needed in a system, the following criteria should be considered. a. Detection performance decreases as the amount of target activity increases. Detection displays should not require monitoring of more than four concurrent and independent detection situations by an unaided operator. b. In a computer-based system relying upon operator updating of target positions, individual displays should not require tracking of more than six independent air targets or more than 15 independent surface targets. Systems which will be employed in situations where there may be groups of targets moving with common velocities should be capable of presenting computer-aided tracking aids such as raid-forming gates which treat the entire group as a single target for tracking purposes.	Professional judgment, based on operational experience with display systems.

MF-1 RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
c. Systems performing automatic detection and tracking shall provide sufficient display capability to accommodate an appropriate level of operator monitoring for manual back-up in case of computer failure. (See also paragraph 5.2.4.5.11.3.) 5.2.4.4.7 <u>Automatic Sequencing</u> - Computer-aided display systems may provide priority-ordered automatic sequencing to facilitate manual track position updating or other recurrent manual operations. With automatic sequencing, each time a position update is entered by the operator, a marker on the display steps to the position of the next track needing updating. 5.2.4.4.8 <u>Data Readout</u> - Computer-aided display systems shall provide convenient operator-oriented facilities for readout of selected information on demand. In tactical data systems this may involve use of a two-coordinate controller to designate specific tracks on the CRT for readout, and an auxiliary display presenting formatted information held by the computer concerning the designated track. 5.2.4.4.9 <u>Handover</u> - Computer-aided display systems shall provide convenient means for transferring responsibilities between operators (e.g., handover of targets on the basis of sector transit or operator overload). 5.2.4.4.10 <u>Display Gates</u> - Computer-aided systems may provide display gates controllable in size and position by the operator to designate areas within which signal return is blanked out (censored) or identified as calling for special processing. 5.2.4.5 <u>Special Requirements for Computer-Generated Displays</u> 5.2.4.5.1 <u>Display of Processed Sensor Data</u> 5.2.4.5.1.1 <u>Quantized Data</u> - Systems which process and quantize sensor data before presenting it to an operator for detection should provide:	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
a. A minimum signal size on the display of 12 minutes of visual angle for the viewer's normal position.	Ref: NAVSHIPS Display Illumination Design Guide (NELC TD 223) 1973, Sec. III.
b. Display coding to maximize the opportunity to discriminate signals from noise.	
c. Operator control to electronically mark points to be monitored, correlated, entered, or dropped.	
5.2.4.5.1.2 Time-Integrated Data - Systems which accumulate processed data and present all or part of that history in integrated fashion on current scans should provide:	
a. Controls for adjusting the amount of data history to be displayed.	
b. Means to differentiate the most recent data from the older data.	
c. Operator control to electronically mark points to be entered or dropped.	
5.2.4.5.1.3 Time-Compressed Data - Systems which accumulate processed data and present all or part of that history in accelerated sequential playback should provide controls for:	Professional judgment.
a. Adjusting the amount of data history to be displayed. (For most applications the minimum number of scans to be displayed in a sequence should be six or more.)	
b. Adjusting playback rate between the limits of 12 and 30 frames per second.	
c. Electronically marking points to be entered or dropped.	
5.2.4.5.2 Alphanumeric Characters	
5.2.4.5.2.1 Character Generation - Provided they meet the legibility requirements specified in 5.2.4.5.2.2 characters may be generated by any of the commonly used techniques including the following.	Ref: Cakir, Hart, & Stewart, The VDT Manual, 1979, pp. 13-14.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
a. Stroke generation, in which the character is drawn by deflecting the CRT beam through a series of connected line segments.	
b. Lissajous generation, in which the beam is deflected through a sequence of segments of lissajous figures.	
c. Facsimile generation, in which character shapes are stored in analog form as a mask within the CRT and are used to shape the electron beam.	
d. Dot matrix generation in which an electronically stored dot matrix memory is used to intensity-modulate the beam as it scans the character space.	
5.2.4.5.2.2 <u>Legibility Requirements</u> - CRT-presented characters shall be designed so as to avoid "look-alike" pairs which might be confused with one another (e.g., B and 8, 5 and S, 0 and D.) Characters should generally conform to the legibility requirements specified in paragraph 5.2.6.2.3.2 except as follows:	Ref: MIL-HDBK-759, p. 195.
a. Stroke width on CRTs for single-operator use may be determined by the normal width of a stroke on the CRT rather than by a fixed ratio of stroke width to height.	
b. Minimum character height on raster scans shall be 7 raster lines.	Ref: Van Cott, <u>Human Engineering Guide to Equipment Design</u>, 1972, p. 100.
5.2.4.5.3 <u>Symbols and Symbol Modifiers</u> - Symbols and their modifiers which are presented on CRTs shall meet the following requirements. (Also see paragraph 5.5.)	
a. Except for dots, small circles, and keyboard-generated symbols such as the dash, quotation marks, commas, etc., minimum height of symbols shall at least equal the minimum height for characters as specified in paragraph 5.5.5.6. Minimum symbol height on raster scans shall be at least 7 raster lines.	Ref: <u>NAVSHIPS Display Illumination Design Guide</u>, 1973, IV-3.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
b. Color coding of symbols shall be used only redundantly with some other coding technique. (For example, if shape coding is utilized to differentiate between hostile and friendly tracks, color coding may also be used to enhance the difference, but color coding shall not be used as the sole means of differentiation.)	Professional judgment.
c. Selection of a symbol set and modifiers shall be based on the following criteria.	
(1) Symbols and modifiers should reflect the interrelationships among the data in the set to be represented. Thus if a target is represented by a circle, an engaged target should be presented as a modified circle (e.g., a circle with a bar across it) rather than as a completely different symbol (e.g., a triangle).	
(2) Clear differentiation shall be maintained between basic symbol types, between modified symbol types, and between modified and unmodified symbols.	
(3) No more than 5 variations (3 preferred) in a single dimension (e.g., hue for color coding) shall be utilized in any set of symbols which must be discriminated from one another on an absolute basis (without side by side comparison).	Absolute discrimination between about 7 values on a single dimension is often cited in the literature. Since performance is likely to be more error-prone under stress than under laboratory conditions, a more conservative figure of not more than 5 discriminations in a single dimension would appear to be warranted.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.4.5.4 Refresh Rates - Except for time-compressed data and warning or alerting signals, all data on CRTs shall be displayed at refresh rates of at least 28 per second or greater as needed to prevent noticeable flicker. 5.2.4.5.5 Display-Compoisiton Features - Convenient controls shall be provided to allow the operator to select the categories of information which are needed for independent display and to determine how the selected information shall be displayed (e.g., normal symbology, dots only, intensified, blinking, etc., if this type of selective control over presentation mode is needed by the operator for task performance). Controls should be on an alternate action basis so that one switch action adds the category and the alternate action removes it (as opposed to two independent controls, one to add, and the other to remove.) Positive indication shall be provided at all times for the state of the display-composition switches (i.e., the operator needs to be able to conveniently read out at any point in time precisely how the display has been structured). 5.2.4.5.6 Operator/Computer Interaction - The opportunity for constructive use of operator/computer interaction shall be considered for the following as applicable: a. Generation of trial solutions to tactical problems. b. Generation of free-drawn graphics. c. Solution of relative motion problems. d. Construction of formatted messages. e. Editing of messages. 5.2.4.5.7 Data Readout - Computer-generated display systems shall provide convenient operator-oriented means for readout of selected information on demand. In tactical data systems this may involve use of a two-coordinate controller to designate specific tracks for readout, a keyboard for entry of instructions to the computer, sophisticated computer algorithms for processing of information per operator request, and displays for presenting formatted information in response to track oriented or other information requests.	Professional judgment, based on data from many sources including NAVSHIPS Display Illumination Design Guide, 1973, p. IV-14.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.4.5.8 Handover - Computer-generated display systems shall provide convenient means for transferring responsibilities between operators (e.g., complete handover of responsibility as in shutting down a console, or handover of individual targets on the basis of sector transit, engagement status, or operator overload).	Professional judgment.

5.2.4.5.9 Inter-Display Pointing - Incorporation of inter-display pointing shall be considered so as to allow each operator to position a display marker and drive one or more slaved markers on other displays as selected, so as to facilitate communication regarding areas of interest.

5.2.4.5.10 Composition and Editing of Messages - When the computer is used to assist the operator in composing and/or editing CRT-displayed messages the following features should be provided.

a. A cursor on the display (e.g., a line beneath a character) to identify where the operator is in the sequence.

b. Controls as needed to allow rapid positioning of the cursor.

c. Selection capability for standard message formats.

d. Automatic composition of those parts of standard formats for which the computer has the data.

5.2.4.5.11 Automation of Functions

5.2.4.5.11.1 Criteria for Automation - Automated systems should be used to:

a. Prevent operator saturation as in the detection and tracking of large numbers of targets in a surveillance system.

b. Detect events (e.g., targets or signals) when the frequency of occurrence is very low and the unaided operator cannot maintain the required vigilance over the long period of time between events.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
c. Replace manual functions wherever the capabilities of the automated system are clearly superior to chose of a purely manual system.	
5.2.4.5.11.2 Data Filtering for Monitoring Automated Functions - Displays used exclusively for monitoring automated functions should operate on a discrepancy or "management by exception" basis wherein only those data which deviate from expectation according to system mode and operational conditions are displayed. (This includes data on processor function as well as operational data.)	Professional judgment.
5.2.4.5.11.3 Data Presentation for Manual Backup - In systems where manual backup may be required in case of computer failure, the backup display shall not operate strictly on a discrepancy basis but rather shall present sufficient data to keep the operator advised of the current state of processing and to provide all the baseline data which would be needed to initiate manual operation at any point in time.	
5.2.4.5.11.4 Timely Data Processing and Display - Automated systems shall be designed so as to: a. Respond to operator information requests and control inputs in a timely manner. b. Impose minimal burden on the operator for routine aspects of data management. c. Present routine information to the operator on a time-phased basis related to the task sequence but present urgent information on a interrupt basis using alerting techniques.	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.4.9 Electronically or Optically Generated Displays - [Same as original]	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.2.5 Large-Scale Displays 5.2.5.1 Design - The design of large-scale displays intended for group observation shall conform with the basic visual criteria in other paragraphs of this standard, and the additional requirements below. Also, see 5.2.6.6. 5.2.5.2 Legibility - The height-to-width ratio, stroke width, size, and spacing of display symbols shall be such that all characters will be legible at the maximum viewing angle and distance (minimum of 15' arc).	The key issue of when and how to use large screen displays is ever present in modern systems, and the present material says nothing about when and how to use such displays. The legibility statement leaves too much to the judgment of the designer, i.e., assumes he will look at all of the other sections dealing with legibility

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.5 <u>Large-Screen Displays</u> 5.2.5.1 <u>Application</u> - Large-screen displays may be used when: a. A group of operators frequently refer to the same information and are required to interact as a team, based on the same information. b. One or more members of a team of operators have to move about, yet require frequent referral to information required to make decisions, but which they cannot carry with them, or do not have displayed at the specific position at which they happen to be. c. There are space or other constraints that preclude the use of individual displays for each team member to call up commonly-used information. d. It may be desirable to have general information available to persons who should not interrupt on-going group operations by looking over the shoulder of individual operators to see their individual displays. Large-screen displays should not be used when the spatial and environmental conditions do not allow satisfactory observational geometry to insure that all critical operators have appropriate visual access in terms of viewing distance, angle and lack of interference from intervening objects or personnel and/or ambient lighting.	The applications statements are ones typically found in analyses leading to decisions on whether to use large screen displays vs individual operator displays and communication links. The advice when not to use such displays is based on some of the typical examples of poor use of large screen displays--the purpose of which is to preclude some one trying to use such a display when the physical constraints make the resulting work conditions extremely awkward or difficult, i.e., difficulties outweigh any slight advantage the large display could have provided, given proper spatial environment.
5.2.5.2 <u>Angle of View</u> - All critical display observers shall be able to view the display as perpendicularly as possible, and in no case at an angle of less than 40° from the plane of the screen. 5.2.5.3 <u>Viewing Distance</u> - The display shall not be placed further from an observer than will provide appropriate resolution of critical detail presented on the display (see legibility requirements 5.5). And the display shall not be closer to any observer than 1/2 the display width or height, whichever is greater.	Although screen/seating criteria are provided for projection systems it is not always the same for non-projected systems that are not audience-oriented.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.5.4 Physical Interruption of View - Large-screen displays shall not be located with respect to critical observers so that view of the display is obscured regularly by persons moving about (i.e., normal traffic patterns).	
5.2.5.5 Control of Displayed Information - Large-screen group display systems shall be designed so that critical information cannot be modified or deleted inadvertently or arbitrarily, i.e.:	Professional judgment.
a. Changes in the group display shall be controllable by designated operators who operate according to pre-established procedures and/or upon command of a person in charge.	
b. Separate displays should be provided for operators who must make changes in display format or content which would be disruptive to other operators.	
c. Display composition features as specified in 5.2.4.2.1.9 shall be provided as appropriate for monitoring and control of display format and content.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.2.6 Other Displays	Too brief to cover the topic.
5.2.6.1 General	
5.2.6.1.1 Types - Where applicable, direct-reading counters, printers, plotters, flags, optical projection displays and light emitting diodes (LEDs) should be considered.	Needs some reorganization in order to accept new requirements.
5.2.6.1.2 Applications - The selection of the above types of displays for various applications should be based on the following specific criteria as well as the criteria in Table III.	
5.2.6.2 Counters	There are more than drum-type counters.
5.2.6.2.1 Application - Counters should be used for presenting quantitative data when a continuous trend indication is not required and when a quick, precise indication is required.	
5.2.6.2.2 Mounting - Counters shall be mounted as close as possible to the panel surface so as to minimize parallax and shadows and maximize the viewing angle.	
5.2.6.2.3 Numeral Proportions - The height-to-width ratio of numerals shall be 1:1 with the exception of the number "1", which shall be one stroke width.	
5.2.6.2.4 Spacing Between Numerals - The horizontal separation between numerals shall be between one-quarter and one-half the numeral width. (Commas shall not be used.)	
5.2.6.2.5 Movement -	
a. Snap Action - Numbers shall change by snap action in preference to continuous movement.	
b. Rate - Numbers shall follow each other not faster than 2 per second when the observer is expected to read the numbers consecutively.	
c. Direction - The rotation of the counter reset knob shall be clockwise to increase the counter indication or to reset the counter.	

ORIGINAL REQUIREMENT	MFI COMMENTS
d. Automatic Reset - Counters used to indicate the sequencing of equipment shall be designed to be reset automatically upon completion of the sequence. Provision shall also be made for manual resetting.	
5.2.6.2.6 Illumination - Counters shall be self-illuminated when used in areas in which ambient illumination will provide display luminance below 1 ft-L (3.4 cd/m^2).	
5.2.6.2.7 Finish - The surface of the counter drums and surrounding areas shall have a dull finish so as to minimize glare.	
5.2.6.2.8 Contrast - Color of the numerals and background shall provide high contrast (black on white or converse, as appropriate).	
5.2.6.3 Printers -	
5.2.6.3.1 Application - Printers should be used when a visual record of data is necessary or desirable.	
5.2.6.3.2 Form of Information - Printed information shall be presented in a directly usable form with minimal requirements for decoding, transposing, and interpolating.	
5.2.6.3.3 Insertion and Removal of Materials - Printers shall be designed to provide for quick and easy insertion and removal of printing materials.	
5.2.6.3.4 Take-up Provision - A take-up device for printed material shall be provided.	
5.2.6.3.5 Supplies - A positive indication of the remaining supply of printing materials (e.g., paper, ink, and ribbon) shall be provided.	
5.2.6.3.6 Annotation - Where applicable printers should be mounted so that the tape may be easily annotated while still in the recorder.	
5.2.6.3.7 Printed Tapes - The information on the tapes shall be printed in such a manner that it can be read directly when it is received from the machine without requiring the cutting and pasting of sections of tape.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.2.6.3.8 Visibility - The printed matter shall not be in any way hidden, masked or obscured so that direct reading cannot be easily and accurately accomplished. 5.2.6.3.9 Illumination - The printer shall be designed with internal illumination if the printed matter is not completely and easily readable in the operational ambient illumination planned for the printer. 5.2.6.3.10 Contrast - A minimum of 50% luminance contrast shall be provided between the printed material and the background on which it is printed. 5.2.6.4 Plotters - 5.2.6.4.1 Use - Plotters should be used when a visual record of continuous graphic data is necessary or desirable. 5.2.6.4.2 Visibility - Plotting points shall be readily visible and shall not be obstructed by the pen assembly or arm. 5.2.6.4.3 Contrast - A minimum of 50% contrast shall be provided between the plotted function and the background on which it is drawn. 5.2.6.4.4 Take-up Device - A take-up device for extruded plotting materials shall be provided when necessary or desirable. 5.2.6.4.5 Job Aids - Aids (e.g., graphic overlays) shall be provided when an operator is required to interpret graphic data, but such aids shall not obscure or distort the data. 5.2.6.4.6 Annotation - Where applicable plotters should be mounted so that the plotted information may be annotated while still in the plotter. 5.2.6.5 Flags - 5.2.6.5.1 Application - Flags should be used to display qualitative, non-emergency conditions.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.2.6.5.2 Mounting - Flags shall be mounted as close to the surface of the panel as possible without restricting their movement or obscuring necessary information. 5.2.6.5.3 Snap Action - Flags shall operate by snap action. 5.2.6.5.4 Contrast - A minimum of 50 percent contrast shall be provided between flags and their backgrounds under all expected lighting conditions. 5.2.6.5.5 Malfunction Indication - When flags are used to indicate the malfunction of a visual display, the malfunction position of the flag shall at least partially obscure the operator's view of the malfunctioning display and shall be readily apparent to the operator under all expected levels of illumination. 5.2.6.5.6 Test Provision - A convenient means shall be provided for testing the operation of flags. 5.2.6.6 Optical Projection Displays - 5.2.6.6.1 Application - Providing ambient light can be properly controlled, optical projection displays are suitable for applications requiring group presentation, pictorial and spatial information, past history vs real-time presentation, synthetically generated pictures, simulation of the external world and superposition of data from more than one source. 5.2.6.6.2 Seating Area - Optical projection displays for group viewing shall be designed such that viewing distance/image width relationship and off-centerline viewing should conform to the preferred limits of Table IV and shall not exceed the acceptable limits indicated. For individual viewing from a fixed location, off-centerline viewing shall not exceed 10°. 5.2.6.6.3 Image Luminance and Light Distribution - Image luminance and light distribution should conform to the preferred limits and shall not exceed the acceptable limits of Table IV. 5.2.6.6.4 Legibility of Projected Data -	

TABLE IV. GROUP VIEWING OF OPTICAL PROJECTION DISPLAYS

FACTOR	OPTIMUM	PREFERRED LIMITS	ACCEPTABLE LIMITS
Ratio of $\frac{\text{viewing distance}}{\text{screen diagonal}}$	4	3–6	2–8
Angle off centerline	0°	20°	30°
*Image luminance (no film in operating projector)	10 ft-L (34 cd/m^2)	8–14 ft-L (27-48 cd/m^2)	5–20 ft-L (17-69 cd/m^2)
Luminance variation across screen (ratio of maximum to minimum luminance)	1	1.5	3.0
Luminance variation as a function of viewing location (ratio of maximum to minimum luminance)	1	2.0	4.0
Ratio of $\frac{\text{ambient light}}{\text{brightest part of image}}$	0	0.002–0.01	0.1 max**

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

ORIGINAL REQUIREMENT	MFI COMMENTS
5.2.6.6.4.1 Style - A simple style of numerals and letters shall be used. Capital letters shall be used, rather than lower case, except for extended copy or lengthy messages. Stroke width shall be 1/6 to 1/8 of numeral or letter height; however, stroke width may be narrower for light markings on a dark background. Letter and numeral widths, character spacing and word spacing shall conform to 5.5.5.4, 5.5.5.5, 5.5.5.9, and 5.5.5.10, respectively. 5.2.6.6.4.2 Size - The height of letters and numerals shall not be less than 15 minutes of visual angle as measured from the longest anticipated viewing distance. 5.2.6.6.4.3 Contrast - Characters may be either dark on light background or vice-versa, except where superposition is used. Colored markings against colored backgrounds of comparable brightness shall be avoided. 5.2.6.6.4.4 Alignment - Misregistration of superimposed alphanumeric data or other symbols shall be minimized. 5.2.6.7 Light Emitting Diodes (LED's) - 5.2.6.7.1 General - In general, the standard for LED's will be the same as the requirements for Transilluminated Displays, paragraph 5.2.2 of this standard, unless specified below. 5.2.6.7.2 Application - LED's may be used for transilluminated displays, including legend and simple indicator lights, and for matrix (alpha-numeric) displays. Red LED's may be used in transilluminated displays in crew stations exposed to ambient illumination of direct sunlight, but LED's used in alpha-numeric displays and green and yellow LED's may not be used without approval of the procuring activity. 5.2.6.7.3 Intensity Control - The dimming of LED's should be compatible with the dimming of incandescent lamps.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.2.6.7.4 Color Coding - LED color coding shall conform to 5.2.2.1.18, herein, with the exception of red alpha-numeric displays; however, they should not be located in the proximity of red lights used as outlined in 5.2.2.1.18. 5.2.6.7.5 Lamp Testing - LED indicator lights with 100,000 hours MTBF (mean time between failure) shall not require the lamp test capability specified in 5.2.2.1.14.	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.6 <u>Other Displays</u>	
5.2.6.1 <u>General</u>	
5.2.6.1.1 <u>Applications</u> - Where applicable, other display concepts devices and/or techniques should be considered including the following:	This seemed the best way to introduce the "other displays" i.e., to not only identify, but delineate application guidelines for each.
a. Digit light arrays to monitor "count-down" operations.	
b. Drum-type, mechanical counters to display discrete numerical values, but non-trend information.	
c. Character readout devices (e.g., stacked edge-lit, back-projected, gas-discharge tube, CRT, plasma, LCD, LED, etc.) that present alternate characters (numerals, letters, or numerals and letters) within the same viewing envelope, may be used in conjunction with, or in lieu of (a) or (b) above.	
d. Mechanical flags incorporated within an instrument to indicate that the instrument is in a Go vs No-Go condition.	
e. Plotters and recorders to provide visual record of continuous graphic data.	
f. Printers for producing hard copy records from manual or computer inputs.	
g. Optical projection systems to present static and/or dynamic information for large screen, group viewing, projection of guidance information on a vehicle windscreen (e.g., head-up display), and for display of composite situation information (e.g., PPI display).	
5.2.6.1.2 <u>Visibility and Legibility</u> - Basic visibility and legibility requirements for other displays described herein shall also apply to the above special displays. Also see requirements on display illumination, paragraph 5.2.1.1.	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.6.2 Special Requirements	
5.2.6.2.1 Digit Light Arrays	
5.2.6.2.1.1 Arrangement - Digit light arrays used for other than countdown purposes shall be arranged in normal single line format with increasing numbers from left to right or from top to bottom. The sequence for countdown operation shall be reversed: i.e., decreasing numbers from left to right c from top to bottom. (See figure______.)	
5.2.6.2.1.2 Spacing - Lights shall be spaced as follows:	Professional judgment.
a. Minimum = One half the diameter of the indicator light.	
b. Maximum = Equal to the diameter of the indicator light.	
5.2.6.2.1.3 Color and Contrast - Black number on a white background shall be used (unless specific approval for a reversed contrast or colors is given by the procuring agency). Adjacent panel surface sh ll appear darker than the lighted indicator (e.g., a minimum contrast of 50 percent), and the surface shall have a dull or matte finish.	
5.2.6.2.2 Drum-Type, Mechanical Counters - Mechanical, drum-type counters shall conform to criteria in Figure_____.	
5.2.6.2.3 Character-Generating Devices	
5.2.6.2.3.1 Application - In making a selection from among the several types of readout devices, consideration shall be given to the limitations of each device in terms of available brightness colors, and reading speed and accuracy (i.e., the character legibility of some indicators is better than others. The following should be used as a guide:	
a. Devices that produce continuous-line characters provide the opportunity to maximize key legibility parameters, i.e., height-to-width ratio, stroke width, luminance contrast and color.	

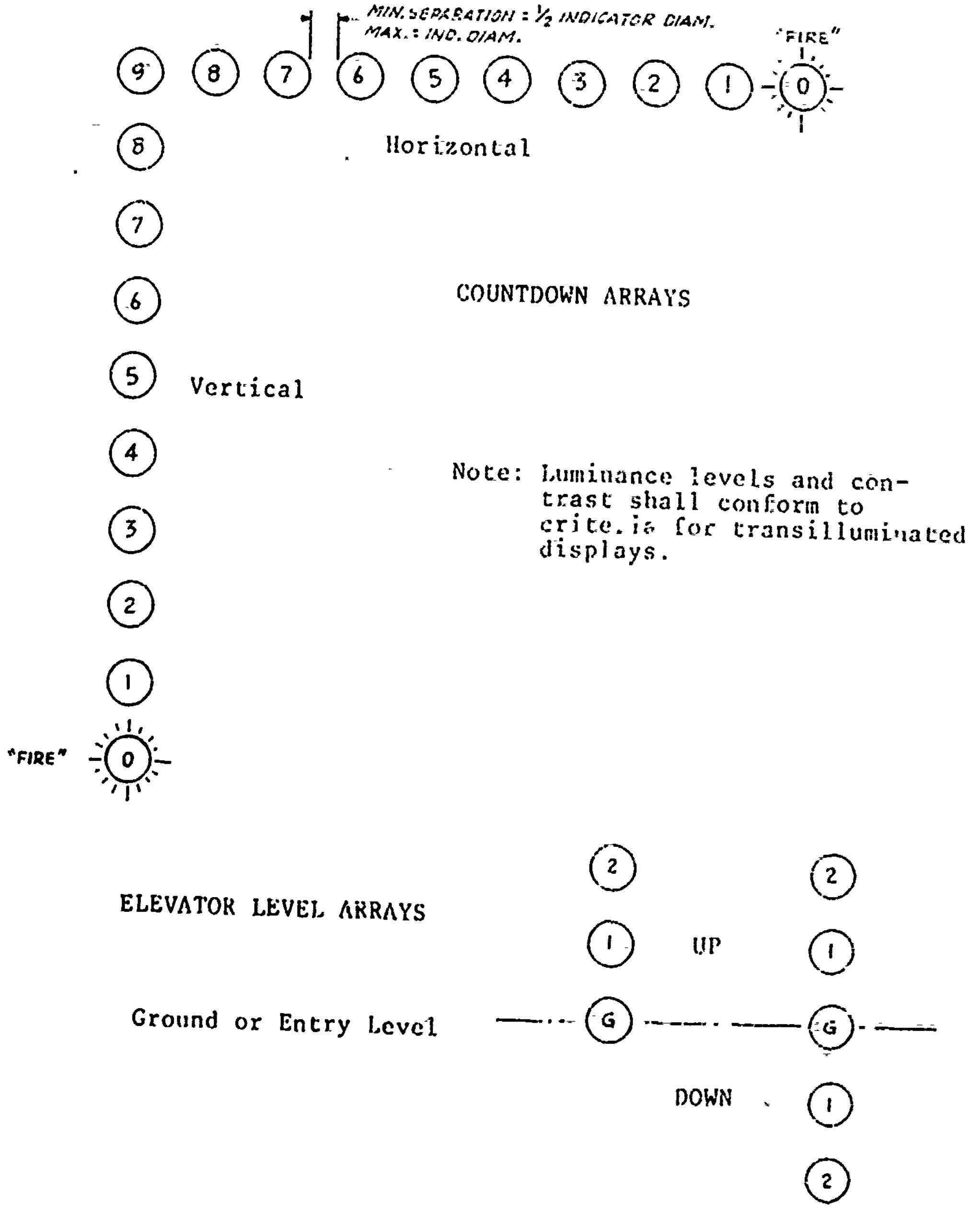
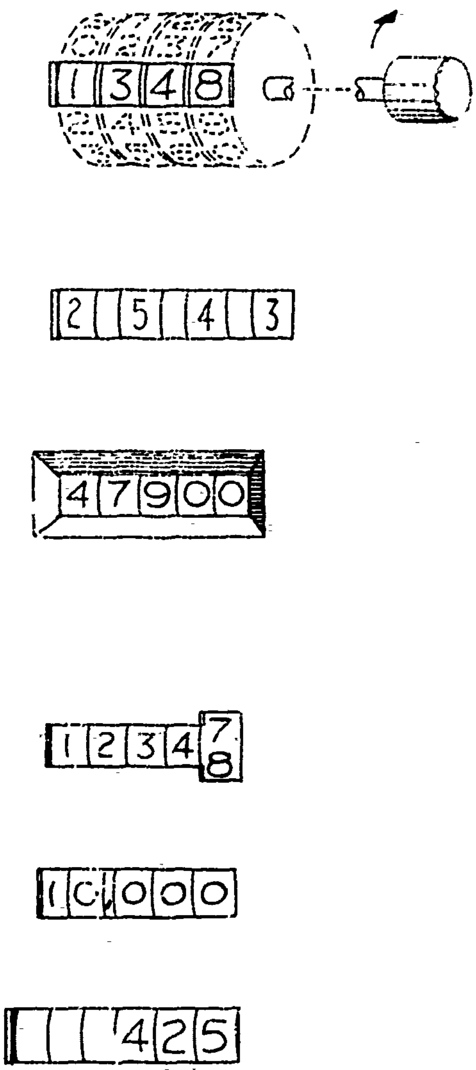


Figure_____ - Digit Light Counter Arrays



a. Counter drums shall be numbered so that a clockwise rotation of drums and/or re-set control produce increasing numerical values.

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

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

b. Spacing between adjacent numerals shall not exceed ¼th width of wide numerals; ½ width of narrow numerals when several numbers are to be read as a total value.

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

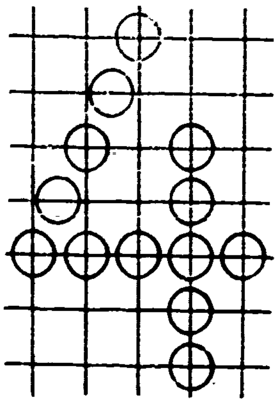
d. When numbers on right drums need not be read accurately, these may move in a continuous motion - in which case at least two of the numbers shall be visible.

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

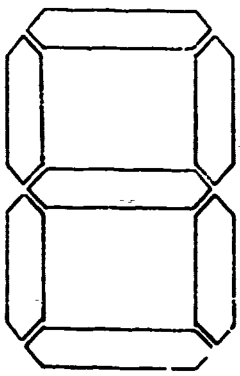
f. If left hand numbers are seldom used, provide a blanking system rather than present several preceding zeros (i.e., the blanking device only exposes left hand drums when numerical value is displayed.

Figure _____ - Drum-Type Counter Design

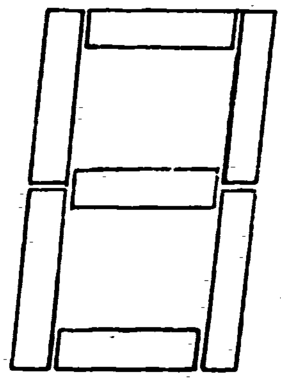
MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
b. Devices that produce characters by means of dot or line segment patterns are limited in terms of the above legibility parameters, dot patterns being the more readable (see Figure_____).	
c. Depending on the state-of-the-art for a given device, some devices may be too large or too small for the particular application, e.g., panel space limits or viewing distance limits.	
5.2.6.2.3.2 <u>Alphanumeric Character Format</u> - The format of alphanumeric characters shall be based on the characteristics of standard Gothic capital letters and numerals and shall contain at least the number of resolution elements shown in Figure_____. Characters and symbols should appear upright or sloping slightly to the right (a positive slope, to the right, of up to 11^{o} may be used). Legibility/readability of unusual formats shall be equivalent to that of standard Gothic capital letters and numerals.	
5.2.6.2.3.3 <u>Contrast Direction</u> - Character generation techniques should be chosen to best fit the operating environment: a. Light symbols on a dark background when work area illumination is low (i.e., less than about 1 f-L). b. Either light or dark background for intermediate illumination levels. c. Dark on light background is preferred when ambient light conditions are high (i.e., more than about 100 f-L).	Ref: Woodson and Conover, <u>Human Engineering Guide for Equipment Designers</u>, 1966, p. 2-34.
5.2.6.2.3.4 <u>Indicator Spacing</u> - When several indicators are used side by side to provide a multi-digit number, the actual spacing between characters shall conform to the requirements stated above for drum-type counters.	
5.2.6.2.3.5 <u>Glare</u> - Devices which are subject to glare problems (e.g., stacked edge-lit, gas-discharge tubes) shall be designed to minimize intersurface reflections, halo effects around glow wires or engravings, "hot spots" from lamp sources, etc. When the particular display may be affected by external (ambient) light	



5 x 7 dot matrix may be used for both letters and numerals, as well as other symbols. A 7 x 9 is preferred when accuracy is of particular importance for alphanumeric data sets.



7-segment bar-type matrix is acceptable for numerals, but cannot provide a full alphabet of letters.



Italic or sloping matrix is acceptable as long as the slope does not exceed 11°.

Figure _____ - Minimal Requirements for Dot and Segmented Matrix Characters

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
reflections, filters and/or anti-reflection coatings shall be provided. 5.2.6.2.3.6 Lamp Replacement - Devices which depend upon incandescent lamp sources shall be packaged for ease of lamp replacement. 5.2.6.2.3.7 Intensity Control - Digital readout devices that may be used under dim-out or black-out operating conditions shall be selected on the basis that operator-controlled dimming shall be provided. 5.2.6.2.4 Mechanical Flags 5.2.6.2.4.1 Application - [Use original material from 5.2.6.5.1] 5.2.6.2.4.2 Mounting - Where practical, flags should be mounted inside the instrument cover glass, as close to the display surface as practical without restricting flag movement. The flag in its stowed position shall not obscure necessary information on the primary display. However, (where practicable) the flag, when in the No-Go position, should extend into the display area (and preferrably obscure some displayed element) far enough to insure that the operator will take note of the condition indicated by the flag (e.g., display or instrument inoperative). 5.2.6.2.4.3 Snap Action - [Use original material from 5.2.6.5.3.] 5.2.6.2.4.4 Contrast - [Use original material from 5.2.6.5.4.] 5.2.6.2.4.5 Legend - When a legend is provided on the flag, lettering shall appear upright when the flag assumes the active or No-Go position. 5.2.6.2.4.6 Test Provision - [Use original material from 5.2.6.5.6] 5.2.5.2.5 Plotters and Recorders 5.2.6.2.5.1 Visibility - Critical graphics (those points, curves grids, etc. that need to be observed during the time that the recording is being made) shall not be obscured by pen assembly, arm or other hardware elements.	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.6.2.5.2 Contrast - [Use original material in 5.2.6.4.3.] [Add:] (Flags used to display system faults should be Flourescent Orange, FED-STD-595a #28915.)	Professional judgment.
5.2.6.2.5.3 Take-up Device - Use original material in 5.2.6.4.4.	
5.2.6.2.5.4 Job Aids - Graphic overlays should be provided where these may be critical to proper interpretation of graphic data as it is being generated. Such aids shall not obscure or distort the data.	
5.2.6.2.5.5 Annotation - Where applicable, plotters should be designed and/or mounted so that the operator can manually write on or mark on the plotting paper while it is still in the plotter.	
5.2.6.2.5.6 Control, Replenishment and Service - Plotters and recorders shall be designed to conform to criteria herein, with regard to the following: a. Control-displays used to start, stop or adjust the machine and critical operating elements. b. Insertion, adjustment for operation, and removal of paper, replenishment of ink supply, replacement of pen or other items determined to be operator tasks. c. Minor servicing on site by a technician, i.e., adjustment of drive system, cleaning, or replacement of operating items that ordinarily would not be available to an operator.	
5.2.6.2.6 Printers - Criteria in 5.2.6.2.5 (Plotters and Recorders) shall apply to printers as applicable. In addition, the following shall be considered. a. The printer shall be free from character line misregistration, character tilt or smear. b. The printer shall not be excessively noisy if it will be located in an area normally occupied by personnel for more than a few minutes, or where critical direct or telephone conversations are required (see 5.8.3).	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.2.6.6 <u>Optical Projection Displays</u> 5.2.6.6.1 through 5.2.6.6.4.4 - [Use original materials as written--add the following:] 5.2.6.6.4.5 <u>Keystone Effects</u> - Projector-Screen arrangement shall be considered to minimize "keystone effects", e.g., distortion of projected data proportions due to non-perpendicularity between projector and screen.	

TABLE IV. GROUP VIEWING OF OPTICAL PROJECTION DISPLAYS

FACTOR	OPTIMUM	PREFERRED LIMITS	ACCEPTABLE LIMITS
Ratio of $\frac{\text{viewing distance}}{\text{screen diagonal}}$	4	3–6	2–8
Angle off centerline	0°	20°	30°
*Image luminance (no film in operating projector)	10 ft-L ($34\ cd/m^2$)	8–14 ft-L ($27\text{-}48\ cd/m^2$)	5–20 ft-L ($17\text{-}69\ cd/m^2$)
Luminance variation across screen (ratio of maximum to minimum luminance)	1	1.5	3.0
Luminance variation as a function of viewing location (ratio of maximum to minimum luminance)	1	2.0	4.0
Ratio of $\frac{\text{ambient light}}{\text{brightest part of image}}$	0	0.002–0.01	0.1 max**

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

ORIGINAL REQUIREMENT	MFI COMMENTS
5.3 AUDIO DISPLAYS - 5.3.1 General - 5.3.1.1 Application - Audio displays should be provided under the following conditions: a. The information that is to be processed is short, simple, and transitory requiring immediate or time-based response. b. The common mode of visual display is restricted by over-burdening; ambient light variability or limitation; operator mobility; degradation of vision by reason of vibration, high g-forces, hypoxia, other environmental considerations; or anticipated operator inattention. c. The criticality of transmission response makes supplementary or redundant transmission desirable. d. It is desirable to warn, alert, or cue the operator to subsequent additional response. e. Custom or usage has created anticipation of an audio display. f. Voice communication is necessary or desirable. 5.3.1.2 Signal Type - Each situation requiring an audio presentation shall be carefully evaluated to determine the optimum type of signal for that presentation, taking into consideration the criteria for different types of audio signals presented in Table V. 5.3.1.3 False Alarms - The design of audio display devices and circuits shall preclude false alarms. 5.3.1.4 Failure - The audio display device and circuit shall be designed to preclude warning signal failure in the event of system or equipment failure and vice versa. 5.3.1.5 Circuit Test - All audio displays shall be equipped with circuitry test devices or other means of operability test. 5.3.1.6 Aircrew Stations - Audio signals for air crew stations shall conform to MIL-STD-411, where applicable.	1. Because of the extensive re-organization and new content needed in this section the original is included in its entirety. 2. One of the serious defects with the original organization is that material on warning is scattered in various places in the section.

ORIGINAL REQUIREMENT	MFI COMMENTS

TABLE V. FUNCTIONAL EVALUATION OF AUDIO SIGNALS

FUNCTION	TYPE OF SIGNAL		
	TONES (Periodic)	COMPLEX SOUNDS (Non-Periodic)	SPEECH
QUANTITATIVE INDICATION	POOR Maximum of 5 to 6 tones absolutely recognizable	POOR Interpolation between signals inaccurate.	GOOD Minimum time and error in obtaining exact value in terms compatible with response.
QUALITATIVE INDICATION	POOR-TO-FAIR Difficult to judge approximate value and direction of deviation from null setting unless presented in close temporal sequence.	POOR Difficult to judge approximate deviation from desired value.	GOOD Information concerning displacement, direction, and rate presented in form compatible with required response.
STATUS INDICATION	GOOD Start and stop timing Continuous information where rate of change of input is low.	GOOD Especially suitable for irregularly occurring signals (e.g., alarm signals).	POOR Inefficient; more easily masked; problem of repeatability.
TRACKING	FAIR Null position easily monitored; problem of signal-response compatibility.	POOR Required qualitative indications difficult to provide.	GOOD Meaning intrinsic in signal.
GENERAL	Good for automatic communication of limited information. Meaning must be learned. Easily generated.	Some sounds available with common meaning (e.g., fire bell). Easily generated.	Most effective for rapid (but not automatic) communication of complex, multidimensional information. Meaning intrinsic in signal and context when standardized. Minimum of new learning required.

ORIGINAL REQUIREMENT	MFI COMMENTS
5.3.1.7 Special Applications - Audio displays such as sonar and electronic countermeasures shall be made compatible with the criteria stated herein. If system design precludes following such criteria, requirements for deviations shall be based upon the specific application. 5.3.1.8 Use with Several Visual Displays - One audio signal may be used in conjunction with several visual displays, provided that immediate discrimination is not critical to personnel safety or system performance. 5.3.2 Audio Warnings - 5.3.2.1 Warning Signals - Audio signals should be provided as necessary to warn personnel of impending danger, to alert an operator to a critical change in system or equipment status, and to remind the operator of a critical action or actions that must be taken. NOTE: Certain audio signals have been standardized for aircraft use by joint service and international agreement. Stipulation of audio signals for future aircraft design should be in consonance with these agreements (see MIL-STD-411). 5.3.2.2 Nature of Signals - Audio warning signals should normally consist of two elements: an alerting signal and an identifying or action signal. 5.3.2.2.1 Two element Signal 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 2.0 seconds of the identifying or action signals. 5.3.2.2.2 Single element Signal - When reaction time is critical, signals shall be of short duration. If a single element signal is permissible, all essential information shall be transmitted in the first 0.5 second. 5.3.2.3 Caution Signals - Caution signals shall be readily distinguishable from warning signals and shall be used to indicate conditions requiring awareness but not necessarily immediate action. 5.3.2.4 Relation to Visual Displays - When used in conjunction with visual displays, audio warning devices shall be supplementary or supportive in nature. The audio signal shall be used to alert and direct operator attention to the appropriate visual display.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.3.3 Characteristics of Audio Warning Signals - 5.3.3.1 Frequency - 5.3.3.1.1 Range - The frequency range shall be between 200 and 5,000 Hz and, if possible, between 500 and 3,000 Hz. When signals must travel over 1,000 ft (305 m), sounds with frequencies below 1,000 Hz should be used. Frequencies below 500 Hz should be used when signals must bend around obstacles or pass through partitions. The selected frequency band shall differ from those most intense background frequencies and shall be in accordance with other criteria in this section. 5.3.3.1.2 Spurious Signals - The frequency of a warning tone shall be different from that of the electric power employed in the system, to preclude the possibility that a minor equipment failure may generate a spurious signal. 5.3.3.2 Intensity - 5.3.3.2.1 Compatibility With Acoustical Environment - The intensity, duration and source location of audio alarms and signals shall be selected so as to be compatible with the acoustical environment of the intended receiver as well as the requirements of other personnel in the signal areas. 5.3.3.2.2 Discomfort - Audio warning signals should not be of such intensity as to cause discomfort or "ringing" in the ears as an after-effect. 5.3.4 Signal Characteristics in Relation to Operational Conditions and Objectives - 5.3.4.1 Audibility - A signal-to-noise ratio of at least 20 dB shall be provided in at least one octave band between 200 and 5,000 Hz at the operating position of the intended receiver.	

ORIGINAL REQUIREMENT	MFI COMMENTS

5.3.4.2 Alerting Capability -

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

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

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

5.3.4.2.4 Headset - When the operator is wearing earphones covering both ears during normal equipment operation, the audio warning signal shall be directed to the operator's headset as well as to the work area.

5.3.4.3 Discriminability -

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

5.3.4.3.2 Coding - Where discrimination of warning signals will be critical to personnel safety or system performance, audio signals shall be appropriately coded. Alarms that are perceptibly different shall be selected to correspond with different conditions requiring critically different operator responses (e.g., maintenance, emergency conditions, and health hazards). Such signals shall be sufficiently different to minimize the operator's search of visual displays.

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

ORIGINAL REQUIREMENT	MFI COMMENTS
5.3.4.3.4 Action Segment - The identifying or action segment of an audio warning signal shall specify precisely the emergency or any other conditions requiring actions. 5.3.4.3.5 Differentiation From Routine Signals - Audio alarms intended to bring the operator's attention to a malfunction or failure shall be differentiated from routine signals such as bells, buzzers, and normal operation noises. 5.3.4.3.6 Prohibited Types of Signals - The following types of signals shall not be used as warning devices where possible confusion might exist because of the operational environment: a. Modulated or interrupted tones that resemble navigation signals or coded radio transmissions. b. Steady signals that resemble hisses, static, or sporadic radio signals. c. Trains of impulses that resemble electrical interference whether regularly or irregularly spaced in time. d. Simple warbles which may be confused with the type made by two carriers when one is being shifted in frequency (beat-frequency-oscillator effect). e. Scrambled speech effects that may be confused with cross modulation signals from adjacent channels. f. Signals that resemble random noise, periodic pulses, steady or frequency modulated simple tones, or any other signals generated by standard countermeasure devices (e.g., "bagpipes"). g. Signals similar to random noise generated by air conditioning or any other equipment. h. Signals that resemble sounds likely to occur accidently under operational conditions.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.3.4.4 Compatibility -	
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 Acoustic Environment - Established signals shall be used, provided they are compatible with the acoustic environment and the requirements specified herein for the voice communication system. Standard signals shall not be used to convey new meanings.	
5.3.4.5 Masking -	
5.3.4.5.1 Other Critical Channels - Audio warning signals shall not interfere with any other critical functions or warning signals, or mask any other critical audio signals.	
5.3.4.5.2 Separate Channels - Where a warning signal delivered to a headset might mask another essential audio signal, separate channels may be provided to direct the warning signal to one ear and the other essential audio signal to the other ear. In such a situation and when required by operating conditions, this dichotic presentation may further provide for alternation of the two signals from ear to ear.	
5.3.5 Verbal Warning Signals -	
5.3.5.1 Nature of Signals - Verbal warning signals shall consist of:	
a. An initial alerting signal (nonspeech) to attract attention and to designate the general problem.	
b. A brief standardized speech signal (verbal message) which identifies the specific condition and suggests appropriate action.	
5.3.5.2 Intensity - Verbal alarms for critical functions shall be at least 20 dB above the speech interference level at the operating position of the intended receiver.	
5.3.5.3 Vocal Criteria -	
5.3.5.3.1 Type of Voice - The voice used in recording verbal warning signals shall be distinctive and mature.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.3.5.3.2 Delivery Style - Verbal warning signals shall be presented in a formal, impersonal and calm manner. 5.3.5.4 Speech Processing - Verbal warning signals shall be processed only when necessary to increase or preserve intelligibility, such as by increasing the strength of consonant sounds relative to vowel strength. Where a signal must be relatively intense because of high ambient noise, "peak-clipping" may be used to protect the listener against auditory overload. 5.3.5.5 Message Content - In selecting words to be used in audio warning signals, priority shall be given to intelligibility, aptness, and conciseness in that order. 5.3.5.6 Message Categories - 5.3.5.6.1 Critical Warning Signals - Critical warning signals shall be repeated with not more than a 3-second pause between messages until the condition is corrected or overridden by the crew. 5.3.5.6.2 Message Priorities - A message priority system shall be established and more critical messages shall override the presentation of any message occurring below it on the priority list. In case two or more incidents or malfunctions occur simultaneously, the message having the higher priority shall be given first. The remaining messages shall follow in order of priority. In the event of a complete subsystem failure, the system shall integrate previous messages via electronic gating and report the system rather than the component failure. 5.3.5.6.3 Mode-Blocking - The verbal warning system shall be mode-blocked in such a manner that meaningless messages for the environmental conditions existing at that time will not be presented. 5.3.6 Controls for Audio Warning Devices - 5.3.6.1 Automatic or Manual Shut-off - When an audio signal is designed to persist as long as it contributes useful information, a shut-off switch which is controllable by the operator, the sensing mechanism, or both, shall be provided, depending on careful consideration of the operational situation and personnel safety factors.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.3.6.2 Automatic Reset - Whether audio warning signals are designed to be terminated automatically, by manual control, or both, an automatic reset function shall be provided. The automatic reset function shall be controlled by the sensing mechanism which shall recycle the signal system to a specified condition as a function of time or the state of the signaling system. 5.3.6.3 Volume Control - 5.3.6.3.1 Automatic or Manual - The volume (loudness) of an audio warning signal shall be designed to be controlled by the operator, the sensing mechanism, or both, depending on careful consideration of the operational situation and personnel safety factors. Control movements shall be restricted to prevent reducing the volume to an inaudible level. 5.3.6.3.2 Ganging to Mode Switches - Volume controls may be ganged to mode switches to provide maximum output during mission phases in which intense noise may occur and to provide reduced volume at other times. Ganging shall not be accomplished if there is a possibility that intense noise may occur in an emergency situation during a mission phase in which the volume would be decreased below an audible level. 5.3.6.3.3 Caution Signal Controls - Audio caution signals shall be provided with the manual reset and volume controls. 5.3.6.4 Duration - Audio warning signal duration shall be at least 0.5 second, and may continue until the appropriate response is made. Completion of a corrective action by the operator or by other means shall automatically terminate the signal. 5.3.6.5 Duration Limitations - In an emergency situation, signals that persist or increase progressively in level shall not be used if manual shut-off may interfere with the corrective action required. 5.3.7 Voice Communication System - 5.3.7.1 Telephone or Radio Communications - Design of military integrated telephone or radio communication systems, either of a switched or point-to-point nature, shall be in accordance with the applicable requirements of MIL-STD-188.	

ORIGINAL REQUIREMENT	MFI COMMENTS

5.3.7.2 Speech Transmission Equipment -

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

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

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

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

5.3.7.2.5 Peak-clipping of Speech Signals - Where speech signals are to be transmitted over channels showing less than 15 dB peak-speech to root-mean-square-noise ratios, peak-clipping of 12 to 20 dB may be employed at system input and may be preceded by frequency pre-emphasis as specified in 5.3.7.2.4.

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

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

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

ORIGINAL REQUIREMENT	MFI COMMENTS
c. A hole or combination of holes covering a total area of 0.1 sq. in. (65 sq. mm) in the shield to prevent pressure buildup.	
d. Prevention of a standing wave pattern by shape, or by use of sound absorbing material.	
e. No impediment to voice effort, mouth or jaw movement or breathing.	
5.3.8 Speech Reception Equipment -	
5.3.8.1 Range - Headphones and loudspeakers shall be subject to the same frequency response restrictions as microphones and transmission equipment except that loudspeakers for use in multi-speaker installations (e.g., where several speech channels are to be monitored simultaneously) shall respond uniformly (±5 dB) over the range 100 to 4,800 Hz.	
5.3.8.2 Loudspeakers for Multi-channel Monitoring -	
5.3.8.2.1 Monitoring of Speakers - When several channels are to be monitored simultaneously by means of loudspeakers, the speakers shall be mounted so that they are not less than 10° apart radially with respect to a central operator position, as in a console-configured control or communication center.	
5.3.8.2.2 Filtering - When additional channel differentiation is required, apparent lateral separation shall be enhanced by applying low-pass filtering (frequency cutoff, F_c = 1,800 Hz) to signals fed to loudspeakers on one side of the central operator position. If there are three channels involved, one channel shall be left unfiltered, a high pass filter with 1,000 Hz cutoff shall be provided in the second channel, and a low-pass filter with 2,500 Hz cutoff shall be provided in the third channel. A visual signal shall be provided to show which channel is in use.	
5.3.8.3 Use of De-emphasis - When transmission equipment employs pre-emphasis and peak-clipping is not used, reception equipment shall employ frequency de-emphasis of characteristics complementary to those of pre-emphasis only if it improves intelligibility, i.e., de-emphasis shall be a negative-slope frequency response not greater than 9 dB per octave over the frequency range 140 to 4,800 Hz.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.3 8.4 Headsets - If listeners will be working in high ambient noise (85 dB(A) or above), binaural rather than monaural headsets shall be provided. Unless operational requirements dictate otherwise, binaural headsets shall be wired so that the sound reaches the two ears in opposing phases. Their attenuation qualities should be capable of reducing the ambient noise level to less than 85 dB(A). Provisions should be incorporated to furnish the same protection to those who wear glasses.	
5.3.9 Operator Comfort and Convenience -	
5.3.9.1 Comfort - Communication equipment to be worn by an operator (e.g., headphones and telephone headsets) shall be designed to preclude operator discomfort. Metal parts of the headset shall not come in contact with the user's skin.	
5.3.9.2 Hands-free Operation - Operator microphones, headphones, and telephone headsets shall be designed to permit hands-free operation under normal working conditions.	
5.3.9.3 Accessibility of Handsets - Where communication requirements necessitate the use of several telephone handsets, the accessibility of their standby locations shall be determined by operational priority, i.e., the most frequently or urgently needed handset shall be the most accessible. Color-coding may also be employed where operating personnel will have visual contact with handsets under the working conditions.	
5.3.10 Operating Controls for Voice Communication Equipment -	
5.3.10.1 Volume Controls - Accessible volume or gain controls shall be provided for each communication receiving channel (e.g., loudspeakers or headphones) with sufficient electrical power to drive sound pressure level to at least 110 dB overall when using two earphones, and shall have pressure operated gain control switches to compensate for altitude in unpressurized compartments. The minimum setting of the volume control shall be limited to an audible level, i.e., it shall not be possible to inadvertently disable the system with the volume control. While separation of power (on-off) and volume control adjustment functions into separate controls is preferred, should conditions justify their combination, a noticeable detent position shall be provided between the OFF position and the lower end of the continuous range of volume adjustment.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.3.10.2 Squelch Control - Where communication channels are to be continuously monitored, each channel shall be provided with a signal-activated switching device (squelch control) to suppress channel noise during no-signal periods. 5.3.10.3 Foot-operated Controls - When normal working conditions will permit the operator to remain seated at the working position an access to "talk-listen" or "send-receive" control switches is required for normal operation or if console operation requires the use of both hands, foot-operated controls shall be provided. Hand operated controls for the same functions shall be provided for emergency use and for use when the operator may need to move from one position to another. 5.3.11 Speaker/Side Tone - Circuits shall be designed so that the speaker's verbal output is in phase with its reproduction as heard on the headset. This side tone should not be filtered or modified before it is received in the headset. 5.3.12 Speech Intelligibility 5.3.12.1 General - When information concerning the speech intelligibility of a system is required, three recommended methods are available, with the appropriate selection being dependent upon the requirements of the test: a. The ANSI standard method of measurement of phonetically balanced (PB) monosyllabic word intelligibility, S3.2-1960, should be used when a high degree of sensitivity and accuracy is required.	

ORIGINAL REQUIREMENT	MFI COMMENTS

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

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

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

TABLE VI. INTELLIGIBILITY CRITERIA FOR VOICE COMMUNICATIONS SYSTEMS

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

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.3 SPEECH INPUT AND AUDITORY DISPLAYS	5.3 "Speech input" was added to the title because of new material as well as existing material on microphones. "Auditory" is used in preference to "Audio" because it has a sensory reference which is more in parallel with "Visual" display.
5.3.1 General - Speech input is received through microphones for processing and transmission through voice communication systems or for entry to speech recognition systems. Auditory 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 accoustically-coded information. The human auditory channel itself is distinguished by the fact that, unlike vision, it is never turned off at the sensory level with respect to the acoustic environment. Although both the eye and the ear integrate over short time intervals, the ear acts as an analyzer with respect to the sound spectrum, whereas the eye integrates across the visible spectrum. These differences and others as discussed in this section shall be considered in planning and designing systems utilizing speech or other acoustic signals.	
5.3.1.1 Comparative Characteristics of Auditory Signals - For the purposes of this standard auditory signals will be considered to be of three basic types: tones, complex sounds, and speech. A comparison of the strengths and weaknesses of these types with respect to their use for various functions is presented in Table V.	
5.3.1.2 Application	
5.3.1.2.1 Voice Communciations - Voice communications should be considered for systems under the following conditions. a. The message content or format cannot be predicted in advance. b. Considerable and/or rapid interaction between operators will be required as where there must be joint solution of a war problem, or where it is necessary to "break into" concurrent information transmission. c. The voice signal itself offers assurance or essential psychological support not otherwise available. d. Users cannot conveniently look at a visual display to obtain information.	Ref: Van Cott, Human Engineering Guide to Equipment Design, 1972, Ch. 4 and 5.

TABLE V. FUNCTIONAL EVALUATION OF AUDIO SIGNALS

FUNCTION	TYPE OF SIGNAL		
	TONES (Periodic)	COMPLEX SOUNDS (Non-Periodic)	SPEECH
QUANTITATIVE INDICATION	POOR Maximum of 5 to 6 tones absolutely recognizable.	POOR Interpolation between signals inaccurate.	GOOD Minimum time and error in obtaining exact value in terms compatible with response.
QUALITATIVE INDICATION	POOR-TO FAIR Difficult to judge approximate value and direction of deviation from null setting unless presented in close temporal sequence.	POOR Difficult to judge approximate deviation from desired value.	GOOD Information concerning displacement, direction, and rate presented in form compatible with required response.
STATUS INDICATION	GOOD Start and stop timing. Continuous information where rate of change of input is low.	GOOD Especially suitable for irregularly occurring signals (e.g., alarm signals).	POOR Inefficient; more easily masked; problem of repeatability.
TRACKING	FAIR Null position easily monitored; problem of signal-response compatibility.	POOR Required qualitative indications difficult to provide.	GOOD Meaning intrinsic in signal.
GENERAL	Good for automatic communication of limited information. Meaning must be learned. Easily generated.	Some sounds available with common meaning (e.g., fire bell). Easily generated.	Most effective for rapid (but not automatic) communication of complex, multidimensional information. Meaning intrinsic in signal and context when standardized. Minimum of new learning required.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.3.1.2.2 Individual Speaker Recognition - Automatic speaker recognition techniques may be employed in systems to positively identify an originator to an addressee or to restrict communications access to specific individuals (e.g., to limit access to a data bank). If individual speaker recognition is used for security purposes (i.e., to deny access to classified material by unauthorized personnel) it should be used in combination with some other control method in order to attain sufficient reliability.	5.3.1.2.2 and 5.3.1.2.3 The Standard needs to recognize the emergency of speech recognition as an important security and control factor.
5.3.1.2.3 Speech Recognition for Information Retrieval and Computer Control - Automatic speech recognition systems which are used to recognize the spoken words but not the individual speaker provide an alternate to keysetting techniques for information retrieval and computer control. However, because of the possible misapplication of automatic speech recognition, such techniques should be considered for use only when: a. The vocabulary needed at each phase of operation is comparatively small. (Vocabularly requirements can be considerably reduced by using syntax control which limits the necessary vocabulary search to the words which are plausible at that particular point in the entry sequence) b. Error rates would be comparable to or more favorable than those with other types of control inputs such as keysets. c. Speed of entry would be equal to or faster than conventional entry techniques. d. Convenient means of error detection and correction are provided. e. Convenient means are provided to inhibit the system except when speech input is intended. f. Performance will be satisfactory even under stress conditions.	Professional judgment.
5.3.1.2.4 Auditory Displays - Auditory displays are necessary when apmplified signals are used in voice communications. They should also be considered under the following conditions.	Ref: Van Cott, Human Engineering Guide to Equipment Design, 1972, Ch. 4.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
a. The information that is to be processed is short, simple, and transitory requiring immediate or time-based response. b. The visual display is restricted by: overburdening; ambient light variability or limitation; operator mobility; degradation of vision by reason of vibration, high g-forces, hypoxia, other environmental considerations; or anticipated operator inattention. c. The criticality of transmission response makes supplementary or redundant transmission desirable. d. It is desirable to capture the operator's attention for advisory, cueing, alerting, or warning purposes. e. Custom or usage has created anticipation of an audio display. f. The operator cannot commit the time necessary for monitoring a visual display. g. An auditory presentation is desirable to reinforce a visual presentation. 5.3.1.2.5 <u>Aircrew Stations</u> - Audio signals for aircrew stations shall conform to MIL-STD-411, as applicable. 5.3.1.2.6 <u>Sensor Applications</u> - Auditory displays for sensor systems such as sonar and electronic countermeasures shall be made compatible with the criteria stated herein. Deviations shall require approval of procuring activity. 5.3.1.3 <u>Circuit Test</u> - All auditory displays shall be equipped with circuitry test devices or other means of testing operability. 5.3.2 <u>Non-Verbal Auditory Signals for Advisory, Cueing, Alerting and Warning Functions</u>	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.3.2.1 General - Auditory signals shall be provided as necessary to warn personnel of impending danger, to alert operators to a critical change in system or equipment status, to remind operators of a critical action or actions that must be taken, or to advise personnel of some change in system state or data. (NOTE: Certain audio signals have been standardized for aircraft use by joint service and international agreement. Stipulation of audio signals for future aircraft design should be in consonance with these agreements.	See MIL-STD-411.
5.3.2.1.1 Frequency Range - The frequency range shall be between 100 and 5,000 Hz and, if possible, between 500 and 3,000 Hz. When signals must travel over 1,000 ft. (305 m), sounds with frequencies below 1,000 Hz should be used. Frequencies below 500 Hz should be used when signals must bend around obstacles or pass through partitions. To the extent possible the selected frequency band should differ from the most intense background frequencies and shall be in accordance with other criteria in this section.	Frequencies as low as 100 Hz are used in ship whistles to get long-range propagation and pass around objects.
5.3.2.1.2 Avoidance of Power Frequencies - In order to avoid possible confusion between power frequencies emitted by malfunctioning power circuits and meaningful auditory signals, the signal frequencies shall always be different from the power frequencies.	
5.3.2.1.3 Compatibility With Acoustical Environment - The intensity, duration and source location of auditory signals shall be selected so as to be compatible environmentally with all personnel in the signal areas as well as with the specific individuals intended to receive the signals. Except when essential for safety, signal level should not be so high as to cause discomfort or ringing in the ears. Criteria in Figures _____ and _____ shall be used as guidance.	Ref: Van Cott, Human Engineering Guide to Equipment Design, 1972, Ch. 4.
5.3.2.1.4 Use of Different Characteristics - When several different auditory signals are to be used concurrently, discriminable differences in spectral compoisition and/or temporal pattern shall be provided. When specific recognition of individual signals is important their differences shall be coded in a simple and easily recognized way.	

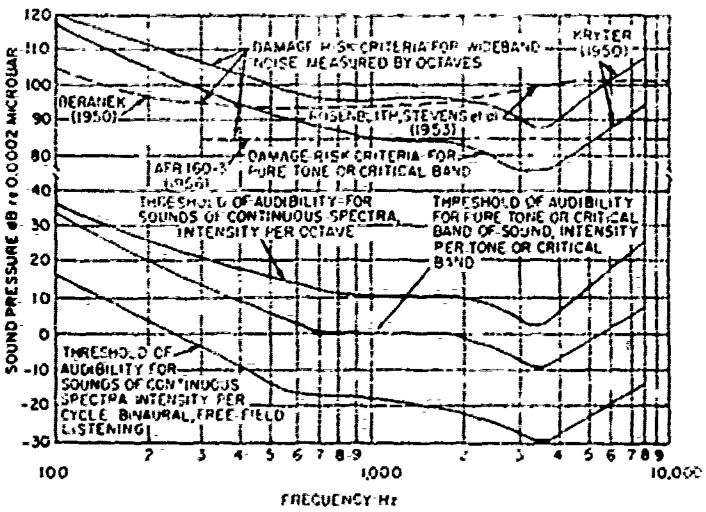


Figure ____ - Audibility Curves and Damage Risk Criteria

Damage-risk criteria of Beranek, Rosenblith and Stevens are the same except at the higher frequencies.

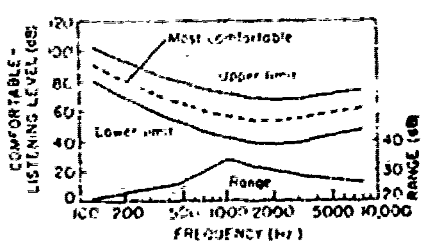


Figure ____ - Comfortable Listening Levels (Pure Tones)

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.3.2.1.5 <u>Prohibited Types of Signals</u> - The following types of signals shall not be used where possible confusion might exist because of the operational environment: a. Modulated or interrupted tones that resemble navigation signals or coded radio transmissions. b. Steady signals that resemble hisses, static, or sporadic radio signals. c. Trains of impulses that resemble electrical interference whether regularly or irregularly spaced in time. d. Simple warbles which may be confused with the type made by two carriers when one is being shifted in frequency (beat-frequency-oscillator effect). e. 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"). f. Signals similar to random noise generated by air conditioning or any other equipment. g. Signals that resemble sounds likely to occur accidently under operational conditions.	(This was originally 5.3.4.3.6 but it should be applicable to all auditory signals - not just warning signals.)
5.3.2.2 <u>Advisory Signals</u> - Auditory signals may be provided to transmit information of an advisory nature which does not require specific operator response or acknowledgement. In quiet areas advisory signals should be presented at a level of 50 to 70 dB on the A-weighted scale. Where there is a noise background they should be at least 15 dB above the noise level in the critical band centered on each major component frequency of the advisory signal. (The width of the critical band varies as a function of the center frequency as indicated in Figure____.)	The values are the professional judgment of Bob Gales. (NOSC)

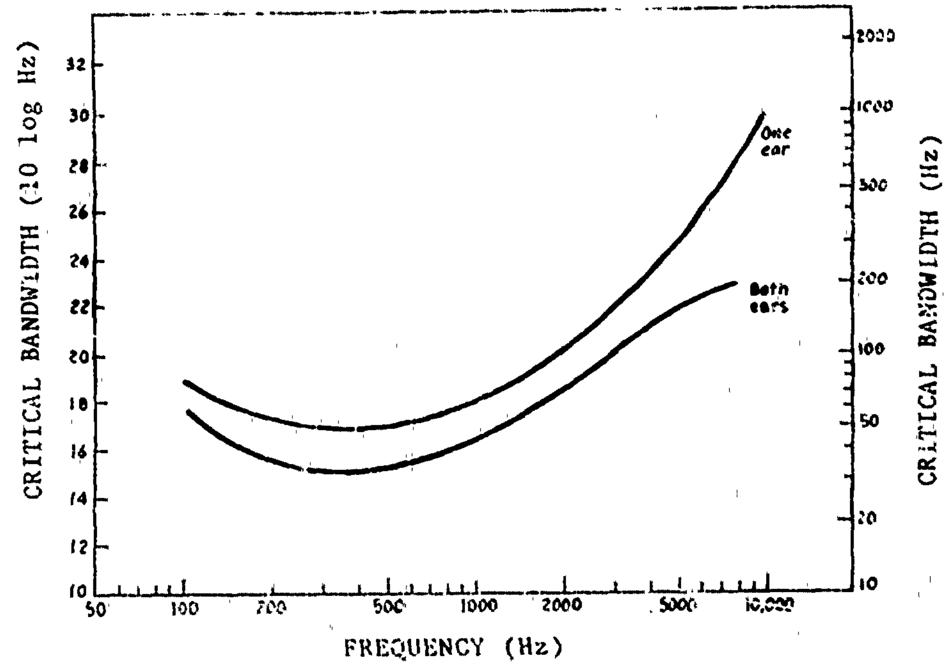


Figure _____ - Generally accepted values of critical bandwidth as a function of frequency.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.3.2.3 Cueing Signals - Auditory cueing signals shall be provided for pacing of operator actions in situations requiring timely execution of task elements but where: (1) operator attention may be diverted from the task at hand, or (2) the operator depends on the cueing signal to know when to perform the task. Cueing signals may be used in combination with visually-presented messages providing specific task element instructions. Dueing signals may be used in combination with visually-presented messages providing specific task element instructions. Cueing signals should be short, tonal, and non-annoying but distinctive in character, and as a general rule should exceed the noise level in the critical band by at least 15 dB. (See critical bandwidth in Figure_____.) Consideration should be given to instrumenting the cueing signal system so as to generate a repetition of the signal if the operator fails to perform the desired action. 5.3.2.4 Alerting Signals - Alerting signals shall be provided whenever there is a requirement for immediate response to a situation outside of the operator's normal task sequence (e.g., when there is incoming traffic on an unattended circuit, or some system function needs attention on an irregular basis, or there may be a minor component failure). Alerting signals should be of a spectral composition and character more demanding of attention than either advisory or cueing signals. They may be momentary or continuous in nature as appropriate, but if momentary they should be repeated periodically if either (1) proper action is taken, nor (2) the signal is turned off. Similarly, continuously-presented alerting signals should persist until initiation of proper action or signal turn-off. After the signal is terminated it should be automatically reset to respond to the next initiating condition. As a general rule alerting signals should exceed the noise level in the critical band for all major signal components by at least 15 dB. (See critical bandwidth in Figure_____.) 5.3.2.4.1 Differentiation From Routine Signals - Alerting signals intended to bring the operator's attention to a malfunction or failure shall be differentiated from routine signals such as bells, buzzers, and normal operation noises.	The values are the professional judgment of Bob Gales (NOSC)

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.3.2.5 Caution Signals - Caution signals shall be used to capture the attention of personnel so as to direct it to potentially destructive conditions requiring immediate awareness. (There is no immediate threat to life or major property damage, but there may be incipient threat to either, or there may be an actual threat to possible major system malfunction or abort.) They may provide either one or two functions. A single function caution signal consists of an alert only and must be accompanied by a visually-presented message identifying the specific nature of the caution situation. Two-function caution signals which provide both the alerting and identification functions should be used where the total number of caution signals is small. Caution signals should consist of distinctive complex sounds at least 15 dB on the A-weighted scale above the noise environment. They should persist intermittently until restoration of normal conditions or manual shut off. Upon termination they should be automatically reset to respond to the next initiating condition. A volume control may be incorporated provided full volume is automatically restored upon initiation of the next caution signal. 5.3.2.6 Warning Signals - Warning signals shall be used to alert personnel of immediate action required in hazardous or emergency situations. These signals shall provide two specific functions: (1) alerting of personnel, and (2) transmission of identifying or action signals. These functions may be accommodated by either a two-element or single element signal as appropriate to the situation in consideration of the total acoustic signal environment. Ordinarily if a small set of warning signals is used the single element signal would be preferred since this would provide the shortest reaction time. Warning signals should consist of distinctive complex sounds of exceptional attention-getting value and presented at a level of at least 20 dB (on the A-weighted scale) above the noise environment. Examples of warning signals include fire alarms, collision alarms, transit bells on cranes, etc. 5.3.2.6.1 Warning Recognition Time - Warning signals shall be sufficiently distinctive that they can be unambiguously recognized as warning signals within 0.5 seconds of initiation. Single-element signals will, in addition, convey full meaning of the signal within that initial 0.5 second period. In the worst case, two-element signals shall convey full meaning of the signal within 2.5 seconds of initiation.	5.3.2.5 A clear differentiation between alerting, caution, and warning signals seems to be needed.

MEI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.3.2.6.2 Control of Warning Signals - Warning signals may be either manually or automatically initiated, whichever is more appropriate to the circumstances. Manually-initiated signals shall also be manually terminated. Automatically initiated signals shall persist until either automatically or manually terminated. 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. Provision for manual termination shall always be provided. Automatic reset for the next initiating condition shall be provided for all signals which can be automatically initiated. 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.	Reviewer consensus and professional judgment.
5.3.2.6.3 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.	
5.3.2.6.4 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.	
5.3.2.6.5 Operation With Headsets - Operators who normally wear earphones covering both ears shall have the warning signal presented in the headset as well as in the work area. When feasible a dichotic presentation should be utilized so as to present the warning signal to one ear and the normal auditory signals to the other ear, and preferably to alternate the signals between ears.	
5.3.3 Voice Communication	
5.3.3.1 Verbal Caution and Warning Signals - Verbal caution signals should be made as standardized as possible. They may be used in connection with an initial non-speech alerting signal. Verbal warning signals, however, shall always be preceded by an initial alerting signal (nonspeech) to attract attention and to designate the general problem. The verbal part of the warning signal shall consist of a brief standardized speech signal (verbal message) which identifies the specific condition and appropriate action.	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.3.3.1.1 Intensity - Verbal signals for caution conditions shall be at least 10 dB above the noise level at the operating position of the intended receiver, and verbal warnings shall be at least 20 dB above the noise level. (All readings on the A-weighted scale.) 5.3.3.1.2 Voice Criteria for Recorded Caution and Warning Messages - The voice used in recording verbal messages should be: clear in enunciation, free from regional dialects, authoritative, confident, and should sound concerned but neither detached nor anxious. Delivery should be brisk but should sound unhurried. 5.3.3.1.3 Speech Processing of Caution and Warning Messages - Verbal caution and warning messages shall be processed only when necessary to increase or preserve intelligiblity, 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. 5.3.3.1.4 Message Content - In selecting words to be used in recorded verbal caution or warning signals, priority shall be given to aptness, intelligibility, and conciseness in that order. 5.3.3.1.5 Repetition of Verbal Warnings - Critical warning signals shall be repeated with not more than a 3-second pause between messages until the warning state is terminated either automatically or manually. 5.3.3.1.6 Prioritization - When there could be a possibility of simultaneous presentation of automatically initiated messages, a message priority system shall be provided, such that the most critical message overrides for initial presentation any messages occurring lower on the priority list. Following initial presentation of the top priority message other messages should be presented in priority order, except that no caution messages should be presented until all warning messages are terminated.	
5.3.3.2 Voice Communication Equipment	This section is substantially the same as 5.3.7 in the original.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.3.3.2.1 Telephone or Radio Communications - Design of military integrated telephone or radio communication systems, either of a switched or point-to-point nature, shall be in accordance with the applicable requirements of MIL-STD-188. 5.3.3.2.2 Microphones and Speech Input Equipment 5.3.3.2.2.1 Frequency - Microphones and associated system-input devices shall be designed to respond optimally to that part of the speech spectrum most essential to intelligibility (i.e., 200 to 6,100 Hz) except where speech transmission bandwidths are substantially narrower as in commercial telephone practice. In these cases the speech input equipment shall be compatible with the transmission bandwidth being used. 5.3.3.2.2.2 Dynamic Range - The dynamic range of a microphone and its associated amplifier shall be great enough to admit variations in signal input of at least 50 dB. 5.3.3.2.2.3 Noise Cancelling Microphones - In very loud, low frequency noise environments (e.g., 100 dB or over), noise-cancelling microphones shall be used and shall be capable of effecting an improvement of not less than 10 dB n peak-speech to root-mean-square-noise ratio as compared with non-noise-cancelling microphones of equivalent transmission characteristics. 5.3.3.2.2.4 Pre-emphasis - If necessary, speech system input devices may employ frequency pre-emphasis with a positive slope frequency characteristic no greater than 18 dB per octave from 140 to 1,500 Hz and no greater than 9 dB per octave over the frequency range 1,500 to 4,800 Hz, when no clipping is used. 5.3.3.2.2.5 Peak-Clipping of Speech Signals - Where speech signals are to be transmitted over channels showing less than 15 dB in peak-speech to root-mean-square-noise ratios, peak-clipping of 12 to 20 dB may be employed at the system input and may be preceded by frequency pre-emphasis as specified in 5.3.3.2.2.4. 5.3.3.2.2.6 Noise Shields - When the talker is in an intense noise field, the microphone should be put in a noise shield. Noise shields should be designed to meet the following requirements:	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES

a. A volume of at least 250 cu. cm (15 cu in.) to permit a pressure gradient microphone to function normally.

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

c. A hole or combination of holes covering a total area of 6.5 sq. mm (0.1 sq. in.) in the shield to prevent pressure buildup.

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

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

5.3.3.2.3 Earphones and Loudspeakers

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

5.3.3.2.3.2 Loudspeakers for Multi-channel Monitoring

a. Mounting of Speakers - If separate speakers on different channels are to be monitored simultaneously the speakers shall be mounted so that they are not less than 10° apart radially with respect to a central operator position, as in a console-configured control or communication center. "Channel-busy" lights shall be provided to show channel utilization.

b. Filtering - When additional channel differentiation is required, apparent lateral separation may be enhanced by applying low-pass filtering (frequency cutoff, F_c= 1,800 Hz) to signals fed to loudspeakers on one side of the central operator position. If there are three channels, one channel should be left unfiltered, a high pass filter with 1,000 Hz cutoff should be provided in the second channel, and a low-pass filter with 2,500 Hz

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
cutoff should be provided in the third channel. "Channel-busy" lights shall be provided to show channel utilization.	
5.3.3.2.4 Use of De-emphasis - If transmission equipment employs pre-emphasis and peak-clipping is not used, reception equipment should employ frequency de-emphasis of characteristics complementary to those of pre-emphasis only if it improves intelligibility, i.e., de-emphasis shall be a negative-slope frequency response not greater than 9 dB per octave over the frequency range 140 to 4,800 Hz.	
5.3.3.2.5 Headsets - If listeners will be working in high ambient noise (85 dB or above), binaural rather than monaural headsets shall be provided. Unless operational requirements dictate otherwise, binaural headsets shall be wired so that the sound reaches the two ears in opposing phases. Their attenuation qualities should be capable of reducing the ambient noise level to less than 85 dB on the A-weighted scale for all users including those who wear glasses.	Ref: HEL-Std S-7-68, p. 175.
5.3.3.2.5.1 Speaker Side Tone - If headsets are used, feedback of the speaker's own voice (side tone) shall be provided via the earphones. The side tone shall not be filtered or modified before it is displayed and it shall be in phase with the speech signal.	
5.3.3.2.6 Operating Controls for Voice Communication Equipment	
5.3.3.2.6.1 Volume Controls - Accessible volume or gain controls shall be provided for each communication receiving channel (e.g., loudspeakers or headphones) with sufficient range to drive sound pressure level to at least 110 dB overall when using two earphones. (Unpressurized aircraft shall be equipped with pressure-operated gain control switches to compensate for altitude changes.) 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. While separation of power (on-off) and volume control adjustment functions into separate controls is preferred, if conditions justify their combination, a noticeable detent position shall be provided between the OFF position and the lower end of the continuous range of volume adjustment.	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.3.3.2.6.2 Squelch Control - Where communication channels are to be continuously monitored, each channel shall be provided with a signal-activated switching device (squelch control) to suppress channel noise during no-signal periods.	
5.3.3.2.6.2 Hands-Free Operation - For situations in which operators using microphones and/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. If there may be any requirement to operate the microphone and/or headset switching from a standing position, then hand-operated switches shall also be provided.	
5.3.3.2.7 Operator Comfort and Convenience	
5.3.3.2.7.1 Comfort - Communication equipment to be worn by an operator (e.g., headphones and telephone headsets) shall be designed to preclude operator discomfort. Metal parts of the headset shall not come in contact with the user's skin. Materials selected shall be impervious to biological organisms such as molds and fungi and shall not deteriorate from humidity or perspiration.	
5.3.3.2.7.2 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. Color-coding may also be employed where operating personnel will have visual contact with handsets under the working conditions.	
5.3.3.2.8 Speech Intelligibility	5.3.3.2.8 is substantially the same as 5.3.1.2.1 in the original.
5.3.3.2.8.1 Testing Methods - When information concerning the speech intelligibility of a system is required, three recommended methods are available, with the appropriate selection being dependent upon the requirements of the test.	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES

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

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

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

5.3.3.2.8.2 Relationship of Test Scores to Operational Intelligibility - Table VI presents the minimum acceptable scores for PB, MRT, and AI tests which shall be qualifying for fulfilling various intelligibility requirements. The efficiency of communications needed and the type material to be transmitted shall determine which of the intelligibility levels of Table VI is to be selected.

Table VI. Minimum Acceptable Test Scores for Various Levels of Intelligibility in Voice Communications Systems

Believe the title modification may be more descriptive of table content

INTELLIGIBILITY LEVEL	SCORE PB	SCORE MRT	SCORE AI
Exceptionally high intelligibility; separate syllables understood	90%	97%	0.7
Normally acceptable intelligibility; about 98% of sentences correctly heard; single digits understood	75%	91%	0.5
Minimally acceptable intelligibility; limited standardized phases understood; about 90% sentences correctly heard.	43%	75%	0.3

ORIGINAL REQUIREMENT	MFI COMMENTS
5.4 CONTROLS -	
5.4.1 General Criteria -	
5.4.1.1 Selection -	
5.4.1.1.1 Distribution of Load - Controls shall be selected and distributed so that none of the operator's limbs will be overburdened.	R ader may interpret to mean that control functions must be divided up equally!
5.4.1.1.2 G-loading - Where applicable, control selection shall include consideration of operation under variable g-loading on the operator.	Each of these requirements tends to be too simplistic to have broad applicability for all functional requirements.
5.4.1.1.3 Multirotation Controls - Multirotation controls shall be used when precision is required over a wide range of adjustment.	
5.4.1.1.4 Detent Controls - Detent controls shall be selected whenever the operational mode requires control operation in discrete steps.	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4 CONTROLS	
5.4.1 General Criteria	
5.4.1.1 Selection - Criteria in Table _____ shall be used in determining the type of control to be used on operator control panels. In addition, the following paragraphs should be consulted before deciding on specific control type and application.	This expansion provides a more comprehensive and definitive set of requirements felt necessary to make "selection" decisions.
5.4.1.1.1 Distribution of Load - Where applicable and appropriate controls shall be selected and distributed so that a single limb is not overburdened.	
5.4.1.1.2 Functional Efficiency - Control selection (e.g., type) and distribution (e.g., operating limb) shall be determined on the basis of the expected proficiency with respect to operating a particular control by means of a particular limb. The following shall be considered: a. Hand manipulation is more precise than foot manipulation. b. More force usually can be applied by the foot and leg than by the hand and arm. c. More operators are right-handed than left-handed and therefore are more accurate, faster and can apply more force with the preferred hand or foot. On the other hand some right-hand manipulations could create difficulties for a left-handed operator, in which case the control selection and/or location should be made that provides the least degradation for either left or right-handed operator. d. Manipulatory characteristics of candidate control devices shall be compatible with operator biomechanical characteristics and limitations, i.e., "natural" musculoskeletal motions, excursions, precision and strength factors shall be considered in choosing the particular control device and locating it with respect to the operator.	
5.4.1.1.3 Environmental and Physical Constraints - Where applicable selection, design, and placement of controls shall include consideration of:	

Table ____ - Control Selection Criteria

FUNCTION	CONTROL: Toggle Switch	Push Button	Bar Knob	Round Knob	Thumb-Wheel D	Thumb-Wheel C.	Crank	Rocker Switch	Lever	Joystick /Ball
Select system power state ON-OFF	1	1	3					1	1*	
3-State (OFF-STBY-ON)	1		1							
Select between OFF/Prime Mode/ Secondary Mode(s)	3	2	1						1	
Select one or more of N related functions	2	1						2		
Select one of N mutually exclusive functions any order		1								
Select one of 3-24 discrete alternatives - sequential order			1							
Select digit - discrete		1 KEYBD	2**		2**					
Set value on - continuous scale				1		2	3		3	
Select value in - discrete steps		1	1		1					
Select operating condition	1	1	2					1	1	
Enter alpha-numeric data		1 KEYBD								
Initiate test subfunction (momentary)	1	1	3					1		
Initiate directional function	1	2 Multiple	3			3		1	1 Multiple	
Generate stepping impulse (Momentary Hold)	1	1								
Slew counters or other numeric readout	1	1		1 Rate Control			1 Manual Only			
Reset mechanical counter, manual				1	3	1				
Interrupt count-down sequence - "hold"	2	1						2		
Engage - Disengage mechanical function									1	
Adjust light level, cont.				1		1			3	
Adjust sound level, cont.				1		1			3	
Coarse adjustment				1 Small Diam.		2 Small Motion	2 Few Turns		2 Short Throw	
Fine adjustment				1 Large Diam.		2 Large Motion	2 Many Turns		3 Long Throw	
Adjust to null position				1		2	3		3	
Single-coordinate tracking				3			2		1	
Two-coordinate tracking							3		1	

* Lever for heavy duty power circuits.

** Only if sequential selection is acceptable.

(1 = Most preferred, 3 = least preferred)

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
a. Operation under variable g-loading on the operator.	
b. Mobility constraints of special clothing, e.g., pressure garments, gloves and mittens, and/or special restraint systems, e.g., seat belts, electrical and life support leads and connections.	
c. The degrading effects of expected environments such as acceleration/deceleration, vibration, extreme cold or heat.	
d. How the operator is supported and/or anchored, i.e., in order to apply required force, to maintain a given control contact for the required duration, and/or to have sufficient stability to perform a precise manipulation.	
5.4.1.1.4 Standard Practice - Unless specified elsewhere in this standard or other government standards and specifications, and/or demonstrable improvement in operator performance is shown by alternate concepts, standard practice relative to certain control-function utilization shall be as follows:	To preclude freakish designs that could result in operator confusion.
a. Two-dimensional vehicle steering shall be by means of a steering wheel.	
b. Three-dimensional vehicle steering/attitude control shall be by means of a joystick or combination joystick wheel, and rudder pedals.	
c. Primary vehicular braking shall be by means of a foot pedal(s).	
d. Primary automotive acceleration shall be by means of a foot pedal.	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
e. Aircraft throttle functions shall be controlled by means of manually-operated levers. f. Automotive transmission gear position selection shall be by means of a lever. g. Continuous-adjustment, panel control functions shall be by means of rotary controls. h. Discrete multi-position-selection panel control functions shall be by means of rotary selector switches, push buttons or mechanically detented levers. i. Multi-axis, console-type tracking function control shall be by means of joystick, track-ball and/or handcranks. j. Valve control functions shall be controlled by means of rotary knobs or T-handles. Valves shall have the word VALVE in their labels. k. Simple two-position, panel control functions shall be accomplished by means of toggle, push button, rocker or slide switches. 5.4.1.1.5 <u>Control Accessibility</u> - All controls shall be located within reach of the operator considering the following factors: a. Operators with the shortest arm and leg reach (e.g., 5th percentile). b. Direct access without making awkward extensions around intervening obstacles. c. Accessible without assuming awkward body positions, and or disturbing critical eye reference requirements. d. Convenient for the nature of the control movements required.	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
e. Compatible with potentially restricting elements within the operating envelope i.e., seat back or side structure that preventsthe operator from bending an arm or leg as necessary to manipulate a control close to his or her body, or a forward panel or structure that could be struck by the knee and thus prevent or disturb the normal movement of the leg in operating a foot control. Note: Refer to NASA Reference Publication 1024 for appropriate reach limits of specified user population.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.4.1.2 <u>Direction of Movement</u> -	Although there is no argument with what is here, we feel that a number of contingencies relative to a broader range of application should be addressed. A slight title change also seems to be in order since more than direction of motion is discussed.

5.4.1.2.1 <u>Consistency of Movement</u> - Controls shall be selected so that the direction of movements of the control will be consistent with the related movement of an associated display, equipment component, or vehicle. In general, movement of a control forward, clockwise, to the right, or up or pressing or squeezing a control shall turn the equipment or component on, cause the quantity to increase, or cause the equipment or component to move forward, clockwise, to the right, or up. Valve controls are excepted (see 5.4.1.2.4).

5.4.1.2.2 <u>Multidimensional Operation</u> - When the vehicle, the equipment, or the components are capable of motion in more than two dimensions, exception to 5.4.1.2.1 shall be made if necessary to ensure consistency of anticipated response (e.g., forward motion of a directional control causes some vehicles to dive or otherwise descend rather than to simply move forward) When several controls are combined in one control device, caution shall be exercised to avoid conflicts (e.g., control motion to the right is compatible with clockwise roll, right turn, and direct movement to the right).

5.4.1.2.3 <u>Operator-control Orientation</u> - Controls shall be oriented with respect to the operator. Where the operator may use two or more vehicle operator stations, the controls shall cause movement oriented to the operator at the affecting station, unless remote visual reference is used.

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

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.1.2 <u>Control Movement Characteristics</u> 5.4.1.2 1 <u>Direction of Motion Expectancy</u> - Expected control-system motion relationships shall be observed in the design, selection and/or arrangement and positioning of controls. Among these are the following: a. Rotary controls are expected to rotate clockwise to effect an increasing function. (See (c).) b. A lever is expected to move forward, up or to the right for an increasing function, but up or aft to apply a braking action. c. A rotary valve control is expected to rotate counter-clockwise to increase line flow, e.g., liquid flow. A double-ended arrow labeled OPEN in the CCW direction and CLOSE in the CW direction shall be used to identify movement relationships. d. An accelerator pedal is expected to be depressed to increase speed of a vehicle. e. A brake pedal is expected to be depressed to cause braking. 5.4.1.2.2 <u>Control-Display Motion</u> - (See 5.1.3.3) 5.4.1.2.3 <u>Control-Device Motion</u> - When a control effects the movement of some appended device directly observable by the operator (e.g., window, windshield wiper, remotely-controlled object such as a crane boom and tackle or hook, remote manipulator, etc.), the motion of the control and the controlled object shall be similar. 5.4.1.2.4 <u>Control-Vehicle Motion Relationships</u> - (See 5.1.3.3.3)	We feel it is important to cover the several contingencies that must be addressed in considering control direction and especially with respect to variations that occur with a variety of applications. These are addressed in a wide variety of handbooks and special reports, but seldom does a particular reference cover all contingencies. The recommendations hopefully are more comprehensive. In addition, accepted conventions are identified to preclude "odd inventions" by some designer who is trying to be different. A recent MFI study of driver control operation expectancies provides evidence to support these control motion principles. (DOT HS-803-456).

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.1.2 5 Other Control-System Motion Relationships - When an operator is not oriented in direct relationship to the normal forward direction or a vehicle or system, controls should be arranged and operate normal to the operator's orientation, i.e., regardless of the fact that the operator may face 90 or 180 degrees from the forward orientation of the system, his controls shall be oriented as if the vehicle or system were headed the same direction as the operator.	Ref: Morgan, Human Engineering Guide to Equipment Design, 1963, pp. 300-301.

ORIGINAL REQUIREMENT	MFI COMMENTS
5.4.1.3 Arrangement and Grouping -	
5.4.1.3.1 Grouping - All controls which have sequential relations, which have to do with a particular function of operation, or which are operated together, shall be grouped together along with their associated displays. When several steps of a sequence are combined on one control, the control movements required shall be minimized and the systems shall not be cycled ON/OFF or through operational modes unnecessarily.	Should start with "primary controls".
5.4.1.3.2 Sequential Operation - Where sequential operations follow a fixed pattern, controls shall be arranged to facilitate operation (e.g., in a pattern left-to-right and top-to-bottom, as a printed page).	
5.4.1.3.3 Location of Primary Controls - The most important and frequently used controls shall have the most favorable position with respect to ease of reaching and grasping (particularly rotary controls and those requiring fine settings).	
5.4.1.3.4 Consistency - The arrangement of functionally similar, or identical, primary controls shall be consistent from panel to panel throughout the system, equipment, unit, or vehicle.	
5.4.1.3.5 Remote Controls - Where controls are operated at a position remote from the display, equipment, or vehicle controlled, control arrangement shall be established to facilitate direction-of-movement consistency. The observed result and not the effecting mode shall be considered.	
5.4.1.3.6 Maintenance and Adjustment - In general, controls used solely for maintenance and adjustment and referred to infrequently shall be covered during normal equipment operation, but shall be readily accessible and visible to the maintenance technician when required.	
5.4.1.3.7 Spacing - Minimum spacing between controls shall comply with Table VII.	

TABLE VII. MINIMUM SEPARATION DISTANCES FOR CONTROLS

	TOGGLE SWITCHES	*PUSH-BUTTONS	CONTINUOUS ROTARY CONTROLS	ROTARY SELECTOR SWITCHES	DISCRETE THUMBWHEEL CONTROLS
TOGGLE SWITCHES	SEE FIG 11	0.5"(13 mm)	0.75"(19 mm)	0.75"(19 mm)	0.5"(13 mm)
*PUSHBUTTONS	0.5"(13 mm)	SEE FIG. 9	0.5"(13 mm)	0.5"(13 mm)	0.5"(13 mm)
CONTINUOUS ROTARY CONTROLS	0.75"(19mm)	0.5"(13 mm)	SEE FIG 6	1.0"(25 mm)	0.75"(19 mm)
ROTARY SELECTOR SWITCHES	0.75"(19 mm)	0.5"(13 mm)	1.0"(25 mm)	SEE FIG 3	0.75"(19 mm)
DISCRETE THUMBWHEEL CONTROLS	0.5"(13 mm)	0.5"(13 mm)	0.75"(19 mm)	0.75"(19 mm)	SEE FIG 5

*For pushbuttons not separated by barriers

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

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.1.3 Arrangement and Grouping	
5.4.1.3.1 Primary Controls - The most important and frequently-used controls shall have the most favorable positions with respect to convenience and ease of use from the specified operator position.	This is first priority.
5.4.1.3.2 Functional Grouping - Controls that are related by function and/or sequence of use shall be grouped together along with their associated displays. When several steps of a sequence are combined in one control, the control movements required shall be minimized and the systems shall not be cycled ON/OFF, or through operational modes unnecessarily. Odd (unrelated control functions) shall not be interspersed within the spatial confines of a group of functionally-related controls.	
5.4.1.3.3 Sequential Operation - [Use original material from par. 5.4.1.3.2.]	
5.4.1.3.4 Emergency Controls - Emergency function controls shall be located where they can be identified and reached with a minimum loss of time. However, their location shall not be such that accidental use or inadvertent contact could result in serious system malfunction and/or ultimate injury to personnel.	
5.4.1.3.5 Remote Controls - [Use original material from par. 5.4.1.3.5.]	
5.4.1.3.6 Consistency - When functionally similar control interfaces appear in more than one operator station within the same or similar systems, control locations and arrangements should also be the same or at least similar.	
5.4.1.3.7 Spacing - [Use original material f m par. 5.4.1.3.7.]	
5.4.1.3.8 Maintenance and Adjustment - [Use original material from par. 5.4.1.3.6.]	

TABLE VII. MINIMUM SEPARATION DISTANCES FOR PANEL-MOUNTED CONTROLS

	TOGGLE SWITCHES	*PUSH-BUTTONS	CONTINUOUS ROTARY CONTROLS	ROTARY SELECTOR SWITCHES	DISCRETE THUMBWHEEL CONTROLS
TOGGLE SWITCHES	See Table	0.5"(13 mm)	0.75"(19 mm)	0.75"(19 mm)	0.5"(13 mm)
*PUSHBUTTONS	0.5"(13 mm)	See Table	0.5"(13 mm)	0.5"(13 mm)	0.5"(13 mm)
CONTINUOUS ROTARY CONTROLS	0.75"(19mm)	0.5"(13 mm)	SEE FIG 6	1.0"(25 mm)	0.75"(19 mm)
ROTARY SELECTOR SWITCHES	0.75"(19 mm)	0.5"(13 mm)	1.0"(25 mm)	* 0.5 (13mm)	0.75"(19 mm)
DISCRETE THUMBWHEEL CONTROLS	0.5"(13 mm)	0.5"(13 mm)	0.75"(19 mm)	0.75"(19 mm)	SEE FIG 5

* Note change

*For pushbuttons not separated by barriers

All values are for one hand operation. Distances are measured in inches and are measured at the closest point of approach for each pair of controls as they are moved throughout their entire range of movement.

ORIGINAL REQUIREMENT	MFI COMMENTS
5.4.1.4 Coding -	
5.4.1.4.1 Methods and Requirements - The selection of a coding mode (e.g., size and color) for a particular application shall be determined by the relative advantages and disadvantages for each type of coding. Where coding is selected for the purpose of differentiating among controls, application of the code shall be uniform throughout the system. (See Table VIII for advantages and disadvantages.)	
5.4.1.4.2 Location-Coding - Controls associated with similar functions should be in the same relative location from panel to panel.	Workstation-to-workstation also.
5.4.1.4.3 Size-Coding - No more than three different sizes of controls shall be used in coding controls for discrimination by absolute size. Controls used for performing the same function on different items or equipment shall be the same size.	Last sentence; requirement not always practical. Size vs manipulability is ignored.
5.4.1.4.4 Shape-Coding - Control shapes shall be both visually and tactually identifiable and shall be designed to be free of sharp edges.	Insufficient guidance.
5.4.1.4.5 Color-Coding -	
5.4.1.4.5.1 Choice of Colors - Controls shall be black (17038) or gray (26231). If color coding is required, only the following colors identified in FED-STD-595 shall be selected for control coding. a. Red, 11105, 21105 b. Green, 14187, 24187 c. Orange-Yellow, 13538, 23538 d. White, 17875, 27875 e. Blue, 15123 or 25123, shall be used if an additional color is absolutely necessary.	

TABLE VIII. ADVANTAGES AND DISADVANTAGES OF VARIOUS TYPES OF CODING

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

ORIGINAL REQUIREMENT	MFI COMMENTS
5.4.1.4.5.2 <u>Immediate Action Controls</u> - Color coding of immediate action controls for aircraft shall conform to MIL-M-18012. 5.4.1.4.5.3 <u>Relation to Display</u> - When color-coding must be used to relate a control to its corresponding display, the same color shall be used for both the control and the display. 5.4.1.4.5.4 <u>Control Panel Contrast</u> - The color of the control shall provide contrast between the panel background and the control. 5.4.1.4.5.5 <u>Ambient Lighting and Color-coding Exclusion</u> - Prior to selection of color code, consideration shall be given to anticipated ambient lighting coordination throughout the mission. Color-coding shall not be used as a primary identification medium if the spectral characteristics of ambient light during the mission, or the operator's adaptation to that light, varies as the result of such factors as solar glare, filtration of light, and variation from natural to artificial light. If red lighting is to be used during a portion of the mission, controls which would otherwise be coded red shall be coded by orange-yellow and black striping. 5.4.1.5 <u>Labeling of Controls</u> - Control labeling shall conform to the criteria in paragraph 5.5. 5.4.1.6 <u>Compatibility with Handwear</u> - Controls shall be compatible with handwear to be utilized in the anticipated environment. Unless otherwise specified, all dimensions cited herein are for bare hands and should be revised where necessary for use with gloves or mittens. 5.4.1.7 <u>Blind Operation</u> - Where "blind" operation is necessary, hand controls shall be shape-coded, or separated from adjacent controls by at least 5 inches (125 mm). 5.4.1.8 <u>Prevention of Accidental Activation</u> - 5.4.1.8.1 <u>Location and Design</u> - Controls shall be designed and located so that they are not susceptible to being moved accidentally. Particular attention shall be given to critical controls whose inadvertent operation might cause damage to equipment, injury to personnel or degradation of system functions.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.4.1.8.2 Internal Controls - Internal or hidden controls should be protected, because it is usually not obvious that such controls have been disturbed and it may be difficult and time consuming to locate and readjust them. 5.4.1.8.3 Rapid Operation - Any method of protecting a control from inadvertent operation shall not preclude its being operated within the time required. 5.4.1.8.4 Methods - For situations in which controls must be protected from accidental activation, one or more of the following methods, as applicable, shall be used: a. Locate and orient the controls so that the operator is not likely to strike or move them accidentally in the normal sequence of control movements. b. Recess, shield, or otherwise surround the controls by physical barriers. The control shall be entirely contained within the envelope described by the recess or barrier. c. Cover or guard the controls. Safety or lock wire shall not be used. d. Provide the controls with interlocks so that extra movement (e.g., a side movement out of a detent position or a pull-to-engage clutch) or the prior operation of a related or locking control is required. e. Provide the controls with resistance (i.e., viscous or coulomb friction, spring-loading, or inertia) so that definite or sustained effort is required for actuation. f. Provide the controls with a lock to prevent the control from passing through a position without delay when strict sequential activation is necessary (i.e., the control moved only to the next position, then delayed). g. Design the controls for operation by rotary action.	

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

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.1.4 Coding	
5.4.1.4.1 Methods and Requirements - Use original material from par. 5.4.1.4.1.	
5.4.1.4.2 Location Coding - Controls associated with similar functions should be placed in the same relative location from operator workstation to workstation and/or panel to panel.	
5.4.1.4.3 Size Coding - Control size should generally not be used as a coding dimension. If it is used no more than three different sizes should be considered. Size coding shall not be used if the extremes are incompatible with the manipulation requirements of any particular control (i.e., the size is too small or too large for efficient manipulation of the control device).	
5.4.1.4.4 Shape Coding - Primary use of shape coding for controls is for identification of control knobs or handles by "feel". However, shapes shall be identifiable both visually and tactually. When shape coding is used, the coded feature shall not interfere with the ease of control manipulation. Shapes shall be equally identifiable regardless of the position of the control knob or handle, i.e., if the knob or handle is rotated, the code shall still be recognizeable by feel. Shape as a coding parameter shall be used only after considering the following: a. Proposed shapes are identifiable when gloves are worn. b. There are a sufficient number of identifiable shapes to cover the expected number of controls that require tactual identification. c. The particular control knobs or handles to be shape-coded lend themselves to positive, non-reversable attachment, i.e., when a replacement is required, it is impossible to attach the new knob in an orientation that may obscure or confuse the operator.	Added considerations based on professional judgment.

TABLE VIII. ADVANTAGES AND DISADVANTAGES OF VARIOUS TYPES OF CODING

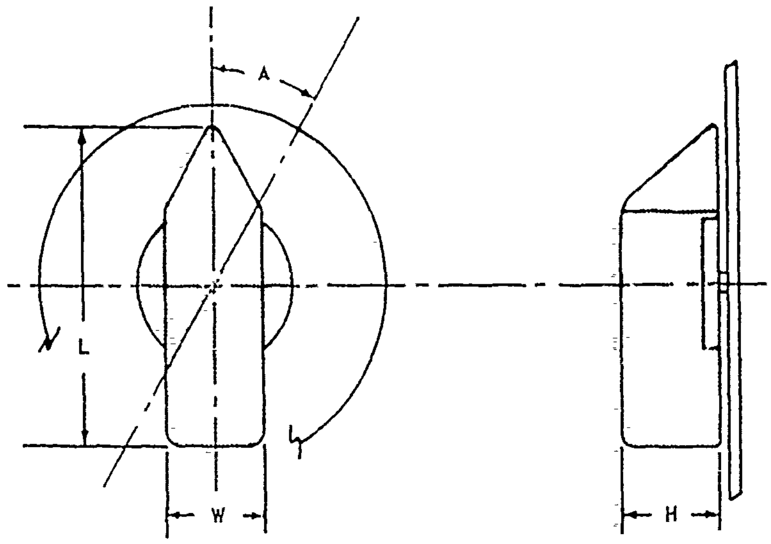
	TYPE OF CODING					
ADVANTAGES	LOCATION	SHAPE	SIZE	MODE OF OPERATION	LABELING	COLOR
Improves visual identification.	X	X	X		X	X
Improves nonvisual identification (tactual and kinesthetic).	X	X	X	X		
Helps standardization.	X	X	X	X	X	X
Aids identification under low levels of illumination and colored lighting.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

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.1.4.5 Color Coding - Basic colors for panel controls are either black (#17038) or gray (#26231)*. If color coding is used over and above these basic colors, the following shall be used: (*MIL-STD-595) a. RED, 11105 (gloss) or 21105 (semi-gloss) b. GREEN, 14187 (gloss) or 24187 (semi-gloss) c. ORANGE-YELLOW, 13538 (gloss) or 23538 (semi-gloss) d. WHITE, 17875 (gloss) or 27875 (semi-gloss) e. BLUE, 15123 (gloss) or 25123 (semi-gloss), shall be used if an additional color is required. Note: When FED Supply, Class 5355, plastic control knobs and coded caps are used for electronic equipment applications, refer to MS 91528 for shape and color code specifications. When color coding is used for "immediate action" aircraft controls, these shall conform to MIL-M018012.	Changes & "Note" eliminates an unnecessary conflict with MIL-M-18012.
5.4.1.4.6 Relation to Display - [Use original material from par. 5.4.1.4.5.3.]	
5.4.1.4.7 Control-Panel Contrast - Controls shall be of a contrasting color from the panel on which they are mounted. Colors shall conform to criteria in 5.7.9.	(5.7.9 Original)
5.4.1.4.8 Ambient Lighting and Color-coding Exclusion - [Use original material from par. 5.4.1.4.5.5.]	
5.4.1.5 Labeling of Controls - [Use original material from par. 5.4.1.5.]	
5.4.1.6 Blind Operation - Where "blind" reach is necessary, hand controls shall be separated from adjacent controls by at least 5 inches (12.7 cm) and/or if separation is not practical, control knobs or handles shall be shape coded.	Provides an alternative. Ref: Morgan, Human Engineering Guide to Equipment Design, 1963, p. 312.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.1.7 <u>Prevention of Accidental Activation</u> - [Use original material from par. 5.4.1.8 through 5.4.1.8.3.] 5.4.1.7.1 <u>Methods</u> - [Use all original materials in paragraph 5.4.1.8.4 with the exception of (f). Modify (f) as follows:] (f) Provide the control with a mechanical or time lock system to prevent the control from passing through a position without a "delay", whenever strict sequential positioning of the control is absolutely necessary (i.e. the control can only move to a "next position" after a delay). 5.4.1.8 <u>Dead Man Controls</u> - [Use original material from par. 5.4.1.8.5.] Add: 5.4.1.9 <u>Compatibility with Handware</u> - [Use original material from 5.4.1.6.]	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.4.2 <u>Rotary Controls</u> -	
5.4.2.1 <u>Discrete Rotary Controls</u> -	
5.4.2.1.1 <u>Selector Rotary Switches</u> -	
5.4.2.1.1.1 <u>Application</u> - Rotary selector switches should be used for discrete function when three or more detented positions are required. Rotary selector switches should not be used for a two-position function unless ready visual identification of control position is of primary importance and speed of control operation is not critical.	A slight rewording is required since the justification (last sentence) is weak and probably indefensible.
5.4.2.1.1.2 <u>Moving Pointer</u> - Rotary selector switches should be designed with a moving pointer and a fixed scale.	The remaining subparagraphs need amplification and in some instances requirements modified to make them more broadly applicable and/or justifiable.
5.4.2.1.1.3 <u>Shape</u> - Moving pointer knobs shall be bar shaped, with parallel sides, and the index end shall be tapered to a point. Exceptions may be justified when pointer knobs are shape-coded when space is restricted and torque is light. Shape-coding shall be used when a group of rotary controls, used for widely different functions, are placed on the same panel and control confusion might otherwise result.	Fig 4 creates apparent conflicts with other specs and in addition does not assist reader relative to visualizing criteria (in table) application.
5.4.2.1.1.4 <u>Positions</u> - A rotary selector switch which is not visible to the operator during normal system operation shall have no more than 12 positions and rotary selector switches that are constantly visible to the operator shall have not more than 24 positions. In addition, the following criteria shall apply: a. Where possible, rotary switch positions shall not be placed directly opposite each other, in order to reduce confusion as to which end of the knob is the pointer b. Stops shall be provided at the beginning and end of the range of control positions if the switch is not required to be operated beyond the end positions or specified limits. c. The switch resistance shall be elastic, building up, then decreasing as each position is approached, so that the control snaps into position without stopping between adjacent positions.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.4.2.1.1.5 Contrast - A reference line shall be provided on rotary switch controls. This line shall have at least 50 percent contrast with the control color under all lighting conditions. 5.4.2.1.1.6 Parallax - The knob pointer shall be mounted sufficiently close to its scale to minimize parallax between the pointer and the scale markings. When viewed from the normal operator's position, the parallax error shall not exceed 25% of the distance between scale markings. 5.4.2.1.1.7 Dimensions, Resistance, Displacement, and Separation - Control dimensions, resistance, displacement, and separation between adjacent edges of areas swept by rotary selector switches should conform to the criteria in Figure 3.	



	DIMENSIONS			RESISTANCE
	L Length	W Width	H Depth	
Minimum	1.0" (25mm)		0.625" (16mm)	1.0 in.-lb (113mN-m)
Maximum	4.0" (100mm)	1.0" (25mm)	3.0" (75mm)	6.0 in.-lb (678mN-m)

	DISPLACEMENT A		SEPARATION	
	*	**	One-Hand Random	Two-Hand Operation
Minimum	15 deg	30 deg	1.0" (25mm)	3.0" (75mm)
Maximum	40 deg	90 deg	.	
Preferred	.	.	2.0" (50mm)	5.0" (125mm)

*For facilitating performance
**When special engineering requirements demand large separation.

Figure 3. ROTARY SELECTOR SWITCH

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.2 Rotary Controls 5.4.2.1 Discrete Rotary Controls 5.4.2.1.1 Rotary Selector Switches	Ref: Woodson and Conover, Human Engineering Guide for Equipment Designers, 1966, Ch. 2.
5.4.2.1.1.1 Application - Rotary selector switches may be used when an operator needs to select from among a number of generally related functions and/or values for a specific function. A two-position rotary selector switch ordinarily should not be used if very rapid two-position or function selection is necessary, i.e., there are other more appropriate control configurations for rapid operation of either-or selector operations.	"Should" to "may". There are other ways to "select".
5.4.2.1.1.2 Positive Detents - Rotary selector switches shall have mechanical detents so that the switch knob cannot be positioned in-between nominal switch positions.	
5.4.2.1.1.3 Number of Switch Positions - No more than 24 switch positions should ever be used, and a maximum of 12 is preferable. If the application involves use of the switch without benefit of visual reference, no more than 5 positions should be used, and these should be located in the upper half of the switch circumference (positions being approximately 30-degrees apart). Unless the switching mode specifically involves multi-rotation, "stops" shall be provided at the beginning and end of the range of control positions. Recommended switch-setting parameters are provided in Table____.	If operator reaches blindly for bar knob and needs to know what position it is on, 12 or 24 positions are too many.
5.4.2.1.1.4 Torque for Actuation - Rotary switch torque requirements shall be compatible with the size of control knob associated with it, i.e., miniaturized switches with knob diameters of 1.0 inch or less (2.54 cm) should not require a torque greater than 2.0 in. lbs. (226 mN m) to rotate the knob. Medium-sized knobs (e.g., 1-2 inch (2.54-5.1 cm diam.) should not require torque greater than 6.0 in lbs. (678 mN m). And larger knobs (e.g., diameters 3 inches (7.6 cm) or greater) should not require torque greater than 10.0 in. lbs. (1.13 Nm).	The torque requirements are placed here instead of in the "new table". The torque requirements are broken into three levels and made "should", to keep from creating unnecessary conflicts. (Note: Most values are from original. However some are from AFSC DH 1-3 or extrapolations therefrom.

TABLE ______

KNOB DETENTS PLACEMENT FOR TACTUAL POSITIONING

TOTAL NO. OF SETTINGS	RECOMMENDED ANGULAR DISPLACEMENT (DEGREES)	RECOMMENDED RADIUS FOR 1/2" SEPARATION (INCHES)	RECOMMENDED STARTING POSITION (DEGREES)		
			RIGHT-HAND OPERATION	LEFT-HAND OPERATION	EITHER HAND
3	40.00	0.716	264.00	16.00	320.00
4	38.57	0.743	253.29	351.00	302.14
5	37.24	0.769	243.31	327.73	285.52
6	36.00	0.796	234.00	306.00	207.00
7	34.84	0.822	225.29	285.67	255.48
8	33.75	0.849	217.13	266.62	241.87
9	32.73	0.875	209.45	248.71	229.08
10	31.77	0.902	202.22	231.85	217.03
11	30.86	0.928	195.42	215.98	205.70
12	30.00	0.955	180,270 or 360	0,90 or 180	0 or 180

Note: New table adapted from Table III of MIL-C-81774A.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.2.1.1.5 Knob Shape - Bar- or bar/pointer-shaped knobs shall be used with rotary selector switches so that an operator can tell which way the knob is pointing, and can quickly differentiate a selector function from a continuously-adjustable control function (see par. 5.4.2.2). A white reference line shall be inscribed on the face of the knob, the line running from approximately the mid point of the knob to the pointing edge. The pointing end of the knob should also be tapered so that the pointing end is easily differentiated from the non-pointing end, and also so that the reference mark can be "followed" (visually) to a point adjacent to a reference mark or numeral on the interfacing panel. Contrast between the reference mark and its knob background shall be at least 50 percent.	Ref: Woodson and Conover, Human Engineering Guide for Equipment Designers, 1966, p. 2-106.
5.4.2.1.1.6 Blind Positioning - When an application requires the operator to judge pointer position without benefit of visual reference, the sides of the knob (except for the tapered end) shall be parallel. If additional shape coding is required, the code shall be applied as an extra cap, i.e., the shape code shall not interfere with the general shape objectives noted above.	This is to clarify a conflict with the "parallel side" criteria we have.
5.4.2.1.1.7 Dimensions, Displacement and Separation - Knob dimensions, switch displacement and control separation shall conform to criteria in Table_____ and Figure_____.	
5.4.2.1.1.8 Knob Mounting - Rotary selector knobs shall be mounted so that the reference mark is sufficiently close to the reference panel markings so that visual parallax is minimized. When viewed from the normal operator's position, the parallax error shall not exceed 25 percent of the distance between scale markings. Rotary selector knob attachment shall preclude the possibility of the knob slipping on the shaft, and/or the knob being replaced with the pointing end opposite from its correct position.	
5.4.2.1.1.9 Open-Window, Skirted Knobs - 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 (see Table_____).	This is new - required to cover a device currently in-use.

Table_____ - Dimensional Requirements For Generic Knob Shapes

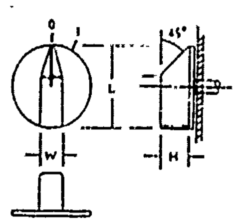
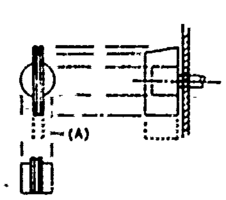
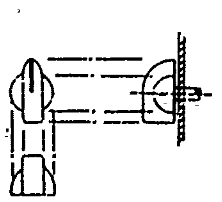
	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	PREFERRED FOR ACCURATE IDENTIF. OF KNOB POSITION BY FEEL. FOR USE ON ELECTRONIC, AIRCRAFT, AUTOMOTIVE, ETC. CONTROL PANELS WHERE HIGH FORCE SWITCHES ARE NOT REQUIRED. SKIRT OPTIONAL. SWITCH RESISTANCE APPROX. MAX: L = 1.5" = 1.0 IN-LB (0.11 N·m) L = 2.0" = 3.0 IN-LB (0.34 N·m) L = 4.0" = 6.0 IN-LB (0.68 N·m)	L = 1.5" (3.8 CM) TO 4.0" (10.16 CM) IF GLOVES ARE WORN, ADD 0.5"	W = 0.5" (1.27 CM) TO 1.0" (2.54 CM)	H = 0.625" (1.59 CM) TO 3.0" (7.6 CM)	MIN = 15"; MIN FOR BLIND POS'N ID = 30°	SEE FIG. ____ FOR SIMULTANEOUS OP'N OF ADJACENT KNOBS (TWO HANDS) ADD 1.0" (2.54 CM) 1.5" (3.8 CM) FOR GLOVES.
	ACCEPTABLE ABOVE CRITERIA APPLICABLE AS LONG AS KNOB POS'NS REMAIN IN UPPER 160° HEMISPHERE  (A) EXTENDED TAIL HELPFUL FOR HIGHER TORQUE. USE ONLY WHEN POINTER MARKING CLEARLY VISIBLE.	SEE ABOVE	SEE ABOVE	SEE ABOVE	SEE ABOVE	SEE ABOVE
	ACCEPTABLE ALTERNATIVE TO A ABOVE.	SEE ABOVE	SEE ABOVE	SEE ABOVE	SEE ABOVE	SEE ABOVE

Table _____ - Rotary Selector Controls (Continued)

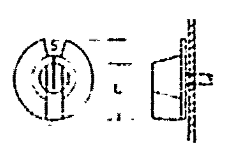
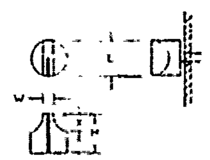
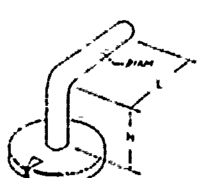
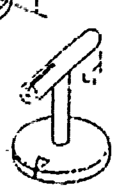
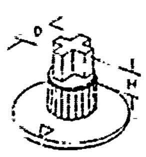
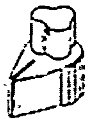
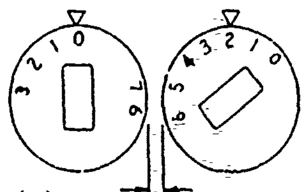
	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	ACCEPTABLE ALTERNATIVE TO A ABOVE WHEN ONLY GROSS SETTING IS REQUIRED (MAJOR NUMBERED POSN'S)	L = MIN 1" (2.54 CM) OTHER-SAME AS A	SEE ABOVE	SEE ABOVE	SEE ABOVE	SEE ABOVE
	ACCEPTABLE ONLY FOR APPLICATIONS WHERE PANEL SPACE IS LIMITED, GLOVES NOT WORN, SWITCH RESISTANCE LESS THAN 6 IN-OZ (.042 N-m)	L = MIN 0.75" (1.9 CM)	W = MIN 0.25" (0.64 CM)	X = MIN 0.5" (1.3 CM)	SEE ABOVE	1.0" (2.54 CM)
	FOR HEAVY DUTY, HIGH TORQUE SWITCHES; F PREFERRED	D = -.625" (1.59 CM) TO 1.0" (2.54 CM)	L . MIN 4.0" (10.2 CM)	H = 1.25" MIN (3.2 CM)	MIN . 10°	END TO END HANDLE SEPARATION . 3.0" (7.6 CM)
	ACCEPTABLE ALTERNATIVE	D = SAME	L_1 = MIN 2.0" (5.1 CM)	H = SAME	SAME	SAME

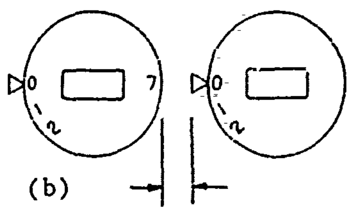
Table ____ - Rotary Selector Controls (Continued)

	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	TACTILE CONTROL IDENTIFICATION, PREFERRED METHOD FOR ROTARY CONTROLS (SEE MS 91528 FOR CODED CAP FORMS/COLORS)	D = MIN 0.630" (1.6 CM)	H = MIN 0.125" (0.32 CM) TO 0.75" (1.9 CM)	—	N/A	N/A
	TACTILE CAP FOR ROTARY SELECTOR KNOB	SAME AS ABOVE	SAME AS ABOVE			



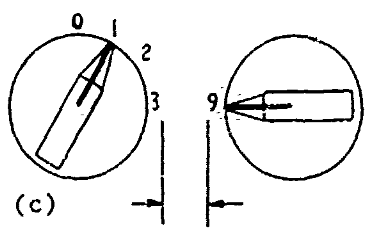
(a)

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



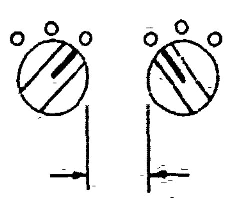
(b)

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



(c)

Separation between moving-pointer/fixed-scale configurations should be based on clear visual separation of adjacent scale characters. The minimum should be at least four character widths. However, if the knob length extends the full width of the skirt and the handle is not tapered at the pointing end, there should be at least a 1.0-inch (2.54 cm) separation between knobs when they are end-to-end.

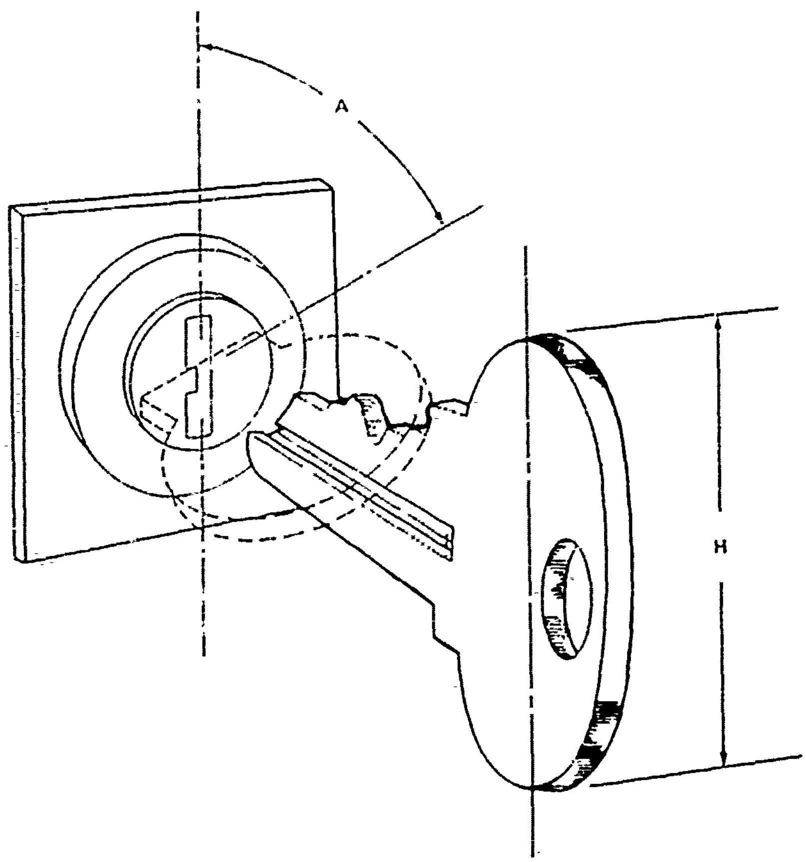


(d)

Separation between small, detented knob configurations as shown should be at least 1.0-inch (2.54 cm) unless there are adjacent panel referencing marks or characters, in which case separation minimums should be established on the basis of (c) above, or the 1-inch criteria, whichever is greater.

Figure _____ - Rotating Knob Separation

ORIGINAL REQUIREMENT	MFI COMMENTS
5.4.2.1.2 <u>Key Operated Switches (KOS)</u> -	
5.4.2.1.2.1 <u>Application</u> - KOS's are used to prevent unauthorized operation. Ordinarily, they control system operation by go no-go.	This section needs expansion to cover other kinds of key operations.
5.4.2.1.2.2 <u>Dimensions, Displacement, and Resistance</u> - Dimensions, displacement, and resistance shall conform to the criteria in Figure 4.	
5.4.2.1.2.3 <u>Other Requirements</u> -	
a. Keys with a single row of teeth should be inserted into the lock with the teeth pointing up or forward.	
b. If keys have teeth on both edges, they should fit the lock with either side up or forward.	
c. Locks should be oriented so the key's vertical position is the OFF position.	
d. Operators should normally not be able to remove the key from the lock unless the switch is turned OFF.	
e. ON and OFF positions should be labeled.	



	DISPLACEMENT (A)	HEIGHT (H)	RESISTANCE
MINIMUM	80°	0.5 in. (13mm)	1 in.-lb (113mN·m)
MAXIMUM	90°	3.0 in. (75mm)	6 in.-lb (678mN·m)

Figure 4. KEY-OPERATED SWITCH

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.2.1.2 <u>Keylocks and Keylock Switches</u>	Title now covers non-electrical keylock applications, plus ignition key switches.
5.4.2.1.2.1 <u>Keylocks</u> - Keylocks used solely to LOCK and UNLOCK vehicle doors and hatches, architectural doors, and/or equipment cabinet doors, covers and drawers shall conform to the following:	
a. Key position and motion relative to locking and unlocking shall conform to criteria in Figure____.	Reviewer consensus and professional judgment.
b. Key dimensions, separation and resistance shall conform to criteria in Figure____.	
c. Reversible key designs should be used, i.e., it is preferable to have keys that will operate the lock with either side "up". If key designs are used that have teeth only on one side, the lock should be oriented so that the "flat" edge of the key will be on the bottom to enter a vertical (lock) slot; to the right to enter a horizontal (lock) slot.	Ref: MIL-HDBK 759, p. 57.
d. Lock systems used for vehicle exterior doors shall be designed so that the operator cannot inadvertently lock himself/herself out of the vehicle.	
e. Keylocks exposed to external weather conditions shall be weatherproof, i.e., they shall not become inoperable due to dirt accumulation or freeze due to moisture collection and freezing temperatures.	
f. When several keylock systems are required on the same vehicle or equipment, and all locks must be accessible to the operator, a single key and identical locks shall be used. On the other hand, when access to certain closures should be limited to people other than the operator, different key/lock assemblies shall be used, i.e., the operator's key will not unlock these special locks.	
5.4.2.1.2.2 <u>Keylock Switches</u> - Keylock switches used not only to provide security (i.e., by removing the key), but also to provide ON-OFF or ignition functions shall conform to the following:	

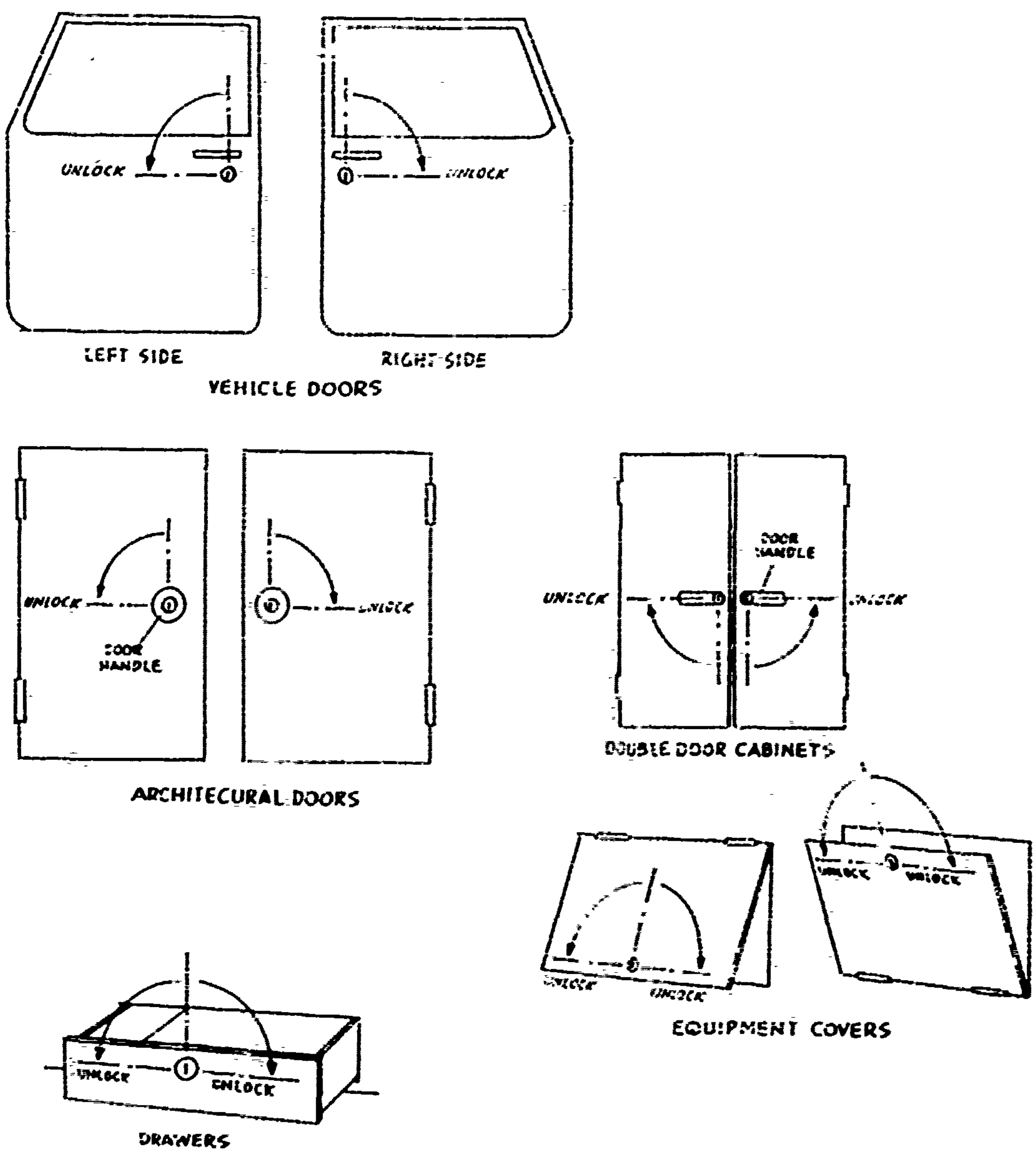
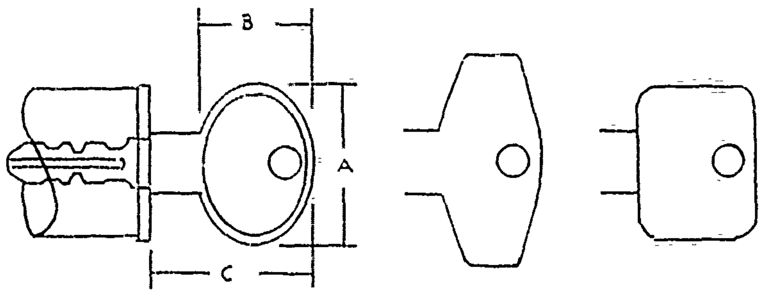
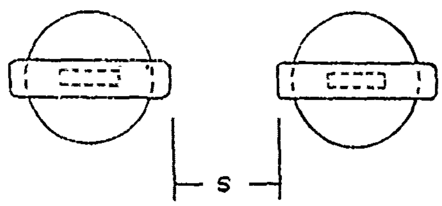


Figure ____ - Keylock Mounting Criteria



OTHER HANDLE SHAPE EXAMPLES; TOTAL SURFACE AREA SHOULD APPROXIMATE THAT OF OVAL SHAPE.



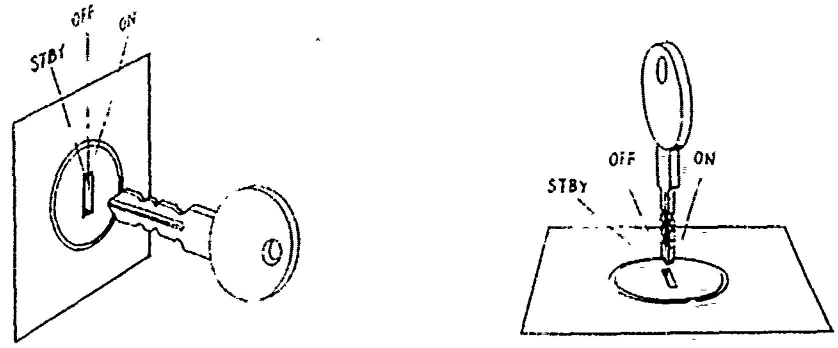
HANDLE EDGE SEPARATION WHEN KEYS AS SHOWN.

	A	B	C	S-Separation	Torque to Actuate	**
Minimum	0.875" (2.2 cm)	0.625" (1.6 cm)	0.875" (2.2 cm)	1.0" (2.54 cm)	1-in. lb. (0.1 N-m)	.11
Maximum	*1.50" (3.8 cm)	*1.50" (3.8 cm)	--- ---	1.0" (2.54 cm)	6-in. lb. (0.7 N-m)	.68

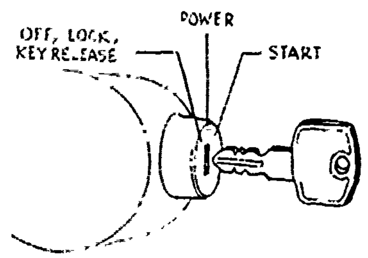
* Practical for carrying key in pocket.
** When locks are new.

Figure ____ - Keylock Criteria

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
a. Key position and motion relative to locking, unlocking, ignition, etc. shall conform to criteria in Figure_____.	
b. Key dimensions, separation and resistance shall conform to criteria 5.4.2.1.2.1 - b.	
c. Key designs shall conform to criteria in 5.4.2.1.2.1 - c.	
d. Keylock switches that will be used out of doors, shall be weatherproofed to prevent failures due to dirt and freezing.	
e. An auditory signal shall be provided for vehicle ignition keylock systems, to advise the operator that the key has been "left" in the ignition lock after the engine has been shut off.	
5.4.2.1.2.3 <u>Color and Shape Coding</u> - Color and/or shape-coding shall be considered as follows:	
a. Color may be used when it is desirable to aid in identifying various keys by function or use location, and there generally is adequate illumination to differentiate the colors. RED should be reserved for "emergency" functions (FED-STD-595 # 11105 or # 21105).	
b. Shape coding may be used when it is desirable to identify a given key by "feel". When shape coding is used, sharp corners shall be avoided.	
c. Size coding may also be used as long as no more than two sizes are employed. The dimensions should reflect the approximate differences between minimums and maximums shown in Figure_____.	
5.4.2.1.2.4 <u>Marking and Labeling</u> - Keylock switch applications shall include appropriate positional markings and labels (see 5.5).	



PANEL-MOUNTED SWITCHES



VEHICLE IGNITION

Notes:

1. Switchlocks should generally be oriented so that the pivotal OFF key position is vertical and/or forward (e.g., horizontal panel).

2. Key displacement between functional positions should be at least 10°. Mechanical detents should preclude positioning the key in-between designated positions.

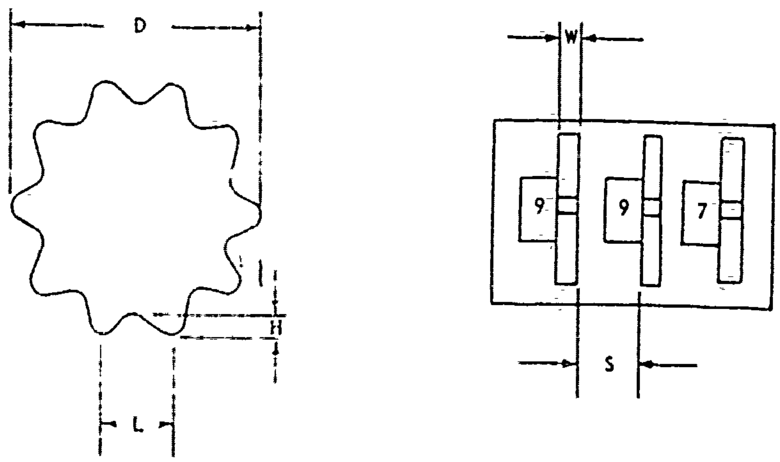
3. When only two functional positions occur (i.e., ON-OFF), displacement between the two positions shall be 90° ($\pm$ 10°).

4. Total displacement of multi-position keyswitches shall not exceed 120°.

Figure ____ - Keylock Switch Criteria

ORIGINAL REQUIREMENT	MFI COMMENTS
5.4.2.1.3 Thumbwheel Controls - 5.4.2.1.3.1 Application - Thumbwheel controls may be used if the function requires a compact digital control-input device (for a series of numbers) and a readout of these manual inputs for verification. The use of thumbwheels for any other purposes is discouraged. Thumbwheels may be either discrete or continuous as applicable. Detent indexing units should provide 10 positions (0 - 9) in digital or binary (3 or 4 bits and complement) outputs. 5.4.2.1.3.2 Shape - Each position around the circumference of a discrete thumbwheel shall have a slightly concave surface or shall be separated by a high-friction area which is raised from the periphery of the thumbwheel. Continuous thumbwheels shall employ high friction raised areas to facilitate movement. The thumbwheels shall not preclude viewing the digits within 30 degrees viewing angle to the left and right of a perpendicular to the thumbwheel digits. 5.4.2.1.3.3 Coding - Thumbwheel controls may be coded by location, labeling, and color (e.g., reversing the colors of the least significant digit wheel as on typical odometers). Where used as input devices, thumbwheel switch OFF or NORMAL positions should be color coded to permit a visual check that the digits have been reset to their normal position. 5.4.2.1.3.4 Direction of Movement - Direction of movement shall be compatible with the criteria set forth in 5.1.3.12.	Since this subsection is under selector controls, continuous thumbwheels should be moved. The illustration (Fig 5) should be redrawn - the "views" do not match. We also disagree with some of the criteria in the table based on product acceptance.

ORIGINAL REQUIREMENT	MFI COMMENTS
5.4.2.1.3.5 Numerals - 5.4.2.1.3.5.1 Internal Illuminance - For areas in which ambient illumination will provide display brightness below 1 ft-L (3.4 cd/m^2), the thumbwheel shall be internally illuminated. Digits shall appear as illuminated characters on a black background, and their dimensions should approximate the following: a. Height: 1/4 inch (6.4 mm) b. Height-to-Width Ratio: 3:2 c. Height-to-Stroke Width Ratio: 10:1. 5.4.2.1.3.5.2 External Illuminance - In areas where ambient illumination will provide a display luminance above 1 ft-L (3.4 cd/m^2), internal illumination is not required. Digits should be bold, black numerals engraved on a light (or white) thumbwheel background. The dimensions should approximate those specified in 5.4.2.1.3.5.1 except that the height-to-stroke width ratio should be approximately 5:1. 5.4.2.1.3.6 Visibility - Thumbwheel design shall permit viewing of in-line digital read-out from all operator positions. 5.4.2.1.3.7 Dimensions - Control dimensions shall conform to the criteria in Figure 5. 5.4.2.1.3.8 Resistance - 5.4.2.1.3.8.1 Discrete (Detented) Thumbwheel Controls - Detents shall be provided for discrete position thumbwheels. Resistance shall be elastic, building up and then decreasing as each detent is approached so that the control snaps into position without stopping between adjacent detents. The resistance shall be within the limits indicated in Figure 5.	

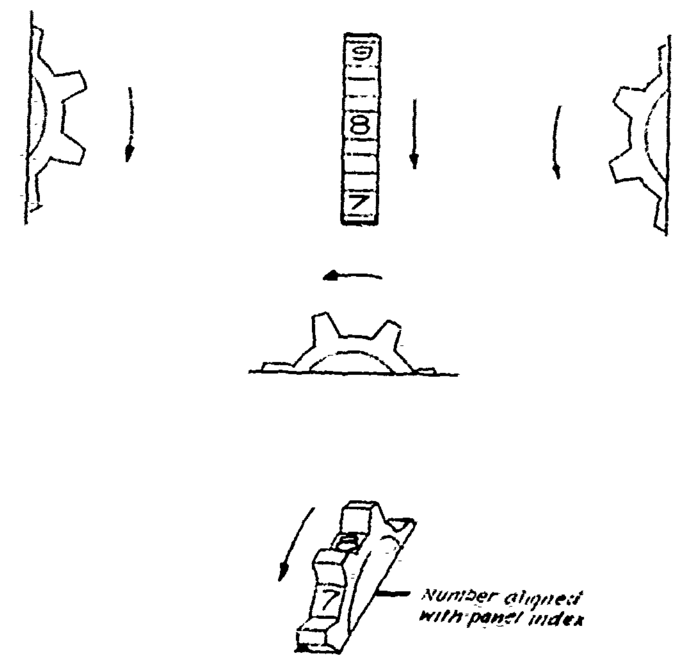


	D DIAMETER	L TROUGH DISTANCE	W WIDTH	H DEPTH	S SEPARATION	RESISTANCE
MINIMUM	1.5 in. (38 mm)	0.45 in. (11 mm)	0.1 in. (3 mm)	0.125 in. (3 mm)	0.4 in. (10 mm)	6 oz (165 mN)
MAXIMUM	2.5 in. (65 mm)	0.75 in. (19 mm)		0.5 in. (13 mm)		20 oz (550 mN)

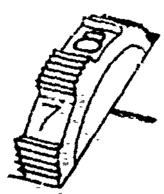
Figure 5. DISCRETE THUMBWHEEL CONTROL

ORIGINAL REQUIREMENT	MFI COMMENTS
5.4.2.1.3.8.2 <u>Continuous Thumbwheel Controls</u> - Resistance shall be provided so that definite sustained effort is required for actuation. The resistance incorporated into continuous thumbwheel controls shall be within the following torque limits: a. Minimum: Determined by jarring, vibration, or other conditions; no practical limit is set by operator performance. b. Maximum: 6 inch-ounces (42 mN·m). 5.4.2.1.3.9 <u>Separation</u> - Control separation shall conform to the criteria in Figure 5. The separation between adjacent edges of thumbwheel controls shall, in any case, be sufficient to preclude accidental activation of adjacent controls during normal setting.	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.2.1.3 Thumbwheel Selector Swtiches 5.4.2.1.3.1 Use - Mechanically-detented thumbwheel controls may be used as an alternative rotary selector device when the application will benefit from the compactness of such devices, and appropriate visual and/or audio feedback is provided. Examples include; numeric thumbwheel readout device, discrete audio volume or panel illumination level selector, etc. 5.4.2.1.3.2 Thumbwheel Orientation and Movement - Selector thumbwheels shall be oriented and move as indicated in Figure ____. 5.4.2.1.3.3 Rim Tabs and Serrations - Raised tabs and/or serrated sections of the thumbwheel rim shall be provided to aid the operator in identifying discrete positions and movement of the control. 5.4.2.1.3.4 Dimensions, Separation and Torque Requirements - Control dimensions, separation and torque requirements shall conform to criteria in Figure ____. Control resistance shall be elastic, building up and then decreasing as each detent is approached so that the control "snaps" into position without stopping between adjacent detents. 5.4.2.1.3.5 Labeling and Visibility - Marking and labeling of thumbwheel controls shall conform to requirements herein with respect to visibility of markings and design of numerals. 5.4.2.1.3.6 Illumination-[(Use original material from par. 5.4.2.1.3.5.1 (except for numeral dimensions).] 5.4.2.1.3.7 Color Coding - Thumbwheel controls may be coded by means of color and/or contact (e.g., dark vs light surfaces). Examples are; (a) reversing the colors of the least significant digit wheel as on a typical odometer, (b) where used as an input device, the thumbwheel switch OFF or NORMAL positions may be color coded to permit a visual check that the digits have been reset to their normal value.	Ref: Van Cott, Human Engineering Guide to Equipment Design, 1972, pp. 363-64.

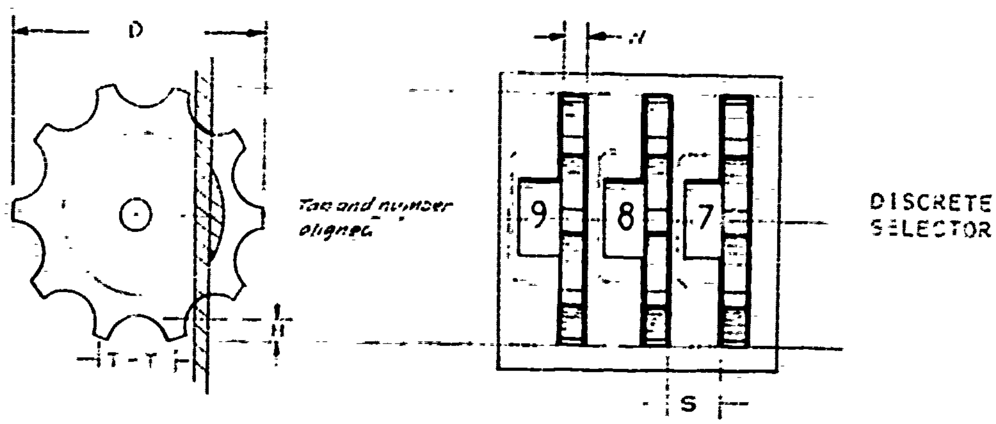


Arrows indicate the direction of control motion to produce a value increase.



Alternate "rim" formats are acceptable as long as they provide positional identification and aid manipulation.

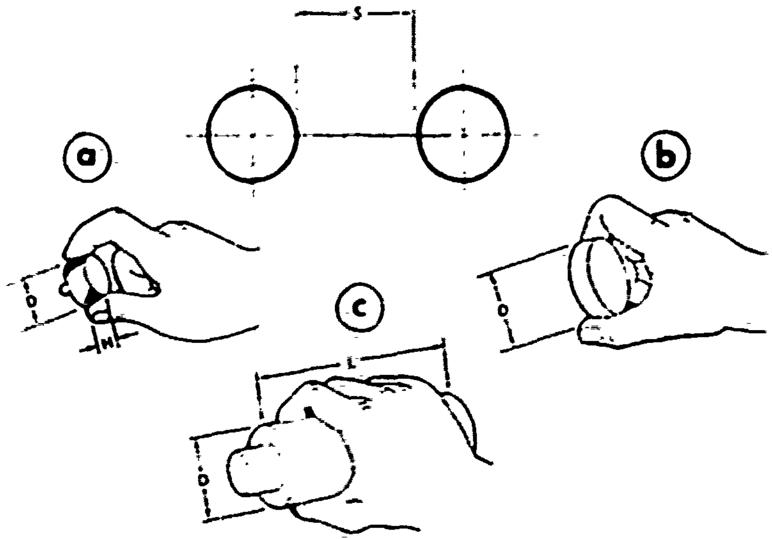
Figure________Thumbwheel Orientation/Motion



	D DIAMETER	W WIDTH	H DEPTH	S SEPARATION	TORQUE FOR ACTUATION
MINIMUM	1.0 IN. (2.54 CM)	0.1 IN. (0.3 CM)	0.125 IN. (0.32 CM)	0.4 IN. (1.0 CM)	1.0 IN-LB (0.11 N·m)
MAXIMUM	3.0 IN. (7.62 CM)		0.5 IN. (1.3 CM)		3.0 IN-LB (0.34 N·m)

FIGURE 5 - THUMBWHEEL SELECTOR CONTROL

ORIGINAL REQUIREMENT	MFI COMMENTS
5.4.2.2 Continuous Adjustment Rotary Controls -	
5.4.2.2.1 Knobs -	Lacks coverage of some important issues.
5.4.2.2.1.1 Application - Knobs should be used when little force is required, and when precise adjustments of a continuous variable are required. A moving knob with fixed scale is preferred over a moving scale with fixed index for most tasks. If positions of non-multirevolution controls must be distinguished, a pointer or marker should be available on the knob.	Fig 6 needs amplification.
5.4.2.2.1.2 Dimensions, Torque and Separation - The dimensions of knobs shall be within the limits specified in Figure 6. Within these ranges, knob size is relatively unimportant, provided the resistance is low and the knob can be easily grasped and manipulated. When panel space is extremely limited, knobs should approximate the minimum values and should have resistance as low as possible without permitting the setting to be changed by vibration or merely touching the control. Resistance and separation between adjacent edges of knobs shall conform to Figure 6.	
5.4.2.2.1.3 Knob Style - Unless otherwise specified by the procuring activity, control knobs shall conform to MIL-STD-1348.	



	DIMENSIONS				
	(a) Fingertip Grasp		(b) Thumb and Finger Encircled	(c) Palm Grasp	
	H Height	D Diameter	D Diameter	D Diameter	L Length
Minimum	0.5" (13 mm)	0.375" (10 mm)	1.0" (25mm)	1.5" (38mm)	3.0" (75mm)
Maximum	1.0" (25 mm)	4.0" (100 mm)	3.0" (75mm)	3.0" (75mm)	

	TORQUE		SEPARATION	
	*	**	S One Hand Individually	S Two Hands Simultaneously
Minimum			1.0" (25mm)	2.0" (50mm)
Optimum			2.0" (50mm)	5.0" (125mm)
Maximum	4.5 in. oz (32 mN·m)	6.0 in. oz (42 mN·m)		

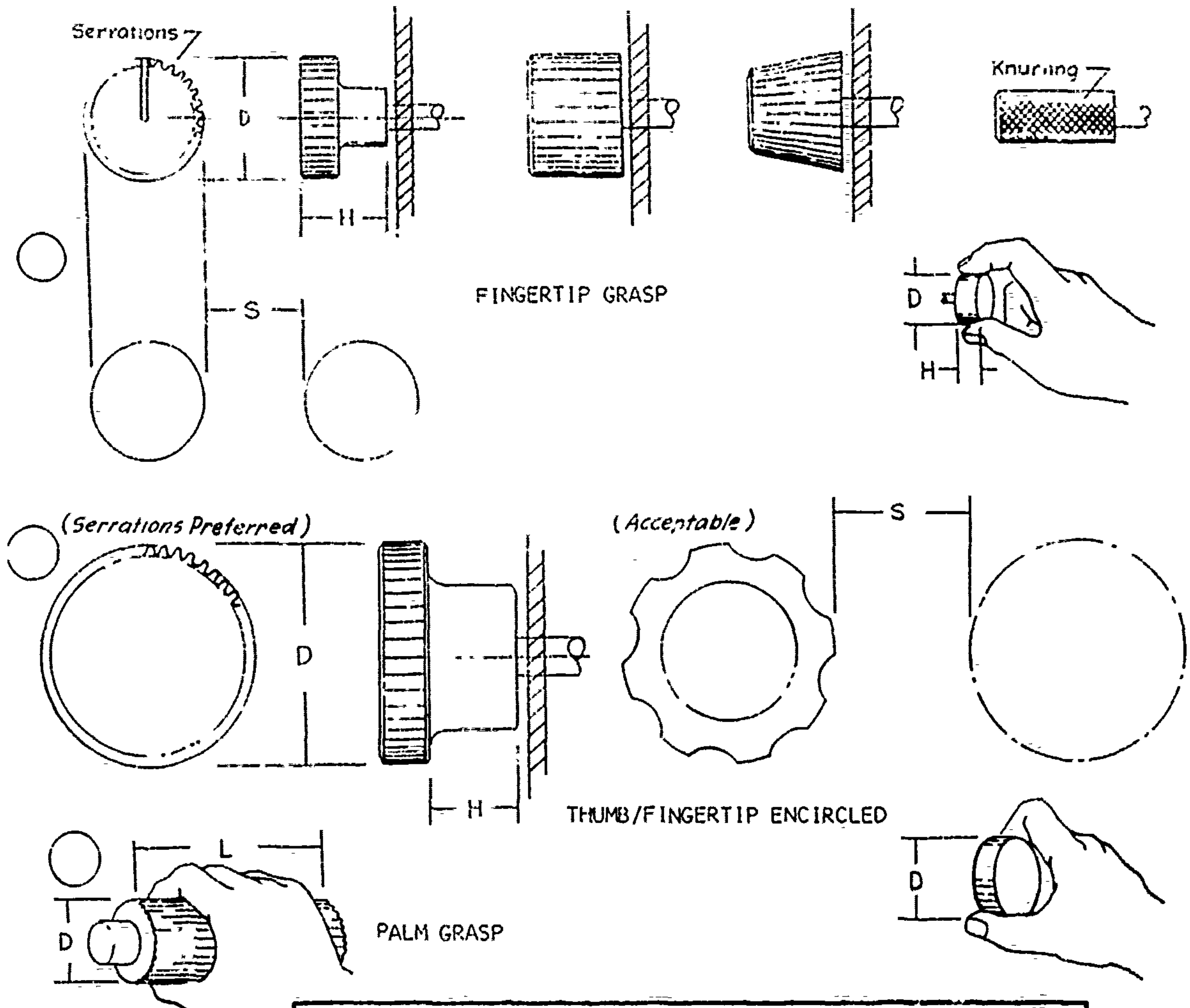
*To and including 1.0 in. (25mm) diameter knobs
**Greater than 1.0 in. (25mm) diameter knobs

Figure 6. CONTINUOUS ADJUSTMENT ROTARY CONTROL KNOBS

(ORIGINAL)

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.2.2 Continuous Adjustment, Rotary Controls 5.4.2.2.1 Knobs	Ref: Van Cott, Human Engineering Guide to Equipment Design, 1972, p. 364-66.
5.4.2.2.1.1 Application - Knobs should be used when little force or rapid, multi-turn adjustment is required, and when precise adjustment of a continuous variable is needed. If the adjustment requires reference to a scale, it is preferred that the scale be placed on a panel and that an index line be inscribed on the pointer (i.e., moving pointer/fixed-scale format). If the range of knob movement involves more than 360 degrees rotation, scales shall not be used.	Expanded to provide broader application coverage.
5.4.2.2.1.2 Dimensions, Torque Requirements, and Knob Separation - The dimensions of knobs shall be within the limits specified in Figure 6. Within these ranges, knob size is relatively unimportant, provided torque requirement is low and the knob can be easily grasped and manipulated. When panel space is extremely limited, knobs should approximate the minimum dimensional values and torque requirements, but torque requirement should be sufficient to minimize inadvertent control movement due to equipment vibration or accidental touching of the control knob). Torque required for actuation and the separation between adjacent edges of knobs shall conform to Figure 6. 5.4.2.2.1.3 Knob Style - Unless otherwise specified by the procuring activity, control knobs shall conform to general styles shown in Figure 6. 5.4.2.2.1.4 Knob Rims - All rotary adjustment knobs shall have rims with suitable surfaces for secure grasp. Very small knobs should have knurled surfaces to provide maximum torquing capability. Intermediate and larger sizes of knobs should have serrated rims, except that knobs used where high torque is required should have rim indentation rather than serration for firmer grasp. Larger knobs should utilize rim indentation to aid gripping for application of higher torques.	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.2.2.1.5 <u>Special Rotary Handle-Knobs</u> - Handle-like rotary knobs may be used for special applications (e.g., motorcycle accelerator control), in which case, dimensional criteria shown in Figure 6 shall be observed. 5.4.2.2.1.6 <u>Contact Hazard</u> - When knobs are used in vehicles and are located where they could be contacted during the sudden deceleration of a crash, frontal surface area should be large, and all edges should be rounded in order to minimize the potential injuries associated with small, sharp knob designs.	



	DIMENSIONS				
	(a) Fingertip Grasp		(b) Thumb and Finger Encircled	(c) Palm Grasp	
	H Height	D Diameter	D Diameter	D Diameter	L Length
Minimum	0.5" (13 mm)	0.375" (10 mm)	1.0" (25mm)	1.5" (38mm)	3.0" (75mm)
Maximum	1.0" (25 mm)	4.0" (100 mm)	3.0" (75mm)	3.0" (75mm)	

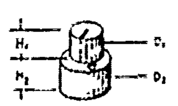
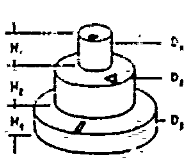
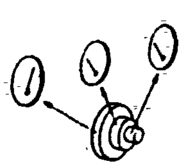
	TORQUE ROMT		SEPARATION	
	*	**	S One Hand Individually	S Two Hands Simultaneously
Minimum			1.0" (25mm)	2.0" (50mm)
Optimum			2.0" (50mm)	5.0" (125mm)
Maximum	4.5 in.-oz (32 mN·m)	6.0 in.-oz (42 mN·m)		

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

Figure 6. CONTINUOUS ADJUSTMENT ROTARY CONTROL KNOBS

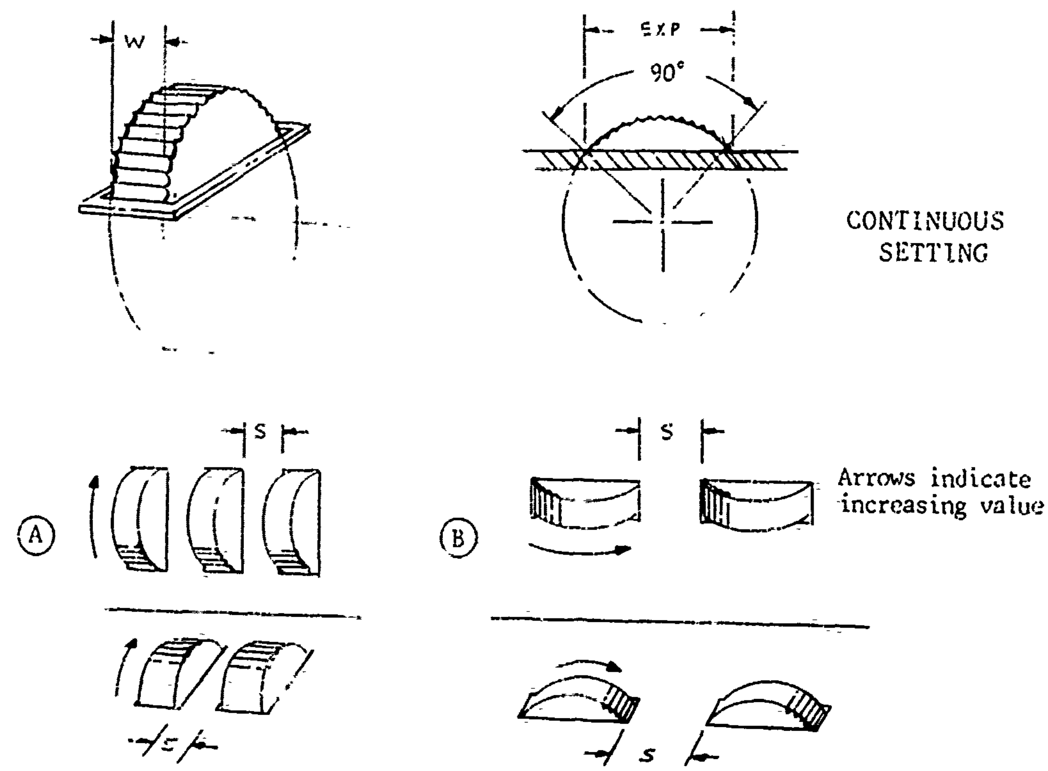
MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.2.2.1.7 Ganged Control Knobs 5.4.2.2.1.7.1 Application - Ganged knob assemblies may be used in limited applications when panel space is at a premium. Two knob assemblies are preferred, although three-knob configurations are permissible. Ganged knob configurations should not be used under the following conditions: a. Extremely accurate or rapid operations are required. b. Frequent changes are necessary. c. Gloves have to be worn. d. Equipment is exposed to the weather or used under rough field conditions. 5.4.2.2.1.7.2 Dimensions, Separation Between Assemblies - Knob dimensions and separation shall conform to requirements in Table_____. 5.4.2.2.1.7.3 Torque Requirement - Torque requirements shall conform to the criteria in Figure 6. Knobs should be serrated; fine serrations should be used on the knob used to make fine adjustment, gross serrations for the knob used to make less fine adjustments. 5.4.2.2.1.7.4 Marking - An indexing mark or pointer shall be provided on each knob in an assembly. Marks or pointers should differ sufficiently to make it apparent which knob indexing mark is being observed. 5.4.2.2.1.7.5 Knob/Display Relationship - When each knob of a ganged assembly must be related to an array of visual displays, the upper knob should relate to the right-most display in a horizontal array, or the uppermost display in a vertical array (see Table_____). 5.4.2.2.1.7.6 Inadvertent Operation - When it is critical to prevent inadvertent activation of one knob as the other is being adjusted, a secondary control movement shall be required (viz;	Ref: Woodson and Conover, Human Engineering Guide for Equipment Designers, 1966, p. 2-104.

Table ____ - Ganged, Rotary Controls

	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	GANGED OR STACKED ROTARY ADJUSTMENT KNOB CONFIGURATION, NOT TO BE USED WHERE RAPID, ACCURATE RESPONSE IS REQUIRED OR GLOVES ARE USED. MAX. TWO-KNOB ASSEMBLIES PREFERRED. D_1 = GROSS ADJUSTMENT D_2 = FINE ADJUSTMENT	D_1 MIN DIAM = 0.5" (1.27 CM) D_2 MIN DIAM = 0.875" (2.2 CM) ± .0625 TOLERANCE	H_1 MIN HEIGHT= 0.625" (1.9 CM) H_2 MIN HEIGHT= 0.5" (1.27 CM)	—	—	SINGLE-HAND OP'N. SEE "CONTR., ROTAR" IN TABLE VII FOR SIMULTANEOUS OP'N OF ADJACENT KNOBS (BOTH HANDS), ADD 1.0" (2.54 CM), 1.5" (3.8 CM) FOR GLOVES.
	IF THREE-KNOB ASSY REQUIRED DIMENSIONAL RELATIONSHIPS SHALL BE OPTIMIZED	SMALL SET: D_1 = 0.5" (1.3 CM) D_2 = 1.75" (4.4 CM) D_3 = 3.0" (7.6 CM) LARGE SET: D_1 = 1.0" (2.54 CM) D_2 = 2.0" (5.1 CM) D_3 = 3.25" (8.3 CM)	H_1 = 0.75" (1.9 CM) H_2 = 0.75" H_3 = 0.25" MIN (0.6 CM)	—	—	SEE ABOVE
	GANGED KNOB/DISPLAY ASSOCIATION	—	—	—	—	—

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
pressing the top knob before it can be engaged with its control shaft). Where inadvertent movement is undesirable but not necessarily critical, optimize knob diameter/depth relationships as shown in Table_____. Contrasting colors between knobs may also be used to improve individual knob identification.	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.2.2.1.8 Continuous Adjustment Thumbwheel Controls	Moved from "Rotary Control" section.
5.4.2.2.1.8.1 Use - Continuously adjustable thumbwheel controls may be used as an alternate to rotary knobs when the application will benefit from the compactness of the thumbwheel device.	
5.4.2.2.1.8.2 Orientation and Movement - Thumbwheels shall be oriented and move in the directions specified in Figure_____.	
5.4.2.2.1.8.3 Thumbwheel Serrations - The rim of the thumbwheel shall be serrated to aid the operator in manipulating the control.	
5.4.2.2.1.8.4 Dimensions, Separation and Torque Requirements - Thumbwheel dimensions, separation and torque requirements shall conform to criteria in Figure_____.	
5.4.2.2.1.8.5 Labeling and Visibility - Marking and labeling of continuously-adjustable thumbwheel controls shall conform to requirements herein with respect to visibility or markings and legibility of label alphanumerics.	

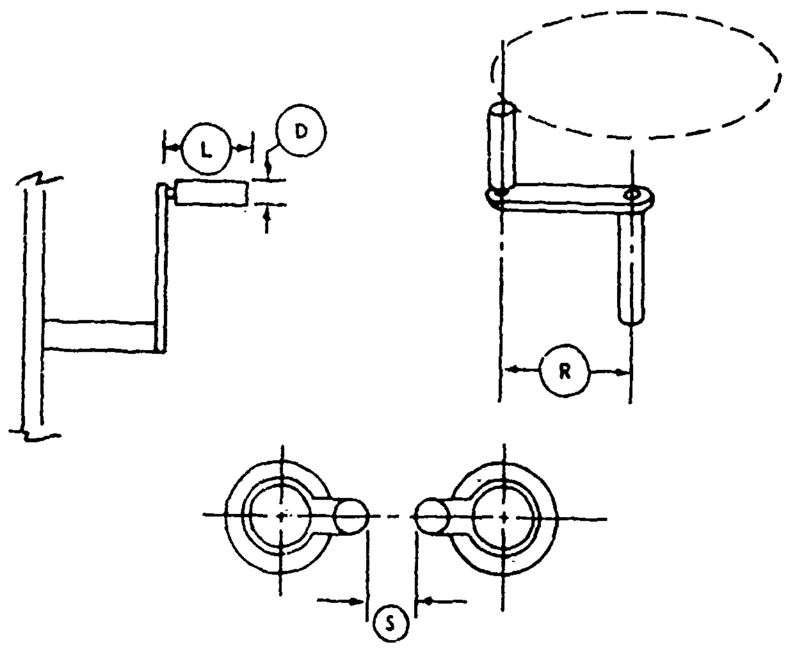


	Rim Exposure	W Width	S (A)	S (B)	Torque Reqm't
Minimum	1.0 in. * (2.54 cm)	0.15 in. * (0.38 cm)	1.0 in. (2.54 cm) Add 0.5 in. for gloves	2.0 in. (5.1 cm) Add 1.0 in. for gloves	To minimize effects of inadvertent input if operator subject to motion
Maximum	N/A	N/A	N/A	N/A	6.0 in.-oz. (420 mN)

*Preferred - Some miniature applications may require less.

Figure 5.a - Thumbwheel Adjustment Controls

ORIGINAL REQUIREMENT	MFI COMMENTS
5.4.2.2.2 Cranks - 5.4.2.2.2.1 Application - Cranks should be used primarily for tasks requiring many rotations of a control, particularly where high rates or large forces are involved. For tasks involving large slewing movements, plus small, fine adjustments, a crank handle may be mounted on a knob or handwheel -- the crank for slewing and the knob or handwheel for fine adjustments. Where cranks are used for tuning or other processes involving numerical selection, each rotation should correspond to a multiple of 1, 10, 100, etc. 5.4.2.2.2.2 Grip Handle - The crank grip handle shall be designed so that it turns freely around its shaft. 5.4.2.2.2.3 Dimensions, Resistance and Separation - Dimensions, resistance and separation between adjacent swept circular areas of cranks shall conform to the criteria of Figure 7.	Needs paragraph re: use of a folding handle type of crank. Fig. 7 should have added illustrations to provide credibility with respect to different types of common cranks.



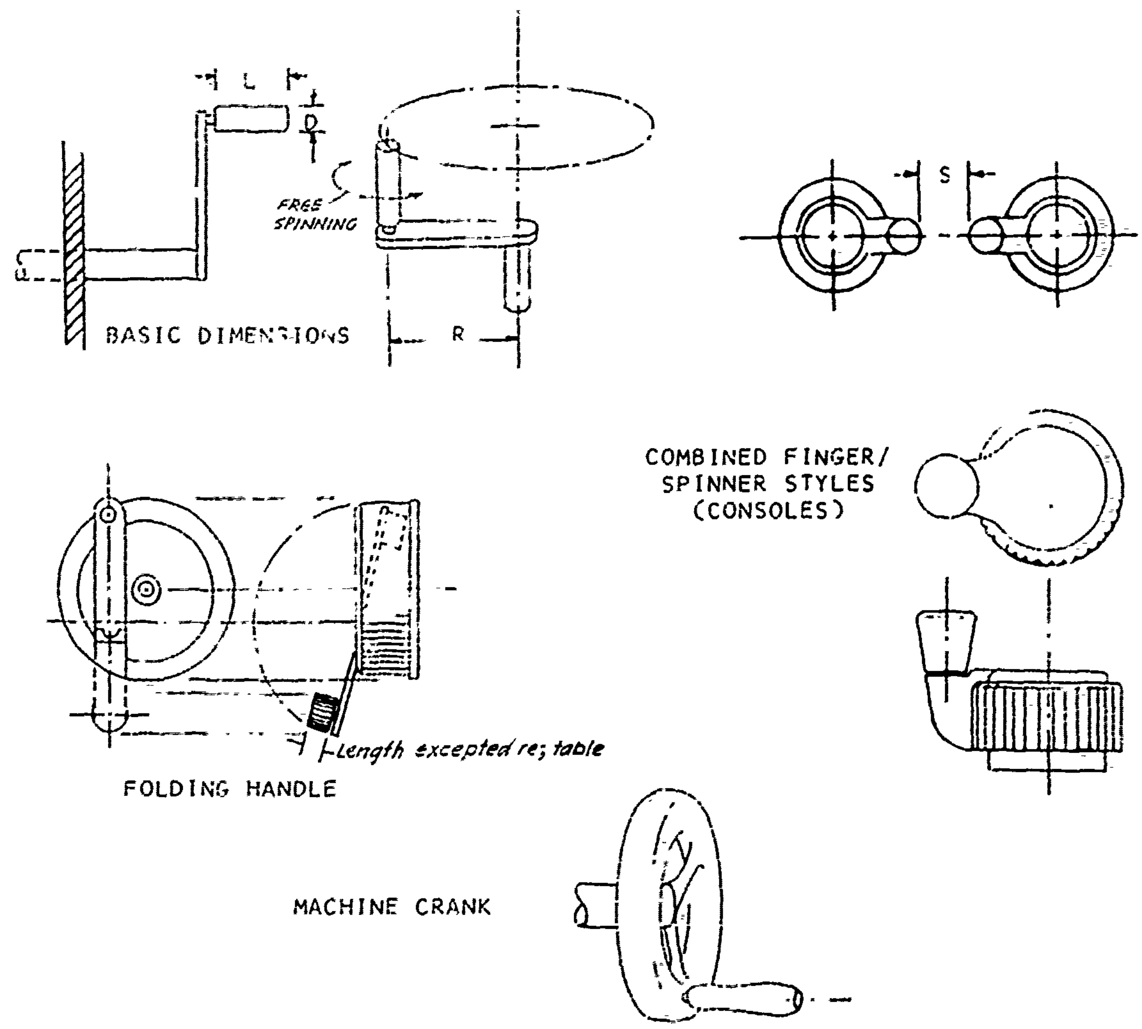
rpm*	DIMENSIONS: Handle D Diameter	Handle L Length	Radius R Minimum	Radius R Maximum
None	1.0" (25mm)	3.75" (95mm)	9.0" (230mm)	16.0" (410mm)
175	1.0" (25mm)	3.75" (95mm)	5.0" (125mm)	8.0" (200mm)
275 (max)	0.5" (13mm)	1.5" (38mm)	0.5" (13mm)	4.5" (115mm)

rpm*	RESISTANCE Minimum	RESISTANCE Maximum	SEPARATION S Minimum	SEPARATION S Maximum
None	2.0 lb (9N)	50 lb (220N)	3.0" (75mm)	-
175	6.0 lb (27N)	15 lb (67N)	3.0" (75mm)	-
275 (max)	2.0 lb (9N)	5 lb (22N)	3.0" (75mm)	-

* Revolutions per minute required of personnel

Figure 7. CRANKS

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.2.2.2 <u>Cranks</u> 5.4.2.2.2.1 through 5.4.2.2.2.3 - [Use original material -- but add the following:] 5.4.2.2.2.4 <u>Folding Handle</u> - When it appears that a crank handle could become a hazard to persons passing a control panel, or it is critical that the handle not be inadvertently displaced by being accidentally bumped, a folding handle type control should be used. Such a control shall be designed so that the handle is spring-loaded to keep it extended in the "cranking" position when in use and folded when not in use.	Original paragraphs remain as they are. This is merely an addition to recognize a commonly-used component not covered originally. Note: On new Fig. a minimum handle length for folding handle depends on practical considerations.



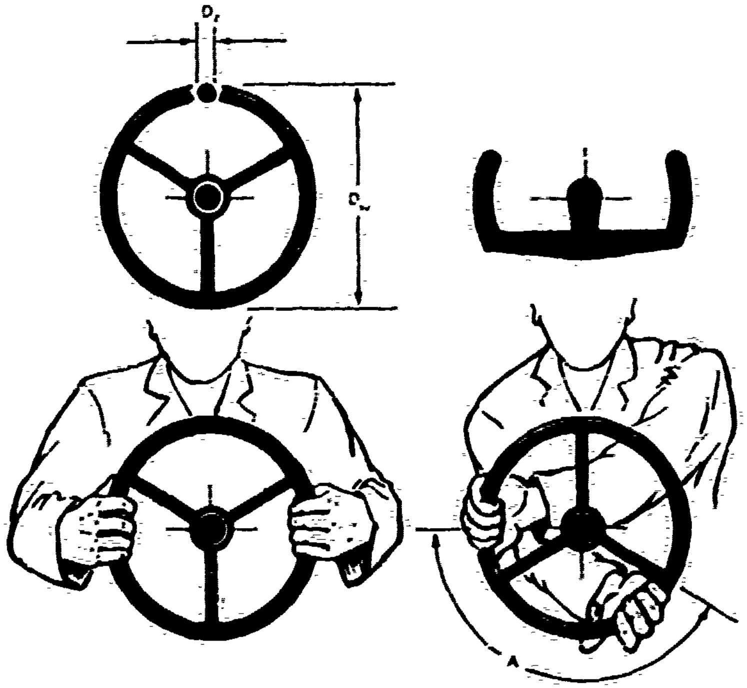
rpm*	DIMENSIONS* Handle D Diameter	L Length	Radius R Minimum	Maximum
None	1.0" (2.5cm)	3.75" (9.5cm)	9.0" (22.9cm)	16.0" (40.6cm)
175	1.0" (2.5cm)	3.75" (9.5cm)	5.0" (12.7cm)	8.0" (20.3cm)
275	0.5" (1.3cm)	1.5" (3.8cm)	0.5" (1.3cm)	4.5" (11.4cm)
(max)		MIN 0.5" (1.3 cm)		

rpm*	FORCE REQM'TS Minimum	Maximum	SEPARATION S Minimum	Maximum
None	2.0 lb (9N)	50 lb (222N)	3.0" (7.6cm)	•
175	6.0 lb (27N)	15 lb (67N)	3.0" (7.6cm)	•
275	2.0 lb (9N)	5 lb (22N)	3.0" (7.6cm)	•
(max)				

* Revolutions per minute required of personnel

FIGURE_____ CRANKS

ORIGINAL REQUIREMENT	MFI COMMENTS
5.4.2.2.3 Handwheels - 5.4.2.2.3.1 Application - Handwheels, which are designed for two-hand operation, should be used when the breakout or rotation forces are too large to be overcome with a one-hand control, provided that two hands will be available for this task. 5.4.2.2.3.2 Knurling - Knurling or indentation shall be built into a handwheel to facilitate operator grasp. 5.4.2.2.3.3 Spinner Handle - When large displacements must be rapidly made, a spinner handle may be attached to the handwheel when not precluded by safety considerations. 5.4.2.2.3.4 Direction of Movement - Except for valves (see 5.4.1.2.4), handwheels shall rotate clockwise for ON or INCREASE and counterclockwise for OFF and DECREASE. The direction of motion shall be indicated on the handwheel, or immediately adjacent thereto, by means of arrow and appropriate legends. 5.4.2.2.3.5 Dimensions, Resistance, Displacement and Separation - Control dimensions, resistance, displacement and separation between edges of adjacent handwheels shall conform to the criteria in Figure 8.	Needs to cover wider range of applications, which also require individual illustration and design information.



A - This is not a useful criterion.

	DIMENSIONS			RESISTANCE	
	D_w Wheel Diameter		D_r Rim Diameter		
	One Hand	Two Hands		One Hand	Two Hands
Minimum	2.0" (50mm)	7.0" (180mm)	0.75" (19mm)	5 lb (22N)	5 lb (22N)
Maximum	4.25" (110mm)	21.0" (530mm)	2.0" (50mm)	30 lb (133N)	50 lb (220N)

	DISPLACEMENT		SEPARATION*
	A		
	One Hand	Two Hands	Two Hands Simultaneously
Minimum	-	-	3.0" (75mm)
Maximum	-	120 deg	5.0" (125mm)

*between adjacent wheels

Figure 8. HANDWHEELS

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.2.2.3 Handwheels (Two-Hand-Operated)	
5.4.2.2.3.1 Application - Handwheels, which are designed for nominal two-hand operation, should be used when the breakout or rotation forces are too high to be easily overcome with a one-handed control, provided that two hands are available for this task. Typical applications to be considered are steering, hatch securing, valve opening/closing and direct-linkage adjustment and hatch locking handwheels.	
5.4.2.2.3.2 Direction of Movement - Handwheel direction-of-movement shall comply with requirements in 5.4.1.2. For all handwheels in which the direction of motion relationship is not directly apparent (expectation), direction-of-motion shall be indicated directly on the wheel rim and/or immediately adjacent thereto on a panel or structural surface, utilizing appropriate labeling and/or directional arrows.	
5.4.2.2.3.3 Dimensions, Torque Requirements, Displacement and Separation - Control dimensions, torque requirements, displacement and separation between adjacent handwheels shall conform to criteria in Table_____.	Ref: Van Cott, Human Engineering Guide to Equipment Design, 1972, Ch. 8.
5.4.2.2.3.4 Position - Handwheels (including steering wheels) shall be selected in terms of size and expected usage to provide operator-use convenience based upon whether the operator is seated or standing to operate the wheel. For seated operation, the wheel should normally be centered on the operator's centerline and sloped so that both of the operator's arms and hands have approximately equal access to the wheel. In addition, wheels operated from the seated position should be sized and positioned for convenient ingress/egress, as well as over-the-wheel viewing where applicable.	
5.4.2.2.3.5 Spinner Handles - For applications where the wheel may be rotated rapidly through several revolutions (e.g., slewing), a spinner handle may be added for added convenience. Such handles shall not be used however, if the projecting handle is vulnerable to inadvertent displacement of a critical wheel setting, or is a safety hazard.	Professional judgment.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.2.2.3.6 Turning Aids - Knurling, indentation, and/or high-friction cover may be built into the handwheel to facilitate operator grasp, i.e., in order to apply maximum torque and/or to reduce the possibility of the wheel from being jerked out of the operator's hands.	
5.4.2.2.3.7 Wheel Hub Delethalization - Steering wheel hubs shall be recessed and provided with a broad pad to minimize the possibility of driver impalement during a crash. Consideration shall also be given to use of a collapsible steering column for rapidly-moving vehicles. Such steering wheels shall be structurally resistant to major rim/spoke distortion considering the loads that could be created by the driver's body being thrust into the wheel during a crash.	
5.4.2.2.3.8 Wheel Shape - Except for the special cases of established uses in submarines and aircraft all handwheels should be round.	
5.4.2.2.3.9 Power Steering Failure - Steering systems shall be designed with sufficient mechanical advantage to meet the force requirements of Table_____, even though the primary operating mode utilizes power-assist, i.e., the operator shall be able to steer the vehicle to a safe stop in the event of power failure.	MFI Study (MFI 73-105, 1972)
5.4.2.2.3.10 Steering Wheel Lock - Vehicles designed to operate on Continental U.S. roads shall meet Federal requirements for locking the steering column with removal of the ignition key.	
5.4.2.2.3.11 Steering Ratio - Steering systems should be designed so that the maximum turning limits of the vehicle can be acquired by no more than 3½ to 4 turns of the steering wheel.	Industry practice.

Table____ - Two-Hand-Operated Handwheels

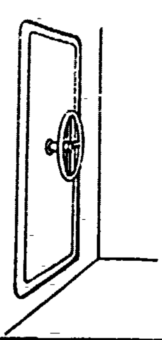
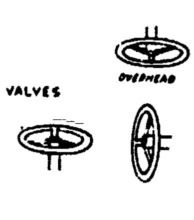
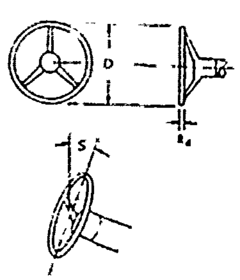
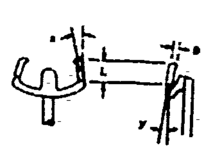
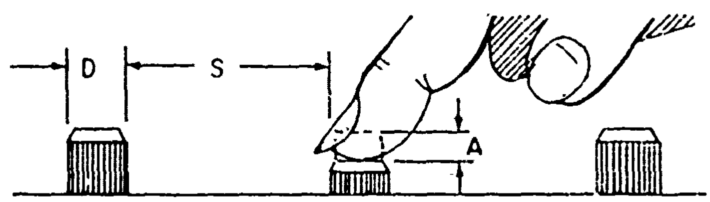
	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	CONTINUOUS ADJUSTMENT FOR ALTERNATE SLEWING/PRECISE POSITIONING, USING DISPLAY REFERENCE. FORCE REQUIREMENT AT THE RIM SHOULD BE BELOW 25 LB (111 N).	DIAM = 14.0" (35.6 CM) ± 6.0" (15.2 CM)	RIM DIAM = 0.75" (1.9 CM) TO 1.25" (3.2 CM)	MINIMUM HAND CLEARANCE AROUND RIM = 3.0" (7.5 CM)	SEE CONTROL/DISPLAY RATIOS 5.1.4	28.0" (71.1 CM) ELBOW-ELBOW CLEARANCE
	CONTINUOUS LOCK-UNLOCK OPERATION	DIAM = 8" FOR <5 LB TO 20" FOR 50 LB	SAME AS ABOVE	SAME AS ABOVE	N/A	SAME AS ABOVE
	HIGH TORQUE VALVES 2.26 N·m OF TORQUE/25.4 mm OF HANDLE DIAMETER (20 IN./LB OF TORQUE/INCH OF HANDLE DIAMETER)	DIAM = 8.0"-16.0" FOR OVERHEAD; 8.0"-20.0" FOR OTHER POS'NS BETWEEN 12-60" (31-152 CM) ABOVE STANDING SURFACE	SAME AS ABOVE	SAME AS ABOVE	SEE 5.1.4 WHEN APPLICABLE	SAME AS ABOVE

Table _____ - Two-Hand-Operated Handwheels (Continued)

	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	VEHICLE STEERING (AUTOMOTIVE). MAX FORCE REQUIRED WITH POWER STEERING = 25 LBS (111 N) MAXIMUM FORCE REQUIRED WITHOUT POWER STEERING = 50 LBS (222 N)	D - DIAM = 14-16" FOR PWR STEERING; 16-20" FOR NON-POWER (35.6-50.8 CM)	R_d - RIM DIAM = 0.75"-1.25" (1.9-3.2 CM)	S - WHEEL SLOPE = DEPENDS ON DRIVER POS'N VERTICAL-HORIZONTAL PREFERRED = 30° FOR LIGHT VEHICLES; 45° FOR HEAVY VEHICLES	MAX = 120° FOR FULL STOP-TO-STOP TURN, BOTH HANDS ON THE WHEEL.	N/A
	AIRCRAFT STEERING (COMBINE WITH LEVER FOR PITCH, RUDDER PEDALS FOR ROLL/STEER)	D - GRIP DIAM = 1.25" (1.9 CM) PREFERRED	L - GRIP LENGTH = MIN 4.0" (10.2 CM)	X-Y GRIP TILT PREFERRED = X = ±5° Y = 0-15°	MAX PREFERRED = ± 30°	N/A

ORIGINAL REQUIREMENT	MFI COMMENTS
5.4.3 Linear Controls - 5.4.3.1 Discrete Linear Controls - 5.4.3.1.1 Push Buttons (Finger or Hand Operated) - 5.4.3.1.1.1 Application - Push buttons should be used when a control or an array of controls is needed for momentary contact or for activating a locking circuit, particularly in high-frequency-of-use situations. 5.4.3.1.1.2 Shape - The push button surface should normally be concave (indented) to fit the finger. When this is impractical, the surface shall provide a high degree of frictional resistance to prevent slipping. 5.4.3.1.1.3 Positive Indication - A positive indication of control activation shall be provided (e.g., snap feel, audible click, or integral light). 5.4.3.1.1.4 Channel or Cover Guard - A channel or cover guard shall be provided when it is imperative to prevent accidental activation of the control. 5.4.3.1.1.5 Dimensions, Resistance, Displacement, and Separation - Except for use of push buttons in keyboards, control dimensions, resistance, displacement, and separation between adjacent edges of finger or hand-operated pushbuttons shall conform to the criteria in Figure 9. 5.4.3.1.1.6 Interlocks or Barriers - Properly designed mechanical interlocks or barriers may be used instead of the spacing required by Figure 9.	Section on push buttons should be combined with one on legend switches since the designer thinks of both as push buttons. Between the few requirements and illustrations, many other push button applications are ignored by absence of discussion and/or illustration. The scope needs to be expanded to reflect the variety of components now available, some of which are found in other MIL specs.

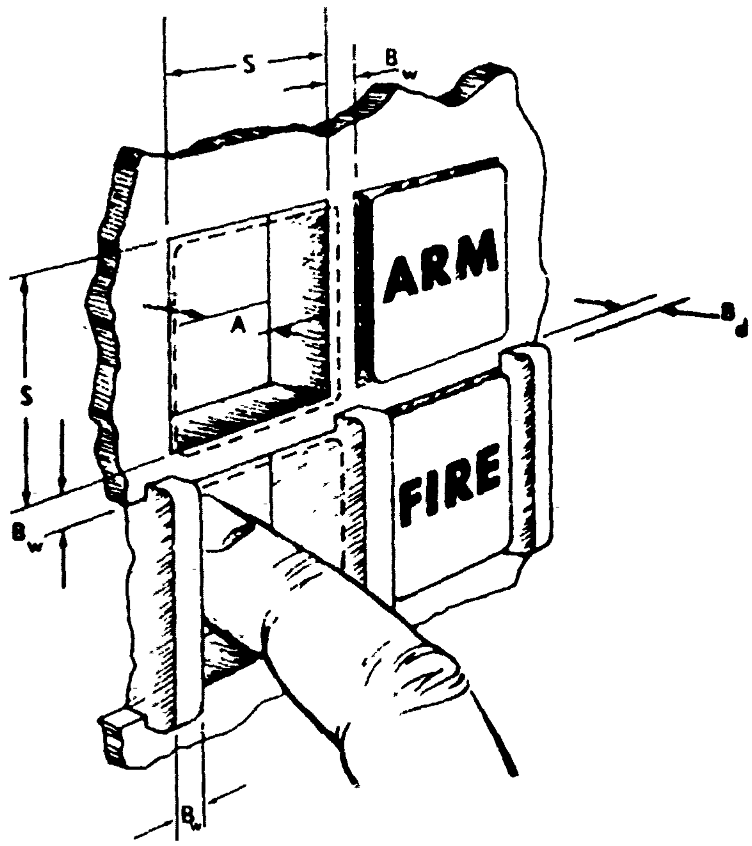


	DIMENSIONS Diameter D Fingertip Operation	DIMENSIONS Diameter D Thumb or Heel of Hand Operation	RESISTANCE Fingertip Operation	RESISTANCE Little Finger Operation	DISPLACEMENT A Thumb or Finger Operation
Minimum	0.385" (10mm)	0.75" (19mm)	10 oz (2.8N)	5 oz (1.4N)	0.125" (3mm)
Maximum	0.75" (19mm)		40 oz (11.0N)	20 oz (5.6N)	1.5" (38mm)

	SEPARATION S Single Finger Operation	SEPARATION S Single Finger Sequential Operation	SEPARATION S Operation by Several Fingers
Minimum	0.5" (13mm)	0.25" (6mm)	0.5" (13mm)
Preferred	2.0" (50mm)	1.00" (25mm)	0.5" (13mm)

Figure 9. PUSHBUTTONS (FINGER OR HAND OPERATED)

ORIGINAL REQUIREMENT	MFI COMMENTS
5.4.3.1.5 Legend Switches -	
5.4.3.1.5.1 Dimensions, Resistance, Displacement, and Separation - Dimensions, resistance, displacement, and separation between adjacent edges of legend switches shall conform to the criteria in Figure 12.	
5.4.3.1.5.2 Barrier Height - Barrier height from panel surface shall conform to the criteria in Figure 12.	
5.4.3.1.5.3 Other Requirements -	
a. For positive indication of switch activation, the legend switch shall be provided with a detent or click. When legend switches are touch sensitive and not mechanical, a positive indication of activation may be an integral light within or above the switch being activated.	
b. The legend shall be legible with or without internal illumination.	
c. A lamp test or dual lamp/filament reliability shall be provided, except for switches using LED's in place of incandescent lamps.	
d. Lamps within the legend switch shall be replaceable from the front of the panel by hand and the legends or covers shall be keyed to prevent the possibility of interchanging the legend covers.	
e. There shall be a maximum of three lines of lettering on the legend plate.	This is silly. Fairly large component are available, and there may be good reason to have more labels, e.g., a 4-way matrix switch (see new illustration).



	S Size	A DISPLACEMENT	BARRIERS*		RESISTANCE
			B_w	B_d	
Minimum	0.75" (19mm)	0.125"** (3 mm)	0.125" (3mm)	0.188" (5mm)	10 oz (280mN)
Maximum	1.5" (38mm)	0.250" (6mm)	0.250" (6mm)	0.250" (6mm)	40 oz (11N)

*Barriers shall have rounded edges.

**3/16" (5mm) for positive position switches

Figure 12. LEGEND SWITCH

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.3.1.1 Push Button Switches (Hand- or Finger-Operated)	Application coverage and illustrations obviously have been expanded to cover common variation.
5.4.3.1.1.1 Application - Push button controls shall be used primarily when a simple switching between two conditions are required, selection of alternate on-off functions from an array of related conditions, or subsystem functions, release of a locking system such as on a parking brake or entry of a discrete control order. Push buttons should not be used indiscriminately merely to make all panel controls "look alike", or where another type of switch could be used to save panel space, e.g., toggle switch. Push button type controls may be used for any of the following kinds of operation singly or in combination. (Refer also to Table ____ and paragraph 5.4.3.1.3.)	Instead of original figures and tables, the new table deals with types of push button applications on an individual basis. Note that we disagreed with several values and have introduced values we feel are more acceptable on the basis of our experience and observation of typical hardware. These seem to be supported by review committee.
a. Momentary contact. (A single "push-HOLD/release-OFF" function.) For this type of function the push button should be one of the following types: (1) non-illuminated (2) continuously ON switchcap light or legend, or (3) momentary ON switchcap light.	
b. Alternate action. Alternate action for a single function may be implemented either in a two-button format or as a single button. With the single-button type a first press sets the switch in the ON state and a second press sets it to OFF. Feedback to indicate the ON state shall be provided either by switchcap lamp or legend or by a closely associated lamp or legend. With the two-button type, the buttons are mechanically interlocked so that one button is always depressed and the other button is in the up position. Although the depressed button provides feedback on switch state, additional feedback by means of switchcap lamp or closely associated lamp or legend should normally be provided.	
c. Stepping action. Successive presses of the switch cycle it through three or more states. Switch state feedback may be provided by selective illumination of integral or associated legends.	

Function	Switch Action	Switch Config.	Switch State Feedback Options* Depressed Switchcap	Integral Lamp(s)	Integral legend(s)	Adjacent lamp(s)	Adjacent legend(s)	Other Display Reflectin Switch Action
1. Send short discrete signal to initiate or terminate some other function.	Momentary contact	Single button	Momentary only	Momentary only	Momentary only	Momentary only	Momentary only	Sufficien
2. Send short signal of controllable duration.	Momentary contact	Single button	Momentary only	Momentary only	Momentary only	Momentary only	Momentary only	Sufficien
3. Choose between two mutually exclusive states	Alternate action, latching	Two-button interlocked	If mechanically latched	C	Sufficient	C	Sufficient	C
		or Single-button	If mechanically latched	C	Sufficient	C	Sufficient	C
4. Step through three or more switch states	Stepping, latching	Single button with legend matrix	(No)	(No)	Sufficient (if multiple legend)	C	Sufficient	C
5. Independently choose one out of three or more mutually exclusive states	Latching and interlocked	Array of buttons	If mechanically latched	C	Sufficient	C	Sufficient	C
6. Independently choose two or more out of a set of control functions each having two states	Alternate action, latching	Array of buttons	If mechanically latched	C	Sufficient	C	Sufficient	C

*Notes: 1. The feedback referred to pertains only to knowledge of switch state, not system state (which may impose additional feedback requirements).

2. A feedback option designated "sufficient" means that, properly instrumented it can provide all the information the operator needs concerning switch state; other methods showing annotation or C (contributing) need to be used in combination to provide adequate feedback.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
d. Sets of related switching functions of the above types. These are combined as an assembly. These may be independent, interlocked or a combination of both, may be momentary or latching or a combination of both; and may be non-illuminated, or have switchcap lights or legends. Feedback as to active switch states shall always be provided. Interlocking and latching functions may be either mechanical or electrical. (See section 5.4.3.1.2 on keyboards, keypads, keysets, and menu selectors.)	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.3.1.1.2 Dimensions, Actuating Force, Displacement and Separation - Dimensions, displacement, and separation of push button controls shall conform to the criteria in Table ____. Actuating force for push buttons shall be within the following limits.	Ref: Woodson and Conover, Human Engineering Guide for Equipment Designers, 1966, p. 2-95, p. 2-96.

a. Very small, or frequently-used push button (see 5.4.3.1.3.2) force requirements should be within the range of 2.78 N (1.0 oz.) to 11.1 N (40.0 oz.).

b. Thumb-operated push button forces should be within the range of 1.1 N (4.0 oz.) to 16.7 N (60.0 oz.).

c. Large push buttons that typically would be operated by two or more fingers, or by the heel of the hand should be within the range of 1.7 N (6.0 oz.) to a maximum of 22.2 N (80.0 oz.).

5.4.3.1.1.3 Indication of Switch Activation - Positive feedback shall be provided to indicate that the push button switch has been activated or deactivated, considering the following:

a. Switch displacement is visible.

b. Tactile/auditory indication, i.e., gradual resistance build-up to sudden resistance-release (snaps into place), accompanied by a audible "click".

c. Accompanying visual indication (e.g., switch cap is illuminated).

5.4.3.1.1.4 Push Button Identification/Legends - Although push buttons may be identifiable by means of panel labels, it is preferred that labels be placed on the push button face (where size and other use factors are compatible). Criteria for labels and legends (5.5) shall be followed. Legends normally should be legible with or without internal illumination, but legends may be invisible during any distinct modes in which the button is never used. A lamp test capability and/or dual lamp reliability shall be provided, except for switches using LED's in place of incandescent lamps. Other considerations include the following:

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
a. There should normally be no more than three lines of lettering on a legend plate. b. Lamps within incandescent legend switches shall be replaceable from the front of the panel, by hand, and the legend or cover shall be keyed to prevent possibility of interchanging legend covers. 5.4.3.1.1.5 <u>Push Button Cap Shape</u> - Cap surfaces should generally be flat, but with rounded edges. However, for certain applications where it is required to insure proper "finger-centering", the cap surface may be made concave. General cap shapes may be round, square or rectangular as long as they provide adequate finger, thumb or hand contact area, and are compatible with identification or legend requirements. 5.4.3.1.1.6 <u>Inadvertent Switch Activation</u> - Primary methods for minimizing inadvertent switch activation shall conform to criteria in Table ____. If however, it is imperative to prevent accidental activation of a specific switch, a channel or cover guard shall be provided, and/or other suitable technique that requires the operator to perform a preceding action prior to final switch activation.	

Table _____ - Push Button Switches

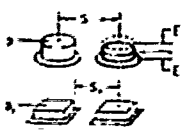
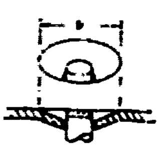
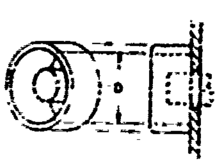
	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	PANEL-MOUNTED PUSH BUTTONS:					
	SINGLE FINGER, ONE BUTTON AT A TIME. NON-LEGEND OR BUTTONS THAT REQUIRE ONLY A SINGLE NUMBER ON THE FRONT SURFACE MAY BE ROUND, SQUARE OR RECTANGULAR.	D - MIN DIAM, OR DIMENSION (D_1) = 0.5" (1.3 CM)*	—	—	E - EXCURSION, PREFERRED MIN. = 0.125" (0.32 CM) PREFERRED MAX = 0.25" (0.64 CM) ADD 0.5" FOR GLOVED OPN NOTES: (1) THE DEPRESSED BUTTON (E_1) SHALL REMAIN EXPOSED BY AT LEAST 0.10" (0.25 CM) (2) SWITCHES WITH NO MOTION (E.G., THERMAL) ARE PERMISSIBLE SUBJECT TO APPROVAL BY THE PROCURING ACTIVITY	S = MIN 0.75" (1.9 CM) (OR) S_1 = MIN 0.5" (1.3 CM) S = 1.0" (2.54 CM) WITH GLOVES
	A CONCAVE SURFACE MAY BE USED TO AID FINGER-CENTERING (NON-GLOVE OPN ONLY).	D - MIN 0.5" (1.3 CM)	—	—		
	RECESSED BUTTON TO MINIMIZE INADVERTEND OPERATION. TAPERED "WELL" GUIDES FINGER.	—	D - MIN WELL OPENING 0.75" (1.9 CM), 1.125" WITH GLOVES.	—		
	PREVENT INADVERTENT OPERATION OF CRITICAL SWITCH, EITHER WITH GUARD RING, OR PANEL WELL.	—	D - SAME AS ABOVE	—		
	* For miniaturized applications diameter as small as 0.125" (0.32 cm) may be used subject to approval by the procuring activity.					

Table _____ - Push Button Switches (Continued)

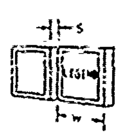
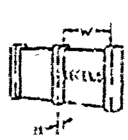
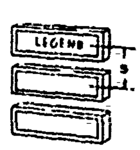
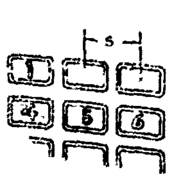
	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	LEGEND, SWITCHLIGHT.	W - MIN = 0.75" (1.9 CM); 1.0" FOR GLOVES	—	—	SAME AS ABOVE	S - PREFERRED MIN = 0.25" (0.64 CM) (EDGE-TO-EDGE)
	SWITCH, SEPARATOR GUARDS FOR CLOSELY SPACED SWITCHES.	SAME AS ABOVE	H - GUARD HT ABOVE UNDEPRESSED SW. SURFACE = 0.19" (0.5 CM) TO 0.25" (0.6 CM)	—		
	OTHER SHAPES ACCEPTABLE TO ACCOMMODATE EXTENDED LEGENDS. SWITCH SHALL ACTUATE EVEN THOUGH PRESSED OFF-CENTER.	—	—	—		S - CTR-CTR MIN. = 0.75" (1.9 CM)
	SURFACE "CONTACT" SWITCH (E.G., NON-DISPLACING) MAY BE USED WHERE INADVERTENT OP. ERRORS ARE NOT CRITICAL. "OUTLINE" GRAPHICS SHALL BE USED TO DELINEATE SWITCH CONTACT AREA, AND INDIVIDUAL SWITCH GRAPHIC SHOULD "ILLUMINATE" WHEN PROPER CONTACT IS MADE.	—	—	—	—	S - MIN CTR-CTR SPACING = 1.0" (2.54 CM); 1.5" WITH GLOVES

Table _____ - Push Button Switches (Continued)

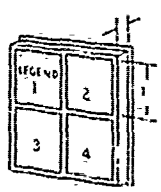
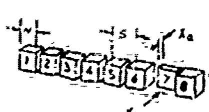
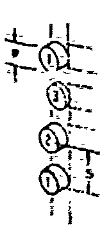
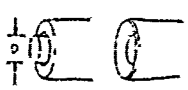
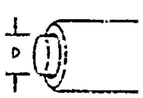
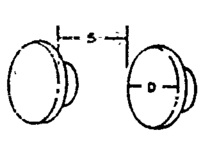
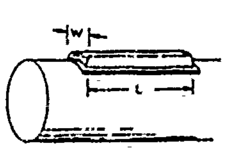
	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	MATRIX LIGHTSWITCH: ALTHOUGH TOTAL SWITCH FRONTAL AREA COULD BE MUCH SMALLER FOR ACTUATION REASONS, MINIMUMS NOTED TO THE RIGHT ARE RECOMMENDED (I.E., FOR ADEQUATE LEGEND SIZE, AND TENDENCY FOR OPERATOR TO PRESS INDIVIDUAL, DESIGNATED AREAS)	D - MINIMUM INDIVIDUAL SCREENS - 0.75" (1.9 CM) X 0.75	—	—	SAME AS ABOVE	WHEN TWO OR MORE UNITS ARE ADJACENT, MIN. SEPARATION - 0.25" (0.64 CM) (EDGE-TO-EDGE)
 	GANGED PUSH-BUTTON ASSEMBLY: SQUARE, RECTANGULAR OR ROUND SHAPES ARE ACCEPTABLE. DEPRESSION OF ANY BUTTON SHALL CAUSE ANY PREVIOUSLY DEPRESSED BUTTON TO RETURN TO DEACTIVATED POSITION. NUMBERED BUTTONS SHALL PROGRESS AS ILLUSTRATED.	W OR D MIN. = 0.375" (0.95 CM) (0.5" FOR GLOVES)	—	—	X_a - MIN EXPOSURE WHEN DEPRESSED = 0.125" (0.32 CM) X_b - MIN DEPRESSION TO ACTIVATE = 0.125" (PREFERRED = 0.1875" (0.48 CM)). NOTE: MAX DISPLACEMENT SHALL NOT EXCEED 0.5"	S - CTR-CTR SPACING MIN = 0.75" (1.9 CM) (1.0" FOR GLOVES)

Table ____ - Push Button Switches (Continued)

	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	HANDLE, END-MOUNTED, PUSH BUTTON SWITCH:					
	INDEX FINGER-OPERATED. RECESS TO PRECLUDE INADVERTENT OPERATION.	D = MINIMUM DIAM = 0.385" (0.98 CM)	—	—	SAME AS ABOVE	N/A
	THUMB-OPERATED	D - MIN = 0.5" (1.3 CM)	—	—	SAME AS ABOVE	N/A
	ALTERNATE FINGER OR HEEL OF THE HAND OPERATION. CONVEX SURFACE DESIRABLE	D - MIN = 1.0" (2.54 CM)	—	—	SAME AS ABOVE	S - MIN FOR PALM OPN = 3.0" (7.6 CM)
	GRIP HANDLE SWITCH ALTERNATE MULTI-FINGER OR PALM OPERATION	W - MIN = 0.25" (0.64 CM)	L - PREFERRED MIN = 1.0" (2.54 CM)	—	SAME AS ABOVE	N/A

ORIGINAL REQUIREMENT	MFI COMMENTS
5.4.3.1.3 Keyboards -	
5.4.3.1.3.1 Application - Arrangements of push buttons in the form of keyboards should be used when alphabetic, numeric or special function information is to be entered into a system.	
5.4.3.1.3.2 Layout and Configuration - The key configuration and the number of keys are directly dependent upon the predominant type of information to be entered into the system. The major forms that keyboards can take, which aid in the entry of such information, are given below:	Too simplistic to cover issues of typewriter vs calculator vs communication keyboards.
a. Numeric Keyboard: The configuration of the keyboard which shall be used to enter solely numeric information should be a 3 x 3 + 1 matrix with the zero digit centered on the bottom row.	No reason for restriction of "0" to a center position; doesn't cover an "Enter" or other typical calculator keysets.
b. Alpha-Numeric Keyboard: Keyboard configurations for applications which require the entry of alphabetic and some numeric information shall conform to MIL-STD-1280. For some applications the entry of data varies from primarily alphabetic to primarily numeric. For these applications two alternatives are suggested. The first being to provide a keyboard of the type shown in Figure 2, page 16, of MIL-STD-1280 (where there is no separation between alphabetic and numeric characters); and the second to provide a separation to emphasize the two separate functions, with the numeric keyboard located to the right of the standard keyboard.	
5.4.3.1.3.3 Dimensions, Resistance, Displacement, and Separation - The control dimensions, resistance, displacement and separation between adjacent edges of the pushbuttons which form keyboards shall conform to the criteria in Table IX. For a given keyboard these criteria shall be uniform for all individual keys. For those applications where operation while wearing (trigger finger) arctic mittens is required, the minimum key size shall be 0.75 inch (19 mm). Other parameters are unchanged from those of bare-handed operation (see Table IX).	Table IX too restrictive for many acceptable keyboards, i.e., it is push button-oriented.
5.4.3.1.3.4 Slope - All nonportable keyboards should have a slope of between 15 and 25 degrees. The preferred slope is 16 to 17 degrees. The slope of a portable device can be varied according to the preference of the operator.	Index finger operations can be all the way from horizontal to vertical. Height of keyboard important - not addressed here!

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.3.1.3 Keyboards, Keypads, Keysets and Menu Selectors 5.4.3.1.3.1 Applications - a. Alphanumeric keyboards with standard typewriter key configurations should be used for applications where a general-purpose entry requirement cannot be satisfied by numeric entries alone, by smaller keysets with either dedicated or programmable keys, or by menu selection techniques.	In many systems most control function are exercised through keyboards, keypads, keysets, or menu selection devices. This section covers these devices with respect to: configuration; dimensions, displacement, and separation; mounting; actuating force; feedback; and function control
b. Keypads (decimal entry keysets) should be used for applications requiring frequent entry of decimal digits, whether as data or as numeric codes. c. Keysets with each key dedicated to a specific switching function should be used whenever the number of switching functions is manageable and need not change with time or operational condition. d. Multi-function (programmable) keysets offering means of changing the switching function of individual keys should be utilized whenever switching requirements vary substantially for different phases or modes of operation and the total number of functions to be switched cannot be conveniently handled by dedicated keys. e. Menu selection techniques which provide for display and selection of switchable states on a CRT may be used as an alternate to the multi-function keyset. 5.4.3.1.3.2 Keyboards (alphanumeric keysets in typewriter configuration) 5.4.3.1.3.2.1 Configuration - Keyboard configurations shall be of the QWERTY arrangement and shall conform to MIL-STD-1280. Key action shall be of the momentary contact type.	This applications section makes a differentiation between the uses of different types of key entry devices.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.3.1.3.2.2 Dimensions, Displacement, and Separation - The control dimensions, displacement and separation between adjacent edges of the push buttons which form keyboards shall conform to the criteria in Table IX. For a given keyboard these criteria shall be uniform for all individual keys.	
5.4.3.1.3.2.3 Mounting - The keyboard should be mounted so that it is directly in front of the operator when it is in use. The first row of keys should be between 23 cm (9 in.) and 30 cm (12 in.) above the seat level and the tiers of keys should slope upward toward the back at an angle between 10° and 30° from the horizontal (17° preferred). See Figure_____.	Includes height above seat level. Broadens the acceptable range of slopes.
5.4.3.1.3.2.4 Actuating Force - The force required for key actuation should fall in the range between 0.25 N (0.9 oz.) and 1.5 N (5.3 oz.)	Ref: Boeing Co., Design Handbook for Imagery Interpretation Equipment, 6.2-15.
5.4.3.1.3.2.5 Feedback - Feedback shall be provided to inform the operator whether or not: (1) the pressed key was, in fact, actuated, (2) the intended key selection was the one which was made, and (3) an entire message or message segment is ready for the next operation (e.g., filing, transmission, computer storage, etc.).	Presents essential requirements with respect to feedback.
5.4.3.1.3.2.6 Function Control - In complex systems when the keyboard serves multiple functions, convenient means of switching keyboard function and indicating keyboard state shall be provided. Keyboard functions which may need to be independently selectable include: a. Posting of data or instructions on a display prior to release to the central processor. b. Composing and posting message text prior to its release. c. Editing posted data or text material. d. Directly entering data or instructions to a computer.	Takes account of the multi-purpose usage of many keyboard installations.

TABLE IX. KEYBOARDS

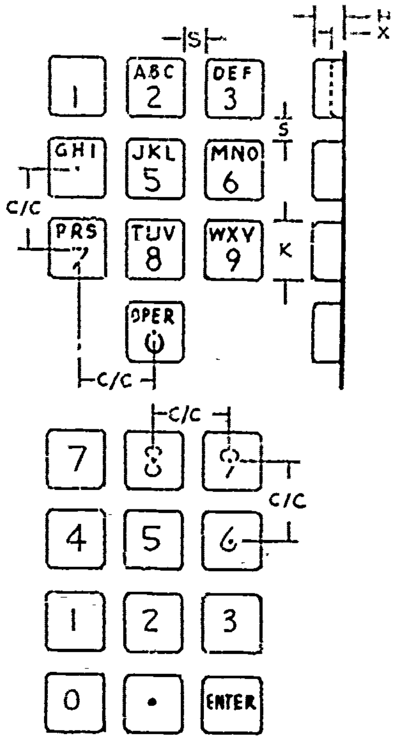
	Dimensions Diameter D*		Resistance		
	Bare-handed	Arctic mittens**	Numeric	Alpha-numeric	Dual Function
Minimum	0.385"	0.75"	3.5 oz	0.9 oz	0.9 oz
Maximum	0.75"		14.0 oz	5.3 oz	5.3 oz
Preferred	0.5"	0.75"			

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

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

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

*See Figure 9
**Trigger finger type



TELEPHONE:

K - Key Size = 0.375-in (0.95 cm)
S - Separation = 0.25-in (0.6 cm)
H - Height = 0.25-in (0.6 cm)
X - Depressed Extension = 0.62-in (0.16 cm)
C/C - Center/Center Spacing = 0.656-in (1.67 cm)

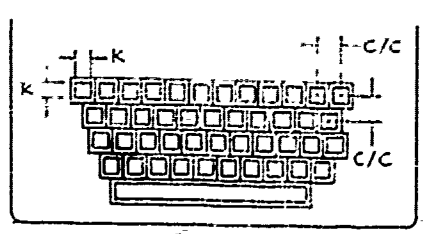
NUMERIC:

C/C - Center/Center Spacing = 0.75-in (1.9 cm)

Note: For other dimensions refer to Table____ for single finger push buttons.

TYPEWRITER:

K - Key Size = 0.50-in (1.27 cm)
C/C - Center/Center Spacing = 0.75-in (1.9 cm)
D - Displacement = 0.187-in (0.47 cm) for electric; 0.625-in (0.16 cm) for typical manual machine.



A - Varies widely; preferred slope is between 16-17°.

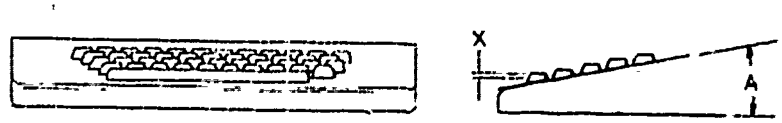


Figure ____ - Nominal Keyboard Characteristics

MFI RECOMMENDED MODIFICATION

5.4.3.1.3.3 Keypads (Decimal Entry Keysets)

5.4.3.1.3.3.1 Configuration - Two different key configurations shall be utilized as follows. (Keys in both are of the momentary contact type.) See Figure_____.

a. For telephone use or any communications addressing function, the push-button telephone configuration shall be used. (This is a 3 x 3 + 1 configuration, with the top row consisting left to right of the numerals 1, 2, and 3; the second row, 4, 5, and 6; the third row, 7, 8, and 9; and the zero is centered under the bottom row.)

b. For entry of data or coded instructions the calculator configuration shall be used. (This is a 3 x 3 + 1 configuration with the top row consisting left to right of the numerals 7, 8, and 9; the second row, 4, 5, and 6; the third row, 1, 2, and 3; and the zero is under the bottom row.) In the event the telephone configuration as well as this configuration is used in the same piece of equipment, the two configurations shall be made distinctively different in appearance from one another.

5.4.3.1.3.3.2 Dimensions, Displacement, and Separation - Telephone-type keypads may be of the commercially-available type unless otherwise specified. Dimensions, displacement and separation of other keypads shall conform to those for commercial push button phones, except as follows.

a. Displacement may be less or zero if touch-activated switches with appropriate feedback are used.

b. Key size, separation, and displacement shall be as indicated in Table IX if heavy gloves or mittens are to be worn by users.

5.4.3.1.3.3.3 Mounting - Keypads may be mounted wherever they are conveniently available for use. Keypads requiring frequent use should be mounted in a preferred location for controls such as a desk top and should be sloped as is required for keyboards (paragraph 5.4.3.1.2.2.3).

RATIONALE/REFERENCES

5.4.3.1.3.3.1 Here is an item which should receive careful attention in the future. Because two different configurations (telephone and calculator) are already in extensive use, we are recommending that for the time being both configurations continue to be used. We don't think this is a good long-term solution, since many equipments might have both configurations and thus introduce higher error rates. In the long run we think that either the telephone configuration or a 5 x 2 configuration should be adopted, and hopefully calculator manufacturers would follow suit. (We have already seen some examples of the telephone configuration is non-communications systems.) Research shows the telephone configuration to be superior to the calculator configuration, but we have not yet seen any solid data on a 5 x 2 configuration which we feel might turn out better than either of the other two.

5.4.3.1.3.3.2 Allows the touch-actuated key if appropriate feedback and key separation is provided.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.3.1.3.3.4 Actuating Force - The actuating force required for keypads shall fall in the range of 0.25 N (0.9 oz.) to 3.9 N (14.0 oz.). (This actuating force range does not apply to touch-activated keypads.) The larger actuating forces should be used where the user wears gloves or mittens, or is subjected to substantial vibration or acceleration.	
5.4.3.1.3.3.5 Feedback - Feedback shall be provided to inform the operator whether or not: (1) the pressed key was, in fact, actuated, (2) the intended key selection was the one which was made, and (3) the entire number set as posted is ready for the next operation (e.g., a computational process, transfer to the computer as data, etc.)	Clarifies the various requirements for feedback.
5.4.3.1.3.3.6 Function Control - Switches for control functions shall be provided as needed for the particular application. Separate clearing functions shall always be provided to allow clearing either (1) only the last posted digit, or (2) all posted digits.	
5.4.3.1.3.4 Dedicated Keysets	
5.4.3.1.3.4.1 Configuration - A dedicated keyset consists of an array of keys or push buttons individually labeled with fixed functional meanings and with a commonality of purpose, such as entry of instructions to a computer. (Dedicated keysets are special-purpose devices whereas keyboards and keypads are inherently general-purpose.) As best fits the purpose, key action may be momentary contact or latching, and key tops may (1) be opaque, (2) contain an indicating lamp, (3) provide a continuously illuminated label, (4) provide an illuminated label when activated, or (5) provide both (3) and (4). The functions and physical configuration of the push buttons in the keyset shall be appropriate to the switching functions it must handle and to the operator's task. (See paragraph 5.4.3.1.1 and Table_____.)	Brings greater specificity to dedicated keysets. (Professional judgment.)
5.4.3.1.3.4.2 Dimensions, Displacement, and Separation - Dedicated keysets which do not utilize switchcap labels shall conform to the dimensionsl requirements for keyboards in Table IX; those which do use switchcap labels shall conform to the requirements for legend switches (paragraph 5.4.3.1.1). (The displacement requirements do not apply to touch-actuated switches.)	

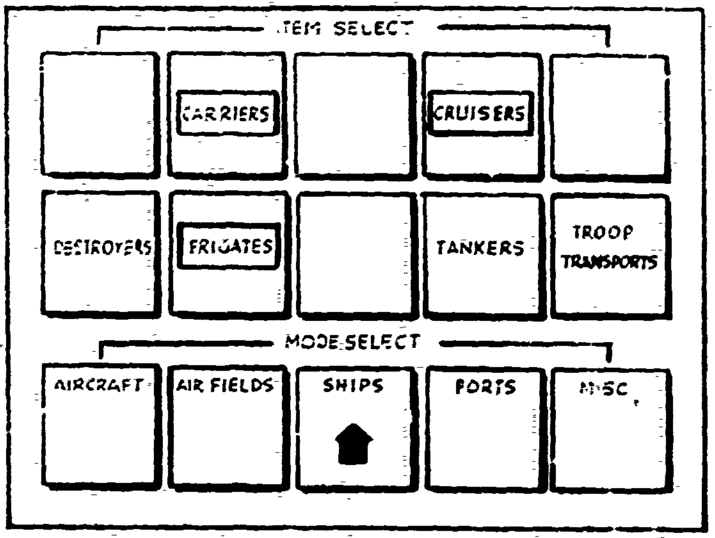
MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.3.1.3.4.3 Mounting - Dedicated keysets may be mounted wherever they are conveniently available for use.	
5.4.3.1.3.4.4 Actuating Force - The actuating force required for dedicated keysets shall fall in the range of 0.25 N (0.9 oz.) to 11.3 N (40 oz.). The larger actuating forces should be used only with large-size illuminated switchcaps, 2.5 cm (1 inch) wide or larger which may be needed to accommodate switchcap labeling. The preferred actuating force for push buttons which can be mounted on 2.0 cm (0.75 in.) centers is about 2.8 N (10 oz.).	
5.4.3.1.3.4.5 Feedback - Feedback shall be provided to inform the operator whether or not: (1) the pressed key was, in fact, actuated, (2) the intended key selection was the one which was made (3) the system is in the process of responding to the actuated key, and (4) the system has completed its response to the actuated key.	
5.4.3.1.3.4.6 Function Control - Switches for control functions governing operation of the keyset shall be provided as needed for the particular application.	
5.4.3.1.3.5 Multi-Function (Programmable) Keysets 5.4.3.1.3.5.1 Special Requirements - Multi-function keysets require instrumentation for accommodating switching at two levels: (1) a gross function, or mode level and (2) a detailed, or item level within each mode.	This is completely new material which is very much needed because of the widespread utilization of multi-function keysets. (Based on professional judgment and experience.)
a. Function (or mode) selection. The amount of selection capability shall be dependent upon the number of different sets of switching functions to be used alternatively. The mechanization of the function selectors should ordinarily by rotary selector or by interlocked push buttons with latching actuation. The complete range of choices as well as the current mode indication should be visible to the operator at all times, except in those instances where function selectors are implemented by entry of coded switching instructions using a general-purpose keyboard. (Mode switching may also be implemented for initiation by the computer, in which case manual switching capability can be correspondingly reduced.)	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
b. Switching for item selection. The amount of selection capability shall be dependent upon the number of switching actions which must be independently controllable. Item selection should be provided by push buttons of the appropriate types (latching or momentary; interlocked or independent) for the specific switching functions.	
c. Item labeling and feedback. Item labels applicable to each mode shall be displayed on or adjacent to the item selector switches, and labels which are inapplicable to the selected mode shall not be visible. Appropriate feedback shall be provided to indicate the current state of each item selector switch. When switching to a new mode, feedback shall be provided as to the current state of each switchable function. In addition, feedback may be needed to indicate which switches can or cannot be utilized in the current mode (i.e., by extinguishing labels for switching functions which are inapplicable).	
5.4.3.1.3.5.2 <u>Configuration</u> - The physical configuration of the keyset shall be appropriate to the switching functions it must handle and to the operator's task. A sample configuration is shown in Figure____.	
5.4.3.1.3.5.3 <u>Dimensions, Displacement, and Separation</u> - The push button switches used in multi-function keysets shall conform to the dimensional requirements for push buttons (paragraph 5.4.3.1.1.2) as applicable.	
5.4.3.1.3.5.4 <u>Mounting</u> - Multi-function keysets may be mounted wherever they are conveniently available for use.	
5.4.3.1.3.5.5 <u>Actuating Force</u> - The actuating force for the push buttons in multi-function keysets shall fall in the range of 0.25 N (0.9 oz.) to 11.3 N (40 oz.). The larger actuating forces should be used only with large-size illuminated switchcaps 2.5 cm (1 inch) wide or larger which may be needed to accommodate switchcap labeling. The preferred actuating force is about 2.8 N (10 oz.).	Professional judgment and experience. General agreement by reviewers.
5.4.3.1.3.5.6 <u>Feedback</u> - Feedback shall be provided per paragraphs 5.4.3.1.3.4.6 and 5.4.3.1.3.5.1.	

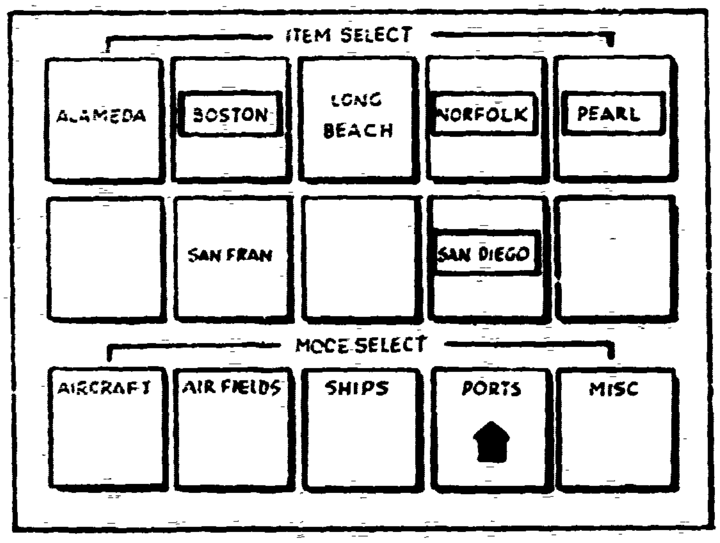
Item Selectors (e.g., push button switches with (multiple) projected legends

Function or Mode Selectors (e.g., split-half push buttons)

*Note: Borders are projected around items that have been selected (feedback information



Example 1
(Ships Mode)

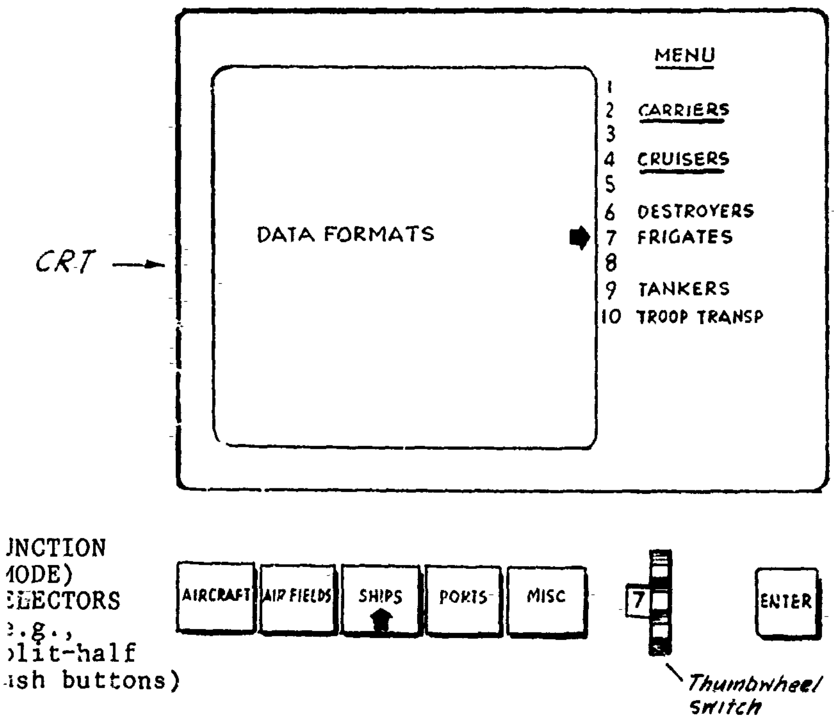


Example 2
(Ports Mode)

Figure ____ - Multi-Function Keyset Format Examples

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.3.1.3.6 Menu Selectors 5.4.3.1.3.6.1 Special Requirements - Menu selectors require control at three levels: (1) Function-level switching to select which one out of the set of menu listings is presented on the display, (2) a control for selection of a particular item from the menu, and (3) a control for entry or activation of the selected menu item. The function selector should be instrumented as in paragraph 5.4.3.1.3.5.1a. Selection of the menu item may be by means of a cursor controlled by push buttons, a thumbwheel, light pencil, or grid/stylus type device. The entry instruction itself should be implemented as a separate momentary-contact switch. 5.4.3.1.3.6.2 Configuration - The physical configuration of menu selector controls and displays shall be appropriate to the switching functions it must handle and to the operator's task. Two sample configurations are shown in Figure_____. 5.4.3.1.3.6.3 Dimensions, Displacement, and Separation - The push button switches shall conform to dimensional requirements for legend swtiches (paragraph 5.4.3.1.1.2). Thumbwheel control if used shall conform to 5.4.2.1.3 or 5.4.2.2.1.8. Menu labels shall conform to size and style in paragraph 5.5.5. 5.4.3.1.3.6.4 Mounting - The cursor control (e.g., thumbwheel or keypad) should be mounted beneath the menu listing. The ENTER button should be close to and preferably to the right of the cursor control. The function (mode) selectors should be mounted conveniently near the cursor control. 5.4.3.1.3.6.5 Actuating Force - Actuating force for push buttons and thumbwheel control shall fall within ranges specified in paragraphs 5.4.3.1.3.5.5 and 5.4.2.2.1.8.4 respectively. 5.4.3.1.3.6.6 Feedback - Feedback shall be provided per paragraphs 5.4.3.1.3.4.6 and 5.4.3.1.3.5.1. Some readily apparent means of differentiating selected menu items from non-selected items, such as underlining shall be employed.	The topic of "menu selectors" is new and deserves special attention because of growing utilization of such techniques. The topic is in the controls section rather than under CRT because the technique is an alternative to use of the multi-function keyset.

Cursor at #7, selected by thumbwheel



Press of ENTER will draw line under FRIGATES and enter it

As the 3 button is pressed cursor appears on LONG BEACH

When ENTER is pressed, cursor will disappear and LONG BEACH wll be under-lined and entered

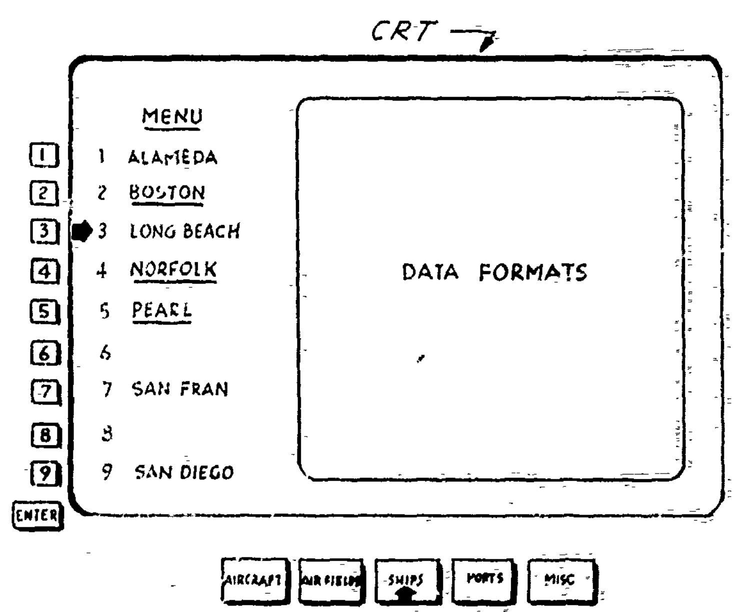
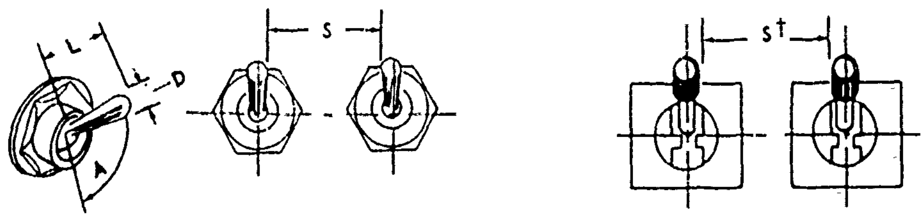


Figure ____ - Menu Selector Types and Format Examples

ORIGINAL REQUIREMENT	MFI COMMENTS
5.4.3.1.4 Toggle Switch Controls -	
5.4.3.1.4.1 Application - Toggle switches should be used for functions which require two discrete positions or where space limitations are severe. Toggle switches with three or more positions shall be used only where the use of a rotary control, legend switch control, etc., is not feasible or when the toggle switch is of the spring-loaded, center-position-off type. (Toggle switches are considered herein to be discrete position controls. Small controls that are the same size and shape as toggle switches and used for making continuous adjustments are described herein as levers.)	Idea of a toggle taking less space than small push buttons or other switch types is hard to defend. Statement also implies these others should not be used for two-position functions.
5.4.3.1.4.2 Accidental Activation - When the prevention of accidental activation is of primary importance (i.e., critical, dangerous or hazardous conditions would result), channel guards, lift-to-unlock switches, or any other equivalent means will be provided. Safety or lock wire shall not be used.	Last statement does not seem necessary - who does this today?
5.4.3.1.4.3 Dimensions, Resistance, Displacement, and Separation - Dimensions, resistance, displacement, and separation between adjacent edges of toggle switches shall conform to the criteria in Figure 11.	
5.4.3.1.4.4 Resistance - Resistance should gradually increase, then drop when the switch snaps into position. The switch shall not be capable of being stopped between positions.	
5.4.3.1.4.5 Orientation - Toggle switches should be vertically oriented with OFF in the down position. Horizontal orientation and actuation of toggle switches shall be employed only for compatibility with the controlled function or equipment location.	"Vertically-oriented" is not clear.



	DIMENSIONS			RESISTANCE	
	L Arm Length *	**	D Control Tip	Small Switch	Large Switch
Minimum	0.5" (13mm)	1.5" (38mm)	0.125" (3mm)	10 oz (2.8N)	10 oz (2.8N)
Maximum	2.0" (50mm)	2.0" (50mm)	1.0" (25mm)	16 oz (4.5N)	40 oz (11N)

	DISPLACEMENT A	
	2 Position	3 Position
Minimum	30 deg	18 deg
Maximum	120 deg	60 deg
Desired	...	25 deg

	SEPARATION S			
	Single Finger Operation	†	Single Finger Sequential Operation	Simultaneous Operation by Different Fingers
Minimum	0.75" (19mm)	1.0" (25mm)	0.5" (13mm)	0.625" (16mm)
Optimum	2.0" (50mm)	2.0" (50mm)	1.0" (25mm)	0.75" (19mm)

*Use by bare finger **Use by gloved finger †Using a lever-lock toggle switch

Figure 11. TOGGLE SWITCHES

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.3.1.4 Toggle Switch Controls	
5.4.3.1.4.1 Application - Toggle switches may be used for functions which require two discrete positions. They may also be used for three discrete positions but a rotary selector or push button array is usually preferred for this application.	Allows use of toggle switches but does not give them preference over other types of controls for the same function.
5.4.3.1.4.2 Prevention of Accidental Activation - When the prevention of accidental activation is of primary importance (i.e., critical, dangerous or hazardous conditions would result), channel guards, lift-to-unlock switches, or any other equivalent means shall be provided.	
5.4.3.1.4.3 Dimensions, Displacement and Separation - Dimensions, displacement, and separation between adjacent toggle switches shall conform to the criteria in Table____.	Displacement requirements were relaxed in some instances on basis of professional judgment.
5.4.3.1.4.4 Actuating Force - Except for the case of a three-position, spring-centering switch, toggle switches should "snap" into position, with an audible "click" to provide positive feedback that the switch has been activated properly. The force requirement should gradually increase with displacement then drop as the switch snaps into position. The switch shall not be capable of being stopped between positions. The range of actuating force shall be between 2.8 N to 11 N (10 to 40 ounces) depending on the length of the switch handle.	
5.4.3.1.4.5 Switch Orientation - Toggle switches used for ON-OFF functions shall be oriented so that the handle moves in a vertical plane unless there is a special requirement for the switch to move laterally (i.e., due to a lack of panel space, to reflect a left-to-right relationship to some display, etc.). The ON position shall be up, forward, or to the right. When toggle switches are located on panels that slope as in "wrap-around" or "stacked" workplace arrangements, switch orientation and movement shall conform to criteria in Figure____.	Clarifies orientation relationships.

Table ____ - Toggle Switches

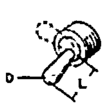
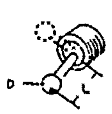
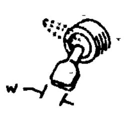
	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	MINIATURE TOGGLE SWITCH: LIMIT USE TO INDOOR APPLICATIONS WHERE LIMITED PANEL SPACE PRECLUDES STD SIZE COMPONENTS.	D - MIN DIAM = 0.125" (0.32 CM)	L - MIN LENGTH = 0.5" (1.27 CM)	—	—	—
	STANDARD CONFIGURATION: USE LARGER SIZES FOR APPLICATIONS WHERE GLOVES OPERATION IS LIKELY.	D - MIN DIAM = 0.1875" (0.48 CM), MAX = 0.3125" (0.79 CM)	L - MIN LENGTH = 0.44" (1.12 CM) TO 1.0" (2.54 CM)	—	—	—
	BALL CAP DESIGN APPLICABLE WHERE FIRM GRASP OF TOGGLE IS NEEDED (DUE TO VEHICLE/OPERATION OSCILLATION).	D - MIN BALL DIAM = 0.1875" (0.48 CM) MAX = 0.3125" (0.79 CM)	SAME AS ABOVE	—	—	—
	FLAT OR APPLIED TAB HANDLES PROVIDE IMPROVED VISUAL POSITION REFERENCE WHEN OPERATIONALLY IMPORTANT.	—	—	W - MIN HANDLE WIDTH = 0.1875" (0.48 CM)	—	—
	APPLIED TAB HANDLE PROVIDES MEANS FOR COLOR CODING.	—	L - 0.375" (0.95 CM) PREFERRED & MIN; MAX = 1.0"	W - 0.375" (0.95 CM) PREFERRED (MIN = 0.1875", MAX = 0.75").	—	—
	ALTERNATE TO ANY STD SIZE CONFIGU- TION ABOVE.	—	SAME AS ABOVE	SAME AS ABOVE	—	—

Table _____ - Toggle Switches (Continued)

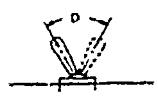
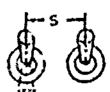
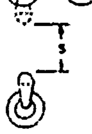
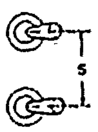
	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	TWO-POSITION SWITCHES ONLY WHEN VISUAL RECOGNITION OF SWITCH POSITION MANDATORY.	—	—	—	D - DISPLACEMENT ANGLE MIN. = 25° PREFERRED	—
	THREE-POSITION SWITCHES.	—	—	—	D - DISPLACEMENT MIN = 17° PREFER - 25°	—
	SIDE BY SIDE ARRANGEMENT VERTICAL DISPLACEMENT.	—	—	—	—	S - CTR-CTR* MIN = 0.75" (1.9 CM) MAX FOR SIMULTANEOUS, MULTI-FINGER USE = 1.25" (2.86 CM)
	TIP TO TIP SEPARATION	—	—	—	—	S - MIN = 1.0"* (2.54 CM)
	VERTICAL ARRAYS	—	—	—	—	S - MIN = 1.0"* (2.54 CM)
						*NOTE: ADD 0.5" FOR GLOVES

Table _____ - Toggle Switches (Continued)

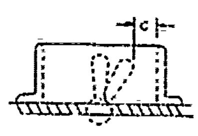
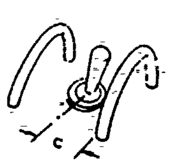
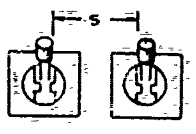
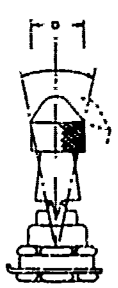
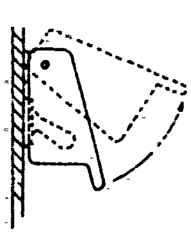
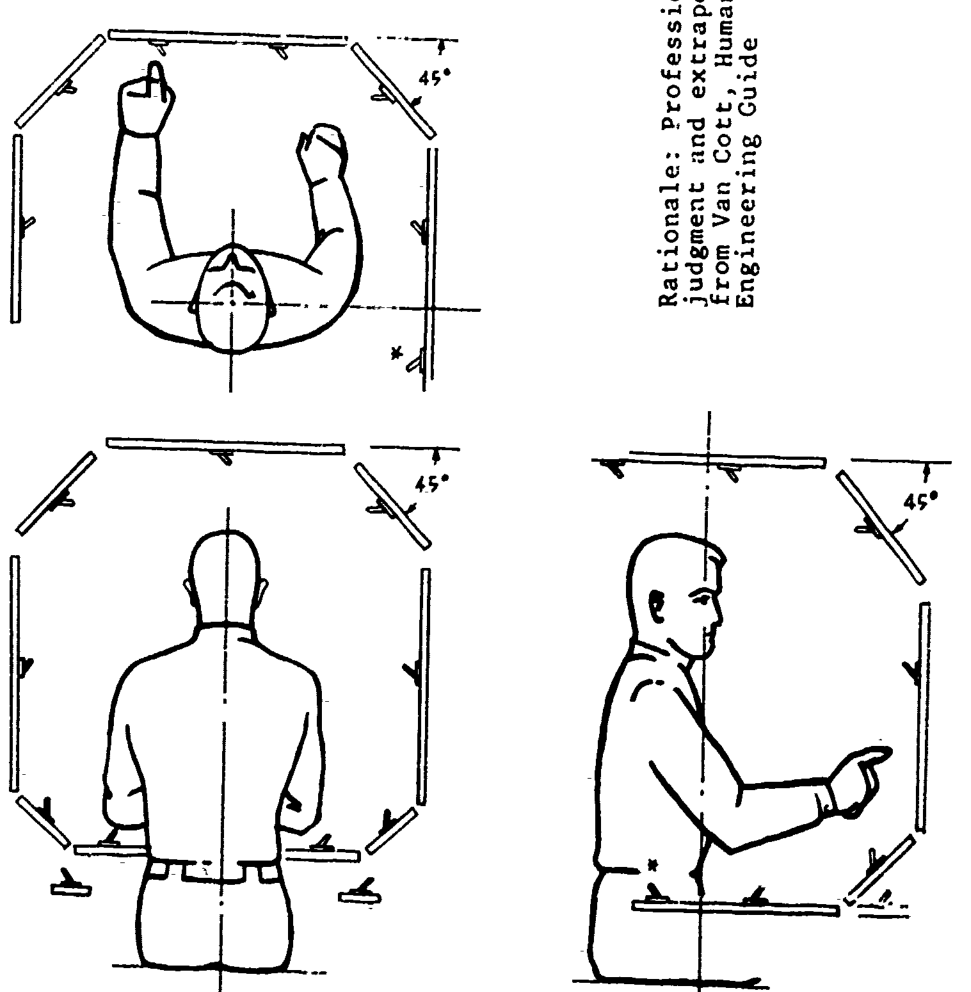
	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	GUARD SWITCHES WHERE ACCIDENTAL DISPLACEMENT OF A SWITCH MAY BE UNDESIRABLE (NOT NECESSARILY DANGEROUS)	C - TIP-GUARD FINGER CLEARANCE = MIN. 0.5" (1.3 CM)	—	—	—	—
		—	C - MIN = 1.0" (2.54 CM), 1.24" FOR GLOVES	—	—	—
	USE TWO-MOTION SAFETY SWITCH WHEN SWITCH-USE ERROR COULD LEAD TO DANGEROUS CONSEQUENCE. (PULL TO OPERATE)	—	—	—	—	S - MIN = 1.0" (2.54 CM) (2.0 PREFERRED) ADD 0.5" FOR GLOVES.

Table ____ - Toggle Switches (Continued)

	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	TYPICAL TWO-STEP INTERLOCKING SAFETY SWITCH.	D - MIN = 0.375" (0.95 CM) MAX = 0.625" (1.59 CM)	—	—	—	SHOULD NOT BE CLOSER THAN 2.0" (5.0 CM) TO OTHER CONTROL OR STRUCTURE.
	ALTERNATE COVER GUARD SWITCH. COVER EASILY COLOR-CODED. NOT APPLICABLE FOR MINIATURE TOGGLES.	—	—	—	—	MAY BE SPACED (HORIZ) AS CLOSE AS 0.5" (1.3 CM), 1.0" FOR GLOVES.

Rationale: Professional judgment and extrapolation from Van Cott, Human Engineering Guide

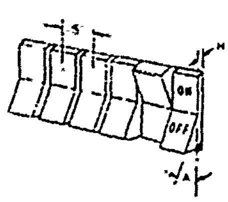
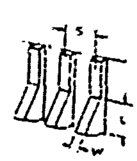
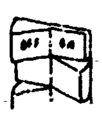
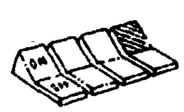


* Generally avoid this area aft of operator's eye ref., but when used treat as though operator is facing to the right.

Figure ____ - Toggle Switch Orientation for 'ON'

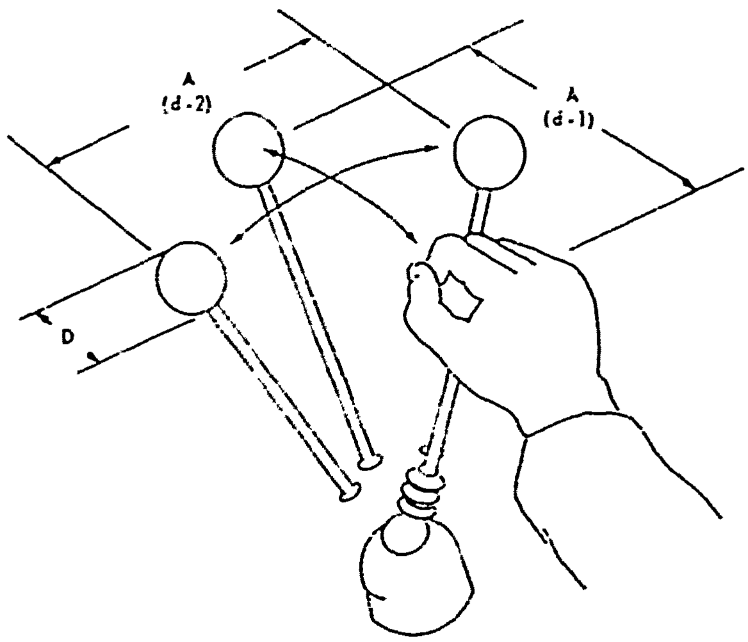
MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.3.1.5 Rocker Switch Controls 5.4.3.1.5.1 Application - Rocker switches may be used for functions which require two discrete positions, as an alternate to toggle switches. They should be considered for applications where the toggle switch handle protrusion might snag the operator's sleeve or phone cord, or, where there is insufficient panel space for separate labeling of switch positions. (Rocker switches are somewhat vulnerable to accidental operation by brushing-type contacts, however.)	Rocker switches are common these days and were not covered in the original document at all.
5.4.3.1.5.2 Dimensions, Displacement and Separation - Dimensions, displacement and separation betwenen adjacent rocker switches shall conform to the criteria in Table____.	Professional judgment.
5.4.3.1.5.3 Actuating Force - The switch should "snap" into position, with an audible "click" to provide positive feedback that the switch has been activated properly. The force required should gradually increase with displacement, then drop as the switch snaps into position. The switch shall not be capable of being stopped between positions. The range of actuating forces shall be between 2.8 N to 11 N (10 to 40 ounces). 5.4.3.1.5.4 Orientation - Rocker switches used for ON-OFF functions shall be oriented so that the handle moves in a vertical plane, except in special cases where a lateral motion is to be related to a right-left display relationship. The ON position shall be up, forward, or to the right. Three-position rocker swtiches shall not be used. 5.4.3.1.5.5 Color and Illumination - Alternate colors may be used to denote the ON and OFF portions of a rocker switch. Alternate illumination of either the ON or OFF switch position may be used to provide positive recognition of which position the switch is in. For other color coding considerations, see 5.2.2.1.18.	

Table ____ - Rocker Switches

	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	STANDARD ROCKER SWITCH: USE AS ALTERNATE TWO-POS'N TOGGLE SWITCH TO PROVIDE LABELING SURFACE, EASE OF COLOR COPING, SWITCH ILLUMINATION.	—	—	—	H - HEIGHT DEPRESSED MIN = 0.125" (0.32 CM) A - ANGLE = 30" MIN.	S - CTR-CTR SEPARATION MIN = 0.75" (1.9 CM) (ADD 0.5" FOR GLOVES).
	NARROW WIDTH, ESPECIALLY DESIRABLE FOR TACTILE DEFINITION WITH GLOVES.	W - MIN = 0.25" (0.64 CM)	L - MIN = 0.5" (1.27 CM)	—	SAME AS ABOVE	SAME AS ABOVE
		—	—	—	—	S - MIN = 1.0" (2.54 CM)
	ALTERNATE (CONTRAST) COLOR FOR ON VS OFF TO PROVIDE CONSPICUOUS CUE OF SWITCH POSITION. ILLUMINATED "ON" DESIRABLE AS SECOND FEEDBACK CUE.	—	—	—	—	—

ORIGINAL REQUIREMENT	HFI COMMENTS
5.4.3.2.1 Levers -	This section omits many requirements which should be stated for levers.
5.4.3.2.1.1 Application - Levers may be used when large amounts of force or displacement are involved or when multidimensional movements of controls are required.	Applications statement not sufficiently comprehensive.
5.4.3.2.1.2 Coding - When several levers are grouped in proximity to each other, the lever handles shall be coded.	Not all closely-grouped levers should be coded.
5.4.3.2.1.3 Labeling - When practicable, all levers shall be labeled as to function and direction of motion.	
5.4.3.2.1.4 Limb Support - When levers will be used to make fine or continuous adjustments, support shall be provided for the appropriate limb segment as follows: a. For large hand movements: elbow b. For small hand movements: forearm c. For finger movements: wrist.	
5.4.3.2.1.5 Dimensions - The length of levers shall be determined by the mechanical advantage needed. When the lever or grip handle is spherical, its diameter shall conform with Figure 13.	
5.4.3.2.1.6 Resistance - The resistance incorporated in levers shall be within the limits indicated in Figure 13 measured as linear force applied to a point on the handle. NOTE: The right hand can apply slightly more force than the left, but the difference is not significant. The same amount of push-pull force can be applied when the control is along the median plane of the body as when it is directly in front of the arm, 7 inches (180 mm) from the median plane. When the control is placed in front of the opposite (unused) arm only 75 percent as much force can be applied. When the control is 10 to 19 inches (250 to 480 mm) forward of the neutral seat reference point, twice as much push-pull force can be applied with two hands as with one-hand operation. Outside this range two-hand operation becomes less effective.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.4.3.2.1.7 Elastic Resistance - For joystick controls, elastic resistance which increases with displacement may be used to improve "stick feel". 5.4.3.2.1.8 Displacement and Separation - Control displacement (for the seated operator) and separation shall conform to the criteria in Figure 13.	



	DIAMETER D: Finger Grasp	DIAMETER D: Hand Grasp	RESISTANCE (d-1): One Hand	RESISTANCE (d-1): Two Hands	RESISTANCE (d-2): One Hand	RESISTANCE (d-2): Two Hands
Minimum	0.5" (13mm)	1.5" (38mm)	2 lb (9N)	2 lb (9N)	2 lb (9N)	2 lb (9N)
Maximum	3.0" (75mm)	3.0" (75mm)	30 lb (135N)	50 lb (220N)	20 lb (90N)	30 lb (135N)

	DISPLACEMENT A: Forward (d-1)	DISPLACEMENT A: Lateral (d-2)	SEPARATION: One Hand Random	SEPARATION: Two Hands Simultaneously
Minimum	-		2.0" (50mm)	3.0" (75mm)
Preferred			4.0" (100mm)	5.0" (125mm)
Maximum	14.0" (360mm)	38.0" (970mm)		

Figure 13. LEVER

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.3.2.1 Levers	This section covers lever applications in a more comprehensive way.
5.4.3.2.1.1 Application - Lever-type controls may be used when large force or displacement is involved, as an alternate control interface for electrical switching when it may be more cost-effective to provide direct mechanical linkage between the control and controlled element, or when multidimensional, mechanical or electro-mechanical, multi-stage control modes are required (e.g., gear shift). Lever-type controls should not be used where very precise electrical outputs are required (i.e., in lieu of a precision electrical adjustment, where a rotary controller is mroe appropriate). Levers should be considered for the following general classes of control: a. Braking (e.g., mechanical) b. Mode Selection (e.g., environmental system) c. Gear Selection (e.g., vehicle/machine transmission) d. Gross, Continuous Adjustment (e.g., temperature, audio volume, throttle, etc.) e. Steering (e.g., joystick, tracked vehicle, etc.).	
5.4.3.2.1.2 Location, Position, Direction and Range of Movement - The location, position relative to the operator, and direction and range of lever movement shall be compatible with operator reach, mobility, natural movements and strength capabilities. In addition, direction of motion requirements noted in 5.1.3 shall be observed. When high forces are required of the operator, the lever handle shall be located between waist and shoulder levels, and the force should normally be applied in a pulling direction.	Ref: Woodson and Conover, Human Engineering Guide for Equipment Designers, 1966, p. 2-102.
5.4.3.2.1.3 Limb and Body Support - When levers will be used to make fairly precise or continuous adjustments, support shall be provided for the appropriate limb segment as follows:	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
a. For large hand movements, support the elbow. b. For small hand and wrist movements, support the forearm. c. For finger movements, support the wrist.	
5.4.3.2.1.4 Force Requirements - The forces required for movement of levers shall be within the limits indicated in Table ____ (measured as linear force applied to a point on the lever handle, and/or in conformance with criteria provided in Figure 15. For joystick controls, elastic resistance which increases with displacement may be used to improve "stick feel".)	See MIL-F-8785 (ASG).
5.4.3.2.1.5 Detents - When levers are used as "selector" controllers, mechanical detents shall be provided (in addition to panel labels or markings) to provide tactile feedback indicating that the lever is positively positioned at designated settings. Detents and panel markings shall coincide precisely.	Adds a requirement for detents.
5.4.3.2.1.6 Non-Slip Handles - Surfaces of lever handles shall provide sufficient friction (i.e., by means of the specific material used, and/or addition of serrations or knurling) to reduce the probability of the operator's hand or fingers slipping while operating the lever.	Adds a requirement for non-slip handles.
5.4.3.2.1.7 Dimensions, Displacement and Separation - Lever dimensions, displacement and separation shall conform to criteria in Table ____.	Ref: Van Cott, Human Engineering Guide to Equipment Design, 1972, pp. 369-70.
5.4.3.2.1.8 Marking and Labeling - Where appropriate, lever handles shall be marked and/or labeled for ease of positioning and identification (see 5.5).	
5.4.3.2.1.9 Coded Handles - Color and/or shape coding may be used when it is important for the operator to quickly identify and/or differentiate among critical controls or several controls that may be grouped in proximity to each other. When shape codes are used, they shall be designed so that they do not interfere with the basic requirements for ease of manipulation, and shall be free of sharp corners that could result in operator injury in the event of violent contact by the operator.	Refers to AFSC requirements for coding; prohibits sharp corners.

Table ____ - Levers

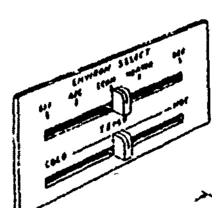
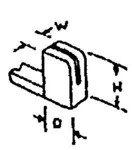
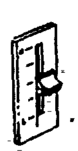
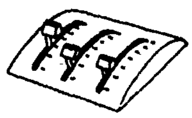
	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	SLIDE-LEVERS MAY BE USED FOR LOW-FORCE, CONTINUOUS ADJUSTMENT OR GROSS MODE SELECTION (DO NOT USE FOR PRECISE-SETTING).	—	—	—	—	—
	HANDLES SHOULD BE "TAB"-SHAPED, WITH LONG DIMENSION PERPENDICULAR TO MOTION AXIS (E.G., TO SERVE AS A POINTER).	D - MIN = 0.5" (1.3 CM) OR 0.75" (1.9 CM) WITH GLOVES	W - MIN. 0.25" (0.64 CM)	H - MIN. = 0.625" (1.59 CM)	—	S - MIN = 0.75" (1.9 CM) OR 1.0" (2.54 CM) WITH GLOVES
	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 AND OR MECHANICALLY CONNECTED SELECTOR OR ADJUSTMENT FUNCTIONS, TO PROVIDE RAPID VISUAL CHECK OF RELATED SETTINGS.	SAME AS ABOVE	SAME AS ABOVE	SAME AS ABOVE	—	SAME AS ABOVE
	NOTE: RESISTANCE FOR ABOVE CONTROL TYPES SHOULD BE; MIN - 10 OZ. (2.8 N) MAX - 40 OZ. (110 N)					

Table _____ - Levers (Continued)

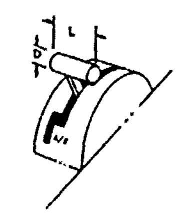
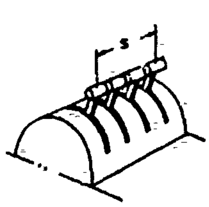
	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	THROTTLE LEVERS: HANDGRIP MAY BE EITHER CYLINDRICAL OR SPHERICAL.	D - MIN = 0.75" (1.9 CM) MAX = 1.125" (2.86 CM) D_1 - 1.50" ± 0.25" (3.8 ± 0.64 CM)	L - MIN = 2.5" (6.4 CM)	C - SAME AS ABOVE	—	2.0" (5.1 CM) MIN. FINGER CLEARANCE ALL SIDES.
	MULTI-ENGINE THROTTLE ASSY: NOTE: WHEN THRUST REVERSE IS INCORPORATED, THE DESIGN SHALL REQUIRE A SEPARATE MANIPULATIVE MOTION I.E., "LIFT" + AFT LEVER MOVEMENT.	—	—	—	—	S - TYPICAL = 4.0" (10.2 CM): NOT TO EXCEED 5.0" (12.7 CM)

Table ____ - Levers (Continued)

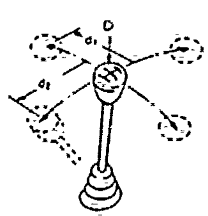
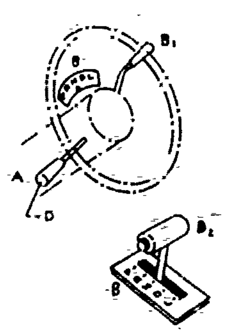
	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	GEAR-SHIFT LEVER:					
	MANUAL TRANSMISSION: LOCATE FOR RIGHT HAND OPERATION RESISTANCE: APPROX. 2-30 LB. (9-133 N)	D-KNOB DIAMETER = 1.25-	—	—	D_1 AND D_2 MIN. BETWEEN DISCRETE POS'NS = 2.0" (12.9 CM); MAX. TOTAL = 8.0" (20.32 CM)	N/A
	AUTOMATIC TRANSMISSION: (B_1 PREFERRED; B_2 ACCEPTABLE). DETENTED POS'NS RQD.* A. OTHER FUNCTIONS: 1. TURN SIG - ROTATE ABOUT COLUMN; CW = R-TURN, CCW = LEFT TURN 2. HEADLIGHT DIMMING - LEVER MOVES TOWARD BOTTOM OF COL. FOR "DIM". B. LETTERS SHALL ILLUMINATE TO INDICATE POS'N OF LEVER RESISTANCE: APPROX. 1-10 LB. (4.4-49 N) * IT SHALL BE IMPOSSIBLE TO LEAVE GEAR-LEVER BETWEEN POS'NS. SEPARATE MOTION RQD TO POSITION LEVER IN REVERSE (I.E., LIFT OR PRESS THUMB BUTTON).	D-HANDLE DIAM = 0.75"-1.25" (1.9-3.2 CM) IF CYLINDRICAL, 1.0"-1.25" IF SPHERICAL	—	C-FINGER CLEARANCE BETWEEN LEVERS AND WHEEL RIM = MIN. 2.0" (5.1 CM)	GEAR SHIFT - MIN. BETWEEN POS'NS = 1.0" (2.54 CM) FOR B_1; 1.5" (3.8 CM) RESEARCH DATA NOT AVAILABLE BUT RECOMMEND 1.0-2.0" (2.54-3.1 CM) BETWEEN DETENTS.	

Table _____ - Levers (Continued)

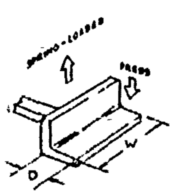
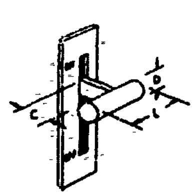
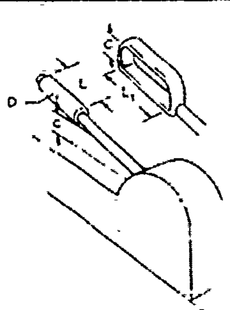
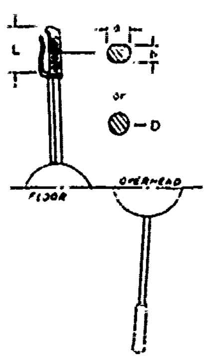
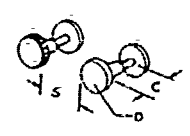
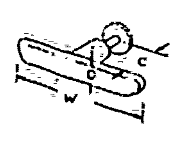
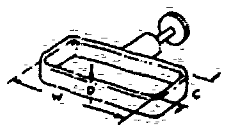
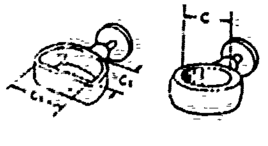
	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	TWO-POSITION, SPRING-RETURN-TO "OFF" TAB-LEVER. USE ONLY IN UP-DOWN ORIENTATION. RESISTANCE: APPROX. 1-6 LB (4.4-27 N)	D - MIN = 0.75" (1.9 CM)	W - MIN = 1.0" (2.54 CM)	—	DISPLACEMENT = 1.0-3.0" (2.54-7.6 CM)	—
	HEAVY-DUTY LEVER DEVICE HANDLES SHOULD PERMIT USE OF AT LEAST THREE FINGERS. USE ONLY IN UP-DOWN ORIENTATION. RESISTANCE: APPROX. 1.10 LB (4.4-44 N)	D - MIN. = 0.625" (1.59 CM)	L - MIN. = 2.5" (6.4 CM)	C - MIN CLEARANCE = 1.25" (3.2 CM), 1.5" (3.8 CM) WITH GLOVES	MIN = 2.0" (5.1 CM)	MIN. SEPARATION BETWEEN ENDS OF HANDLES = 0.75" (1.9 CM) OR 1.0" (2.54 CM) WITH GLOVES; MIN. OF 2.0" CLEARANCE BEHIND HANDLE.

Table _____ - Levers (Continued)

	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	HAND BRAKE, WITH THUMB BUTTON RELEASE. (SEE ALSO FOOT PEDAL ALTERNATIVE). L_1 - LOOP HANDLE ACCEPTABLE	D - DIAM = 1.0"-1.25" (2.54-3.2 CM)	L - LENGTH = 40" (10.2 CM) MIN. L LENGTH MIN = 4.5" (11.4 CM)	 C - MIN CLEARANCE = 2.0" (5.1 CM)	NOMINAL = 4.0"-5.0" (10.2-12.7 CM)	MIN = 2.5" (6.4 CM) ALL SIDES OF HANDLE
	HIGH FORCE LEVERS: CTR OF HANDLE SHOULD BE APPROX. 9-10" LATERALLY FROM OPERATOR CENTERLINE, AT ELBOW LEVEL. PROVIDE CLIP-TYPE RELEASE WHERE APPLICABLE. ROUND OR OVAL-SHAPED HANDLE SHOULD BE USED. RESISTANCE: APPROX. MAX - 42 LB (187 N)	a x b = 1.5 x 1.0" (3.8 x 2.54 CM) MAX; D = 1.5"-1.75" (3.8-4.45 CM) WITH CLIP LEVER MAX FORE-AFT SPAN SHOULD NOT EXCEED 3.0" (7.6 CM)			MAX FOR SEATED OP = 14.0" (35.6 CM)	MIN CLEARANCE SHOULD BE 2.0" IN FRONT, 3.0" EITHER SIDE.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.3.2.2 Push-Pull Controls 5.4.3.2.2.1 Applications - Push-Pull controls may be used when two discrete functions are to be selected. However such applications should be used sparingly and for applications in which such configurations are typically expected (e.g., vehicle headlight switch, choke, etc.). They may also be used in certain cases where limited panel space suggests a miniaturized knob that may be used to serve two related, but distinct functions (e.g., an ON-OFF/Volume switch for a T.V. monitor). A three-position push-pull control is acceptable in isolated instances where the criticality of inadvertent selection of the wrong position has no serious consequences (e.g., the typical vehicle headlight switch configuration that provides three "pull" positions (e.g., OFF/Park/Headlight) plus a rotary panel light and dome light switch).	NEW: This type of control is not presently covered by 1472B. Such controls are typical in vehicular systems and therefore should be included.
5.4.3.2.2.2 Handle Dimensions, Displacement and Clearances - Push-Pull control handles shall conform to criteria in Table____.	Ref: Woodson and Conover, Human Engineering Guide for Equipment Designers, 1966, p. 2-101.
5.4.3.2.2.3 Rotation - Except for combination push-pull/rotate switch configurations, push-pull control handles shall be keyed to the shaft so they do not rotate, unless the control is to be used for a special handbrake application, in which case the handle is rotated to disengage the brake setting. When the control system provides a combination push-pull/rotate functional operation, a round knob style is used, the rim of the knob shall be serrated to denote (visually and tactually) that the knob has the capability of being rotated.	Serration of rim on knobs which rotate as well as pull maintains compatibility with requirement for serration of all continuously-adjustable knobs.
5.4.3.2.2.4 Detents - Mechanical detents shall be provided push-pull control configurations and these shall provide sufficient tactile indication of positions that the operator is not in doubt as to when the control is "in-position".	
5.4.3.2.2.5 Snagging and Inadvertent Contact - The following shall be considered in determining whether to use push-pull type controls, where they should be located and in what direction the operating axis should be: a. Possibility of bumping a control while getting into or out of the operator position (e.g., as in a vehicle).	

Table _____ - Push-Pull Controls

	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	PUSH-PULL CONTROL, LOW RESISTANCE, FOR TWO-POSITION, MECHANICAL AND/OR ELECTRICAL SYSTEMS ALTERNATE THREE-POS'N PLUS ROTARY FUNCTION ACCEPTABLE FOR APPLICATION SUCH AS VEHICLE HEADLIGHT PLUS PARKING LTS., PANEL & DOME LTS. PROVIDE SERRATED RIM.	D - MIN DIAM = 0.75" (1.9 CM)	C - MIN CLEARANCE = 1.0" (2.54 CM), 1.5" (3.8 CM) WITH GLOVES		1.0" ± 0.5" (2.65 ± 1.27 CM) MIN BETWEEN PULL POS'NS = 0.5" (1.27 CM)	S - MIN SPACE BETWEEN = 1.5" (3.8 CM), 2.0" (5.1 CM) WITH GLOVES
	ALTERNATE HANDLE; MINIATURE ELECTRICAL PNL SWITCH ONLY. AVOID GLOVE USE APPLICATION.	D - MIN DIAM = 0.25" (0.64CM)	N/A	L - MIN LENGTH = 0.75" (1.9 CM)	0.5" (1.27 CM) MIN.	S - MIN = 1.0" (2.54 CM)
	HI FORCE PUSH-PULL, FOR TWO-POSITION MECHANICAL SYSTEM ONLY.	W - MIN WIDTH = 4.0" (10.2 CM)	D - DEPTH = 0.625"-1.5" (1.59-3.8 CM)	C - MIN CLEARANCE = 1.25" (3.2 CM), 1.5" (3.8 CM) WITH GLOVES	MIN = 1.0" (2.54 CM) 2.0" (5.1 CM) PREFERRABLE	
	SAME AS ABOVE PREFERRED WHERE POSSIBLE GARMENT OR CABLE-SNAG POSSIBLITY EXISTS.	SAME AS ABOVE	SAME AS ABOVE	SAME AS ABOVE	SAME AS ABOVE	S - MIN = 0.5" (1.27 CM)
	NOTE: 1 & 2 FINGER PULLS ALSO ACCEPTABLE FOR LESS THAN 4 LB (17.8 N) APPLICATIONS.	C = 0.75" (1.9 CM) FOR ONE FINGER 1.0" (2.54 CM) FOR GLOVES	C_1 = 2.0" (5.0 CM) FOR TWO FINGERS	C_2 = 1.0" (2.54 CM) FOR TWO FINGERS		

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
b. Possibility of snagging clothing, communication cables, or other equipment items on the control.	
c. Possibility of inadvertently deactivating the control setting as the operator reaches for another control.	
5.4.3.2.2.6 Direction of Control Motion - Control direction shall be as follows:	Ref: Woodson and Conover, Human Engineering Guide for Equipment Designers, 1966, p. 2-101.
a. Pull towards the operator for ON or activation; push away for OFF or deactivation.	
b. Rotate to the right for activation or increasing function in the case of combination pull/rotary switches. An exception shall be permitted in the case of certain contemporary automotive switches (e.g., combination headlight, parking light and panel/dome light switch).	
5.4.3.2.2.7 Force Requirements - Preferred maximum forces for pulling a panel control with fingers should be 17.8 N (4 lbs.); for pulling a T-bar with four fingers the maximum should be 44 N (10 lbs.).	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.3.2.3 <u>Integral, Handle-Mounted Controls</u> 5.4.3.2.3.1 <u>General</u> 5.4.3.2.3.1.1 <u>Application</u> - Handle-mounted, auxiliary controls may be integrated into the handles of primary controllers such as joysticks, equipment such as cameras, power tools, etc., when such integration enhances the simplicity and/or efficiency and safety of system operation.	NEW: These types of controls are not presently covered by 1472B, although they are used quite extensively in military systems.
5.4.3.2.3.1.2 <u>Number of Controls</u> - The number of controls integrated into a handle shall not exceed three (e.g., a trigger, plus two thumb-operated switches in a joystick handle) unless specified by the procurement specification or upon specific approval by the procuring agency.	A limit of 3 is needed to prevent designers from going overboard and implementing too many functions in a single control mechanism, based on professional judgment.
5.4.3.2.3.1.3 <u>Inadvertent Input</u> - The type of auxiliary switch, its motion characteristics and location shall be such that movement of the auxiliary switch will cause minimal probability that the primary control or equipment operation and/or positioning is inadvertently disturbed.	
5.4.3.2.3.2 <u>Thumb Switches</u> 5.4.3.2.3.2.1 <u>Switch Types</u> - Push buttons, slide, or rotary thumb switches may be used as appropriate for any of the following switch modes: a. Push button: ON-OFF (e.g., communication). b. Two-dimensional toggle: two-axis, spring centering (e.g., aircraft trim). c. Slide switch: single-axis ON-OFF, momentary ON plus ON-Hold (e.g., safety switch for hand-held power tool). d. Rotary thumb wheel: rotary selector (maximum of three positions), continuous adjustment (e.g., audio volume). Other auxiliary thumb-operated control applications shall be subject to the approval of the procuring agency.	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.3.2.3.2.2 Location and Operation - Thumb switches shall be positioned and operate in a fashion that is compatible with comfortable and natural thumb articulation limits, considering the total range of hand sizes for the expected user population, and constraints imposed by the wearing of gloves.	
5.4.3.2.3.2.3 Actuating Force - The actuating force required shall not exceed limits for push buttons, slides or thumbwheels as specified in other sections of this standard.	
5.4.3.2.3.2.4 Dimensions and Displacement - Dimensions and displacement of handle-mounted, auxiliary, thumb switches shall conform to criteria in Table_____.	Professional judgment, based on anthropometric relationships.
5.4.3.2.3.3 Index Finger-Operated Switches and Triggers	
5.4.3.2.3.3.1 Application - Index finger-operated, auxiliary handle-mounted controls should be used for typical "trigger" operations (e.g., weapon firing, camera film operation, power tool motor activation, etc.). Since the operator typically expects to use the index finger for these types of functions, other index finger operations shall not be implemented without express approval of the procuring activity.	Incorporates population stereotypes with respect to use of triggers.
5.4.3.2.3.3.2 Location and Operation - Trigger controls shall be located and operate in a manner that is compatible with the inherent limitations for using the basic control handle, i.e., the operator shall not be required to shift his or her hand from the normal hand grip position in order to actuate the trigger. If the trigger must be operated simultaneously while holding another auxiliary switch (safety), location and operation of both controls shall be such that the operator can comfortably and naturally activate both controls without inadvertently disturbing the primary handle positioning or aiming. Special consideration shall be given to restrictions that may be imposed by hardware effects on finger reach and mobility.	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.3.2.3.3.3 Actuating Force - Trigger-pull characteristics, including force profile for trigger displacement shall be as specified by the procurement agency. Unless otherwise directed by the procuring activity, trigger response shall be "even" throughout trigger pull, i.e., breakout vs. steady-state shall be approximately equal with no apparent "build-up" prior to final contact with the mechanical stop.	No research data on trigger resistance and dynamic characteriscics could be found.
5.4.3.2.3.3.4 Safety - Inadvertent trigger operation shall be minimized through proper use of trigger guards, safety latches or other means to prevent (1) inadvertent operation during non-operating modes (i.e., storing or carrying) and (2) inadvertent operation during primary firing/operating modes (i.e., trigger activation before the operator is "ready".	
5.4.3.2.3.3.5 Dimensions, Displacement and Clearance - Trigger dimensions, displacement and clearance limits shall conform to criteria in Table____.	Professional judgment based on anthropometric relationships.
5.4.3.2.3.4 Grip-Actuated Switches	
5.4.3.2.3.4.1 Application - Handle-mounted grip switches shall be used only for discrete ON-OFF enabling functions with respect to (1) a trigger mechanism, or (2) control outputs from a joystick-type device.	
5.4.3.2.3.4.2 Dimensions, Displacement and Actuating Force - The grip-actuated switch shall be compatible with the natural placement and contour of the operator's hand palm, as it conforms to the handle during use of the primary handle manipulation (i.e., for moving a joystick, positioning a tool or camera). The switch tab should be approximately 3 inches (7.6 cm) long by 0.375 inches (0.95 cm) wide, and rounded edges. Switch displacement shall be between 0.125 and 0.25 inches (0.3-0.6 cm). Actuating force requirement shall not exceed 5.0 lbs. (22.5 N), nor be less than 10 oz. (2.7 N).	

Table _____ - Grip-Mounted Switches

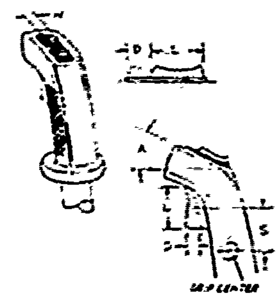
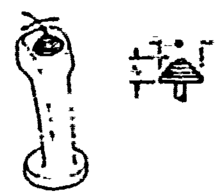
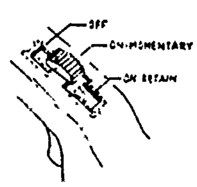
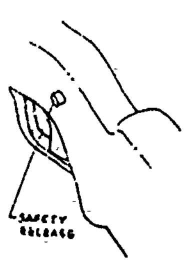
	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	THUMB-ACTUATED SWITCH, TWO OR THREE POSITION, SINGLE AXIS: TYPICAL APPLICATION IS SUPPLEMENTAL ON-OFF FUNCTION COUPLED TO PRIMARY CONTROL GRIP. CONCAVE CONTACT SURFACE WITH SERRATION DESIRABLE.	L - MIN SW LENGTH = 0.625" (1.59 CM)	W - MIN WIDTH = 0.25" (.64 CM)	—	D - MIN = 0.25" (0.64 CM) MAX = 0.75 (1.9 CM)	N/A
				A - PREFERRED ANGLE BETWEEN 30 AND 45 DEG.		
	INDEX FINGER OPERATED TRIGGER: APPLICATIONS INCLUDE HAND WEAPONS, JOYSTICK WEAPON FIRING CONTROL, ETC. SLIGHT CONCAVE SURFACE DESIRABLE.	L - MIN = 1.0" (2.54 CM)	SAME AS ABOVE	—	D - MIN = 0.125" (0.32 CM) MAX = 0.625" (1.59 CM)	S - GRIP/TRIGGER CTR SPACING = 2.0 ± 0.25" (5.1 ± 0.64 CM)
	THUMB-OPERATED, TWO-DIMENSIONAL SW, SPRING-CENTERING: TYPICAL APPLICATION TRIM CONTROL. SWITCH CAP SHOWN IS TYPICAL.	D - DIAM = 0.75" ± 0.25" (1.9 ± 0.64 CM)	H = 0.75 ± 0.25" (1.9 ± 0.64 CM)	—	D - MIN = 0.25" (0.64 CM) MAX = 0.75" (1.9 CM)	N/A
	REF: MS 87017 FOR SPECIAL HELICOPTER GRIP SWITCH REQM'TS.					

Table _____ - Grip-Mounted Switches (Continued)

	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	ACTIVE THUMB-OPERATED SAFETY/TRIGGER CONTROLS MECHANICAL THUMB SWITCH GUIDE (SPRING-LOADED, MOMENTARY-TO-OFF). MUST HAVE THUMB SWITCH IN MOMENTARY OR RETAIN, TO ACTIVATE TRIGGER.	—	—	—	—	—
	MOMENTARY SAFETY BUTTON (MUST BE HELD TO ACTIVATE TRIGGER).	—	—	—	—	—

MPI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
.4.4 <u>Two-Axis Controllers for Display System Applications</u> .4.4.1 <u>General</u> - Display systems requiring a single operator o make control movements along two orthogonal coordinate axes imultaneously should utilize one of the following types of ontrollers: simultaneously-operated handcranks, ball control, oystick, grid and stylus devices, pantograph, or free-moving y controller (Mouse). Selection should be made on the basis f matching controller characteristics with system requirements. ee Table______ and paragraphs 5.4.4.2 through 5.4.4.9.	This is a new section which presents requirements for two-axis controllers which are used in conjunction with displays. It cov rs simultaneously-operated handcranks, ball controls, isometric joysticks, isotonic joy-sticks, free-moving xy controllers, light pens, and stylus actuated devices. The coverage includes applications, dynamic character-istics, and dimensions and mounting.
.4.4.2 <u>Simultaneously-Operated Handcranks</u> .4.4.2.1 <u>Application</u> - Simultaneously-operated handcranks should e used in preference to other two-axis controllers where extreme recision is required in setting crosshairs or reticles as in ap readouts or optical sighting mechanisms. This type of control ay also be used in other applications requiring x and y control rovided there is no requirement for rapid or frequent operation.	Simultaneously-operated handcranks are preferred for precision because there is no cross-coupling between the axes as is the case with a single device operating in both axes of movement.
.4.4.2.2 <u>Dynamic Characteristics</u> - The dynamic characteristics f simultaneously operated handcranks shall be the same as those pecified for single cranks in paragraph 5.4.2.2.2 and figure 7. he gear ratio and dynamic characteristics of the cranks shall be uch as to allow precise placement of the follower (e.g., cross-airs) without overshooting or undershooting and successive orrective movements. .4.4.2.3 <u>Dimensions</u> - The dimensions for handcranks shall be s indicated in figure 7.	
.4.4.3 <u>Ball Control</u> (Also known as track ball, ball tracker, oyball, and rolling ball.) .4.4.3.1 <u>Application</u> - A ball control suspended on low-friction earings may be used for various control functions such as data ickoff on a display. The ball control, because of its inherent ositional stability is particularly well suited for use on moving latforms. The ball control cannot provide an automatic return o point of origin, hence if used in applications requiring utomatic return to origin following an entry or readout, the	This is necessary new material because of the extensive use of ball controls.

Table _____ - Two Axis Controllers for Display System Applications

Type of Controller	Control Order Utilized	Acceptable Display Applications			
		XY Data Pickoff	Continuous Tracking	Free-Drawn Graphics	Setting Cross-Hairs
Simultaneously-Operated Handcranks	Position	(Not Acceptable)	(Not Acceptable)	(Not Acceptable)	Good
Ball Control	Position	Good	Fair	Poor	Good
Isometric Joystick (Stiff Stick)	Position, Rate, Aided	Good	Good	Fair	Fair
Isotonic Joystick (Displacement Stick)	Position, Rate, Aided	Good	Good	Good	Fair
Grid and Stylus Devices	Position	Good	Fair	Good	Good
Free-Moving XY Controller (Mouse)	Position	Good	Not Acceptable	(Not Acceptable)	Fair
Light Pen (augmented)	Position	Good	Fair	Good	Fair

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
interfacing system much provide this. Because the ball can be rotated without limit in any direction it is well suited for applications where there may be accumulative travel in a given direction. In any application which would allow the ball to drive the follower on the display off the edge of the display, indicators shall be provided to advise the operator how to bring the follower back onto the display. Ball controls should not be used for velocity control or in rate-aided control systems.	When controlling velocity it is important to know where the zero-zero point is physically lcoated. The ball cannot provide this, but the centered position of a joystick does provide it.
5.4.4.3.2 Dynamic Characteristics - The ball control shall be capable of rotation in any direction so as to generate any combination of x and y output values. When moved in either the x or y directions alone there shall be no apparent cross-coupling (follower movement in the orthogonal direction). For applications requiring precise control, ball controls shall have frictional resistance of less than 1 N (3.5 oz.). For ball controls used under vibration or acceleration conditions, frictional resistance may be increased to 1.7 N (6.0 oz.). Neither backlash nor cross-coupling shall be apparent to the operator in manipulating it. Control ratios and dynamic features shall be designed to meet the dual requirement of rapid gross positioning and smooth, precise fine positioning. Ball controls should be used only as position controls (i.e., a given movement of a gall makes a proportional movement of the follower on the display).	Professional judgment.
5.4.4.3.3 Dimensions and Mounting - The diameter of the ball shall be between 5 cm (2.0 inches) and 15 cm (6.0 inches) depending upon the application and mode of operation to be used. The smaller diameters should be used only where space availability is tight and when there is no need for great precision. A diameter of approximately 10 cm (4.0 inches) is preferred for most applications. The preferred mounting for the ball control is in a horizontal surface such as a shelf or desk top as shown in Figure ____. The exposed ball surface should be between 100° and 140° with 120° preferred.	5.4.4.3.3 These requirements are comparable with the characteristics of devices manufactured by Measurement Systems, Inc., a highly regarded vendor in this area. Exposure of too much ball surface would allow application of force at points on the ball's surface where the resulting torque would be substantially reduced. Exposing too little of the ball surface would limit the movement of the hand to needlessly small excursions.
5.4.4.4 Isometric Joystick - (Also known as stiff stick, force stick, or pressure joystick).	

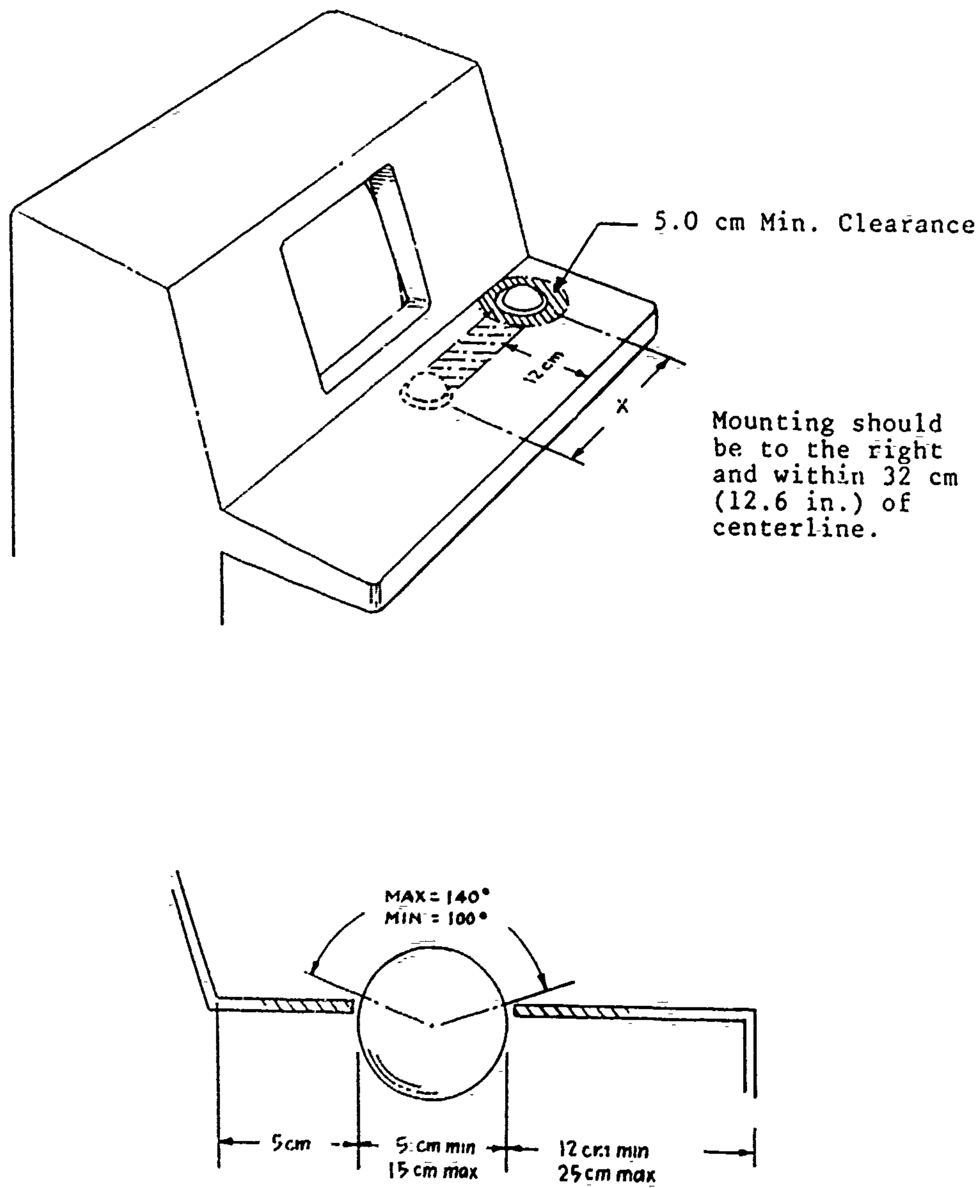


Figure _____ - Ball Control Mounting and Dimensions

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.4.4.1 Application - The isometric joystick may be used for control of various display functions such as data pickoff from a CRT. In rate control applications which may allow the follower to transit beyond the edge of the display, indicators shall be provided in order to advise the operator how to bring the follower back onto the display. Isometric joysticks are particularly appropriate for applications: (1) which require return to center after each entry or readout; (2) in which operator feedback is primarily visual from some system response rather than kinesthetic from the stick itself; and (3) where there is minimal delay and tight coupling between control input and system reaction. Isometric sticks should ordinarily not be used in any application where it would be necessary for the operator to maintain a constant force on the stick so as to generate a constant output over a sustained period of time.	Constant feedback is required for an operator to be able to maintain constant force on a stick, and even when this is provided, maintenance of constant force is fatiguing.
5.4.4.4.2 Dynamic Characteristic - The isometric stick shall have minimal deflection in response to applied force, except that it may deflect perceptibly against a stop at full applied force. The x and y output should roughly approximate the magnitude of the applied force as perceived by the operator. Maximum force for full output with fingertip operation shall not exceed 44 N (10 lbs.). For hand-grasped joysticks maximum force for full output shall not exceed 119 N (26.7 lbs.). One or more switches actuated either by thumb or finger pressure may be integrally-mounted if compliant with 5.4.3.2.3.	Supported by expert judgment of Mort Mehr, Measurement Systems, Inc.
5.4.4.4.3 Dimensions and Mounting - Simple isometric joysticks (without integral switching) used in display systems should be of the finger-grasped shape and should be not more than 12 cm (4.7 inches) in shaft length and 1.5 cm (0.6 inches) in diameter. When integral switching is required, the hand-grasped shape should be used, with limiting dimensions of 11 cm (4.3 inches) and 18 cm (7.1 inches) for shaft length, and maximum grip diameter 5 cm (2.0 inches). The joystick preferably should be mounted in a shelf or desk surface as shown in Figure ___ so as to provide a minimum hand rest length of 12 cm (4.7 inches) from the shelf edge to the joystick shaft. In addition, clearances of 10 cm (3.9 in.) to the side and 5 cm (2 in.) to the rear shall be provided to allow for hand movement.	Based on Measurement Systems, Inc. practices, which have evolved from extensive R&D

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.4.5 Isotonic Joystick (Also known as displacement joystick.)	With automatic sequencing, the computer positions the cursor for each successive operation independently of the instantaneous joystick displacement. When control is restored to the joystick the cursor would jump to whatever coordinates it is set to unless the joystick is zero set for the return of control.
5.4.4.5.1 Application - The isotonic joystick may be used for various display functions such as data pickoff from a CRT and generation of free-drawn graphics. In rate control applications which allow the follower to transit beyond the edge of the display, indicators shall be provided in order to advise the operator how to bring the follower back onto the display. Also, isotonic joysticks which are used for rate control should be spring-loaded for return to center when the hand is removed. Isotonic joysticks shall not be used in connection with automatic sequencing of a hook or bug unless they are instrumented for null return or are zero-set to the instantaneous position of the stick at the time of sequencing. Upon termination of the automatic sequencing routine, joystick center shall again be registed to scope center.	
5.4.4.5.2 Dynamic Characteristics - Maximum angular excursion of the isotonic joystick shaft from center position shall not exceed 45°. Movement shall be smooth in all directions, and rapid positioning of a follower on a display shall be attainable without noticeable backlash, cross-coupling or need for multiple corrective movements.	Excursions greater than 45° would seem to be pushing into the mounting surface rather than parallel to it.
Control ratios, friction, inertia, etc., shall be designed to meet the dual requirements of rapid gross positioning and precise fine positioning. Recessed mounting or pencil attachments may be utilized as indicated in Figure ___ to provide greater precision of control. One or more switches actuated by either thumb or finger pressure may be integrally-mounted if compliant with 5.4.3.2.3.	Professional judgment.
When used for generation of free-drawn graphics, the refresh rate for the follower on the CRt shall be sufficiently high to ensure the appearance of a continuous track.	If the refresh rate is not high enough the operator will either need to slow down his movement rate in order to get a continuous line, or will have to accept uneven trace brightness.
5.4.4.5.3 Dimensions and Mounting - Dimensions for isotonic joysticks used in display systems should be within the limits specified for isometric joysticks in 5.4.5.4.3 and mounting should conform to Figure ____, except that the clearance radius will be maximum stick excursion from center, plus 10 cm (3.9 inches).	

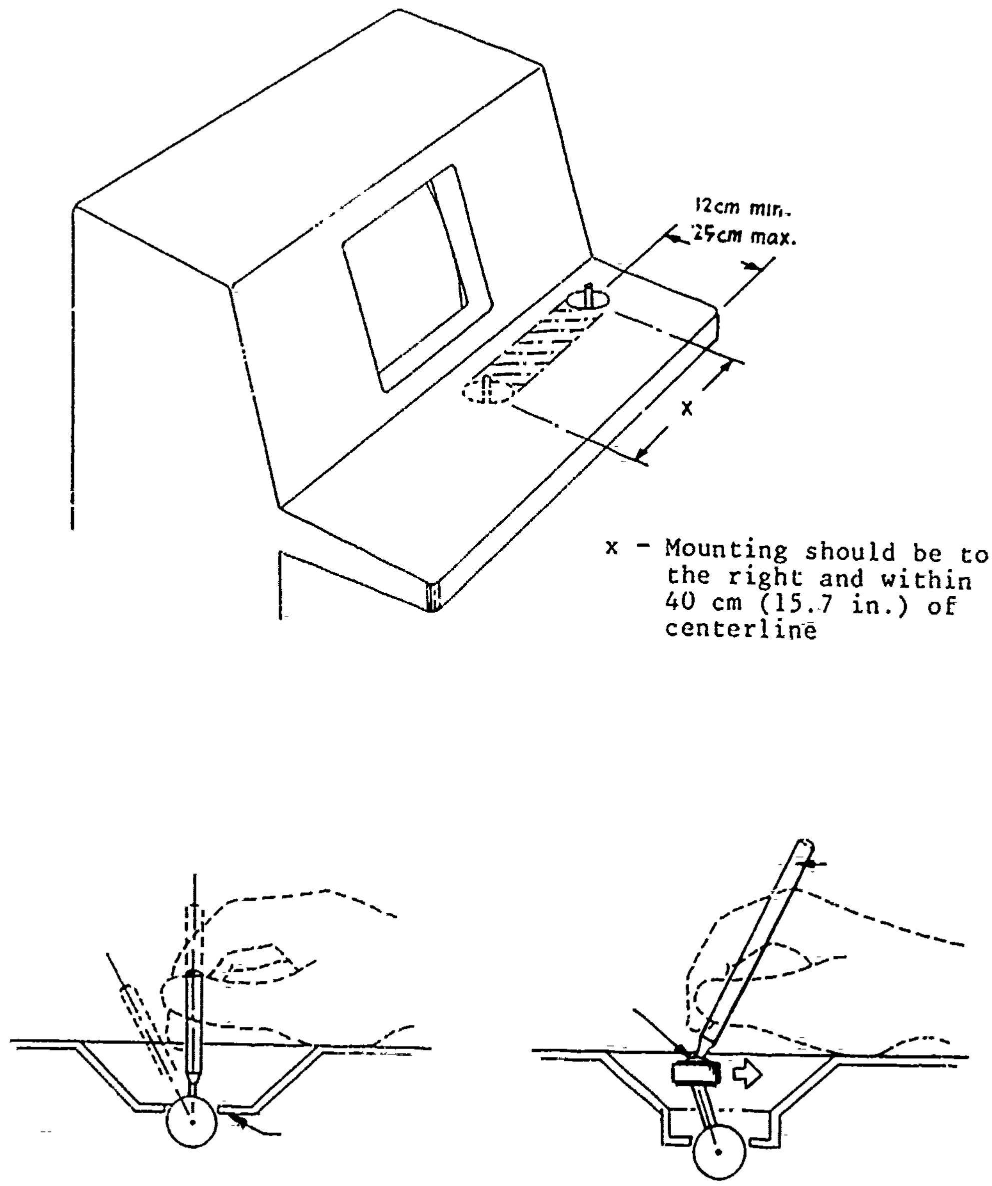


Figure ____ - Console Joystick Mounting

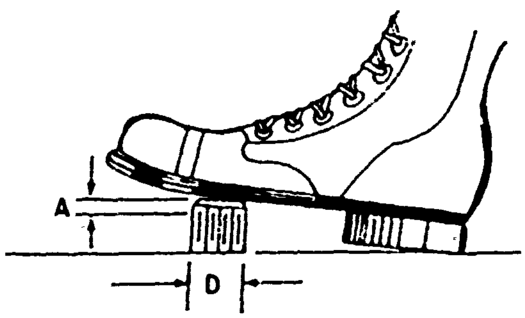
MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.4.6 Grid-and-Stylus Devices - These provisions cover various techniques which utilize some means of establishing an x and y grid and a stylus for designating specific points on that grid for control purposes (e.g., time-shared x and y potential grids and a voltage-sensitive stylus).	Professional judgment based on scattered research data, operational experience, and basic human engineering principles.
5.4.4.6.1 Application - Grid and stylus devices may be used for data pickoff from a CRT, for entry of points on a display, for generation of 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. In either case a follower (bug, mark, hook, etc.) must be presented on the display at the coordinate values selected by the stylus. Devices of this type should be used only for zero order control functions (i.e., displacement of the stylus from the reference position causes a proportional displacement of the follower).	
5.4.4.6.2 Dynamic Characteristics - Movement of the stylus in any direction on the grid surface shall result in smooth movement of the follower in the same direction. Discrete placement of the stylus at any point on the grid shall cause the follower to appear at the corresponding coordinates and to remain steady in position so long as the stylus is not moved. Refresh rate for the follower shall be sufficiently high to ensure the appearance of a continuous track whenever the stylus is used for generation of free-drawn graphics.	
5.4.4.6.3 Dimensions and Mounting - Transparent grids which are used as display overlays shall conform to the size of the display. Grids which are displaced from the display should approximate the display size and should be mounted below the display in an orientation to preserve directional relationships to the maximum extent (i.e., a vertical plane passing through the north/south axis on the grid shall pass through or be parallel to the north/south axis on the display).	
5.4.4.7 Free-Moving XY Controller (Mouse)	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.4.7.1 Application - This type of controller may be used on any flat surface to generate x and y coordinate values which control the position of the follower on the associated display. It may be used for data pickoff or for entry of coordinate values. It should be used for zero order control only (i.e., generation of x and y outputs by the controller results in proportional displacement of the follower). It should not be used for generation of free-drawn graphics.	Although a "Mouse" type of device could be used for free-drawn graphics it would seem far less desirable than a stylus or joystick because of their similarity to the pencil.
5.4.4.7.2 Dynamic Characteristics - The design of the controller and placement of the maneuvering surface shall be such as to allow the operator to consistently orient the controller to within $\pm 10^{\circ}$ of the correct orientation without visual reference to the controller. (That is, for example, when the operator grasps the controller in what he tactually assumes is the correct orientation and moves it rectilinearly along what he assumes to be straight up the y axis, then the direction of movement of the follower on the CRT shall be between 350° and 010°). The controller shall be movable easily in any direction without a change of hand grasp and shall result in smooth movement of the follower in the same direction ($\pm 10^{\circ}$). The controller shall be cordless and shall be operable with either the left or right hand. A complete excursion of the controller from side to side of the maneuvering area shall move the follower from side to side on the display regardless of scale setting or offset unless expanded movement is selected for an automatic sequencing mode of operation. In any application which would allow the controller to drive the follower off the edge of the display, indicators shall be provided to advise the operator how to bring the follower back onto the display.	Professional judgment.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.4.7.3 Dimensions and Shape - The free-moving xy controller should have no sharp edges but should be shaped roughly as a rectangular solid, with limiting dimensions as follows.	The controller should not be round; it should have a configuration which allows the operator to grasp it in approximately the orientation it should be in for manipulation. Otherwise it might be grasped in such a way that movement of the follower would be in an incompatible direction, thus requiring shifting of the grasp on the controller to get the proper alignment.
	Min. / Max.
Width (spanned by thumb to finger grasp): 4 cm (1.6 in.) / 7 cm (2.8 in.)	
Length: 7 cm (2.8 in.) / 12 cm (4.7 in.)	
Thickness: 2.5 cm (1.0 in.) / 4 cm (1.6 in.)	Dimensional requirements are professional judgment based on anthropometric considerations.
5.4.4.8 Light Pen	
5.4.4.8.1 Application - A simple light pen may be used as a track-oriented readout device. That is, it may be positioned on the display screen so as to detect the presence of a computer-generated track by sensing its refresh pattern and the display system will then present a "hook" on the designated track. With suitable additional circuitry a follower can be made to track the movement of the light pen across the surface, thus allowing it to function as a two-axis controller capable of serving the same purposes served by the grid- and stylus devices (paragraph 5.4.4.6.1).	
5.4.4.8.2 Dynamic Characteristics - Dynamic characteristics of the light pen used as a two-axis controller shall be as in paragraph 5.4.4.6.2.	
5.4.4.8.3 Dimensions and Mounting - The light pen shall be between 0.7 cm (.3 in.) and 2.0 cm (.8 in.) in diameter and between 23 cm (4.7 in.) and 18 cm (7.1 in.) in length. A convenient clip shall be provided at the lower right side of the CRT to hold the light pen when it is not in use.	Professional judgement based on anthropometric considerations

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.4.9 Quickened and Predictor Types of Controllers 5.4.4.9.1 Applications - Complex tracking functions may require use of quickened or predictor approaches to control-display implementation. These approaches shall be utilized only with the concurrence of the procuring activity.	It would be a considerable task to prepare specific requirements for quickened or predictor approaches to control-display implementation. The best short-term way of handling this appears to leave it in the hands of the procuring activity.

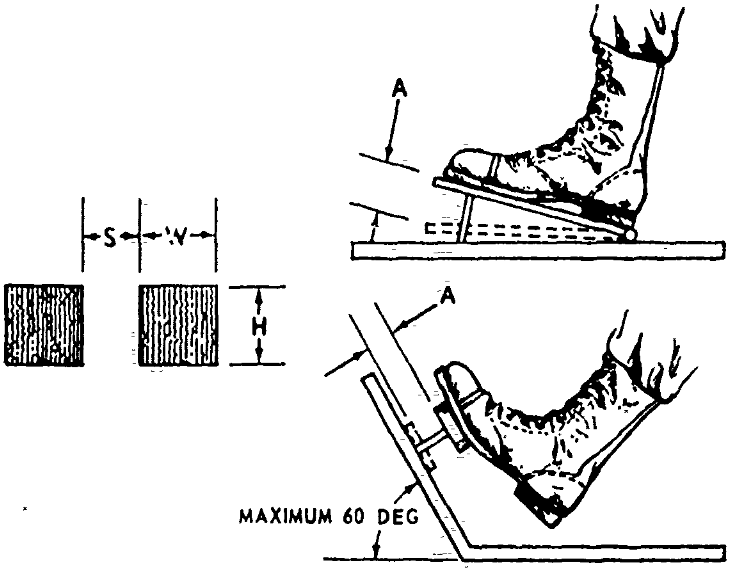
ORIGINAL REQUIREMENT	MFI COMMENTS
5.4.3.1.2 Push Buttons (Foot-Operated) - 5.4.3.1.2.1 Application - Foot-operated push buttons should be used only in those cases where the operator is likely to have both hands occupied at the time the push button is activated or when load sharing among limbs is required. Because foot-operated push buttons are extremely susceptible to accidental activation, their uses shall be limited to noncritical operations such as press-to-talk switches. 5.4.3.1.2.2 Operation - Foot-operated push buttons shall be designed to be operated by the toe and the ball of the foot rather than the heel. Where space permits, foot-operated push buttons shall be replaced by, or supplemented with, a pedal to aid in locating the activating control. Friction surfaces shall be used on foot-operated push buttons. 5.4.3.1.2.3 Positive Indication - A positive indication of control activation shall be provided (e.g., snap feel, audible click, associated light, or side tone). 5.4.3.1.2.4 Dimensions, Resistance, Displacement, and Separation - Dimensions, resistance, and displacement of foot-operated push buttons shall conform to the criteria in Figure 10. Separation between adjacent edges of foot-operated push buttons shall conform to the criteria in Figure 14.	Foot controls are separated into Foot Switches (under push buttons) and Pedals. In our opinion this is confusing to designers because they will be looking for foot control requirements as separate from hand controls. By reference to proposed materials it can be seen that we believe there are missing requirements, and the overly simplistic specification of dimensions, force, displacement, etc. are not only difficult to relate to specific types of control applications, but some of the values are questionable across the board.



	DIAMETER	RESISTANCE		DISPLACEMENT			
	D			A			
		Foot Will Not Rest On Control	Foot Will Rest On Control	Normal Operation	Heavy Boot Operation	Ankle Flexion Only	Total Leg Movement
Minimum	0.50" (13mm)	4.0 lb (18N)	10.0 lb (45N)	0.50" (13mm)	1.0" (25mm)	1.0" (25mm)	1.0" (25mm)
Maximum	--	20.0 lb (90N)	20.0 lb (90N)	2.5" (65mm)	2.5" (65mm)	2.5" (65mm)	4.0" (120mm)

Figure 10. PUSHBUTTONS (FOOT OPERATED)

ORIGINAL REQUIREMENT	MFI COMMENTS
5.4.3.2.2 Pedals -	
5.4.3.2.2.1 Application - Pedals shall be used when a large amount of displacement or force is required and when foot activation is desirable.	5.4.3.2.2.1 This is an overly-simplistic statement on applications for pedals.
5.4.3.2.2.2 Null Position - Pedals should be designed so that they will return to the null position when force is removed.	Some pedals such as rudder controls should not return to null position when force is removed.
5.4.3.2.2.3 Dimensions, Resistance, Displacement, and Separation - Dimensions, resistance, displacement, and separation between adjacent edges of pedals shall conform to the criteria in Figure 14.	This table is too limiting.
5.4.3.2.2.4 Heel Support - When the pedal angle is greater than 20° above the horizontal, a heel support should be provided.	
5.4.3.2.2.5 Non-Slip Material - Pedals shall be covered with a non-slip material.	
5.4.3.3 Force-Sensitive Controls - Force sensitive isometric controls should be considered for use in tracking applications, especially those which must be performed under vibration conditions.	
5.4.4 High-Force Controls -	
5.4.4.1 Arm, Hand, and Thumb-Finger Controls - Where arm, hand and thumb-finger controls requiring high control forces are to be used, the maximum force requirements shall not exceed those specified in Figure 15.	
5.4.4.2 Leg Controls - Where leg controls requiring high control forces are to be used the force push exerted by the leg depends on the thigh angle and the knee angle. Figure 16 specifies the mean maximum push at various knee and thigh angles. The maximum push is at about the 160° angle referred to as the limiting angle.	



	DIMENSIONS		DISPLACEMENT			
	H	W	A			
	Height	Width	Normal Operation	Heavy Boots	Ankle Flexion	Total Leg Movement
Minimum	1.0" (25mm)	3.0" (75mm)	0.5" (13mm)	1.0" (25mm)	1.0" (25mm)	1.0" (25mm)
Maximum	-	-	2.5" (65mm)	2.5" (65mm)	2.5" (65mm)	7.0" (180mm)

	RESISTANCE			
	Foot Not Resting on Pedal	Foot Resting on Pedal	Ankle Flexion Only	Total Leg Movement
Minimum	4 lb (18N)	10 lb (45N)	-	10 lb (45N)
Maximum	20 lb (90N)	20 lb (90N)	10 lb (45N)	180 lb (800N)

	SEPARATION	
	S	
	One Foot Random	One Foot Sequential
Minimum	4.0" (100mm)	2.0" (50mm)
Preferred	6.0" (150mm)	4.0" (100mm)

Figure 14. PEDALS

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.5.2.3 Foot-Operated Controls 5.4.5.2.3.1 General - Foot-operated controls should be considered under the following conditions: a. Control system forces require that the human interface force application will be beyond the maximum manual strength capability of the operator, and/or so near this limit to cause serious fatigue for the operator. b. The operator's hands are generally occupied by other manual control tasks at the same moment that an additional control action is required. c. Specific foot-operated controls have been so well established that the average operator expects such operating functions to be performed using foot controls, e.g., aircraft rudder/brake pedals, automotive clutch, brake and accelerator pedals, etc. d. When a safety "shut-down" control is required during an operation in which the operator's hands cannot be freed to reach a safety switch, e.g., sheet metal cutting machine. Foot-operated controls should not be used under the following conditions: a. For a standing operator who may be working on a moving platform (i.e., where balancing on the non-operating foot may become difficult as the operating foot is moved from a support to actuating position). b. To effect very precise control operations. c. To select among a great many separate foot controls. 5.4.5.2.3.1.1 Operation - Foot controls shall be located and designed so they can be operated in as "natural" a pattern as practicable. Specifically, the following should be avoided: a. Frequent, maximum reaching.	We have tried to be more specific in terms of the broader applications need. These recommendations are based on DOT research of recent years, attempting to develop standards for cars, trucks and buses--as well as including key aircraft-related variations that need to be presented, to be compatible with current Military design practices.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
b. Requirement to hold the leg or foot in an awkward position for extended periods of time.	
c. Requirement for the operator to sit in a twisted position to operate a control that is used frequently and/or for an extended period to time, i.e., pedals shall be laid out symetrically with reference to the operator's principal operating orientation.	
d. Maximum force application frequently or for extended duration.	
e. Requirement that the operator "look" for a particular foot control in order to select the right one.	
f. Placement of a foot control where it might be "stepped on" and inadvertently actuated, and/or where typical shifting from one foot control to another creates a high probability that the foot or clothing might be entrapped by an intervening control as the operator shifts the foot from one control to another.	
5.4.5.2.3.2 Foot-Switches	Many specific requirements not previously covered in 1472B.
5.4.5.2.3.2.1 Application - Foot-operated switches should be used only in those cases where the operator is likely to have both hands occupied at the time the push button is activated, or where load-sharing among limbs is desirable. Because foot-operated switches are susceptible to accidental activation their uses should be limited to non-critical or infrequent operations such as press-to-talk communication, vehicle headlight dimming, etc.	
5.4.5.2.3.2.2 Operation - Foot switches shall be located so that they can be operated by the toe or ball of the foot rather than by the heel. They shall not be located so near an obstruction that the operator cannot position the sole of the shoe squarely (centered) on the switch button. A pedal may be used atop the button to aid in location and operation of the switch. When switches are used in an environment in which the switch may become wet and slippery, the switchcap surface should possess a frictional surface to minimize the possibility of the foot slipping off the switch.	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.5.2.3.2.3 Switch Location - In addition to the above, foot-operated switches shall be located so the operator has some normal heel resting position on a floor board, etc. Avoid placing a foot switch beneath or behind other pedals wherein it might be possible for the operator's foot to become momentarily interfered with or trapped during transfer between the switch and a pedal or steering column.	
5.4.5.2.3.2.4 Dimensions, Displacement, and Separation - Dimensions, displacement and separation of foot-operated switches shall conform to the criteria in Figure 10. Although not recommended (i.e., only one switch per foot is preferred), when more than one switch is provided for the same foot to operate, such switches shall be separated by at least 7.6 cm (3 inches) horizontally and 20.3 cm (8 inches) vertically.	Ref: Woodson and Conover, Human Engineering Guide for Equipment Designers, 1966, p. 2-110.
5.4.5.2.3.2.5 Actuating Force and Feedback - A positive indication of control activation shall be provided (e.g., snap feel, audible click, association with an obvious change in a visual or auditory display). Actuating force shall be between 44 N and 88 N (10 and 20 lbs.).	
5.4.5.2.3.3 Pedals	
5.4.5.2.3.3.1 Application - Pedal controls should be used only when the operator is likely to have both hands occupied at the time the foot operation is required, when the control system force is too high for manual force capability of the operator, or where standardized use of pedals has created a stereotype expectancy on the part of the operator (e.g., vehicle pedal control configurations such as clutch, brake, accelerator, rudder, etc.). Applications other than these shall be subject to approval of the procuring activity.	
5.4.5.2.3.3.2 Location - Pedal controls shall be located so that the operator can reach them easily without extreme stretching or torso twisting, so that the operator can reach the maximally-displaced pedal within anthropometric and force-capability of the operator (see Figure ____). Pedals that may be held or that have to be adjusted fairly precisely (accelerator, clutch, etc.) shall be located so the operator can "rest" and "steady" the foot,	Requires figure of foot pedal location relative to vehicle driver.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
i.e., the pedal shall be an appropriate critical distance above the floor so the operator's heel can rest on the floor while articulating the ankle/foot. When this cannot be done (and the pedal angle is more than 20-degrees from the horizontal floor), a heel rest shall be provided.	Ref: Woodson and Conover, Human Engineering Guide for Equipment Designers, 1966, p. 2-110.
5.4.5.2.3.3.3 Spring-Return - Except for controls which generate a continuous output such as rudder controls, accelerator pedals, etc., foot controls shall have a spring-return system with sufficient force to return the pedal to the original null position without requiring assistance from the operator (e.g., brake or clutch pedals). For pedals in which the operator may normally rest the foot on the control between operations, sufficient spring tension shall be provided to prevent the weight of the foot from inadvertently activating the control (e.g., accelerator pedal).	
5.4.5.2.3.3.4 Play - Pedal control systems shall be designed to minimize excess "play" (i.e., movement that does not activate the control system).	New requirement for tighter control coupling.
5.4.5.2.3.3.5 Adjustment - Control, and/or seat adjustment shall be provided, sufficient to accommodate the leg reach capabilities of the total range of expected operators (i.e., 5th percentile female-95th percentile male). Consideration shall also be given to combined vertical/horizontal adjustment effect on reach. For seated operator configurations where external vision is critical and corresponding control panel constraints may be present, pedal/seat/vision requirement shall be considered together to provide the best-fit among eye reference, seat and pedal adjustment position and adjustment range.	Pedals cannot be properly operated by all segments of the population unless some adjustment is provided to accommodate different statures.
5.4.5.2.3.3.6 Pedal Travel Path - The travel path (typically an arc) shall be considered in the design of pedal systems, and shall be compatible with the natural articulation path of the operator's limbs (i.e., thigh, knee, ankle).	New requirement needed to ensure maximum application of force.
5.4.5.2.3.3.7 High Force Application Aids - When the force required to fully actuate a pedal is extremely high, appropriate aids shall be provided to assist the operator in applying maximum force to the pedal. The following should be considered: a. Seat backrest.	New requirement.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
b. Optimized seat height-to-pedal and normal reach distance for maximum force (i.e., SRP/Pedal at same vertical height; reach distance so the upper thigh and lower leg create an angle just short of horizontal--see Figure_____.)	Requires new figure in anthropometric section.
c. Double-width pedal so that both feet could be used.	
5.4.5.2.3.3.8 Non-Slip Pedal Surface - Pedals used for high force applications shall be provided with a non-skid surface. Similar surfaces are desirable for all pedals.	
5.4.5.2.3.3.9 Dimensions, Force Requirements, Displacement and Separation - Dimensions, force requirements, displacement and separation of pedals shall conform to the criteria in Table_____.	
5.4.5.2.3.4 Automotive-Related Foot Control Combinations	It is considered important to conform with stereotypes that have been firmly established within the driver population.
5.4.5.2.3.4.1 Applications - Assemblies of foot-operated controls shall conform to industry practice with respect to arrangement, i.e.:	
a. Manual Transmission: Clutch shall be positioned for left foot operation, service brake and accelerator for right foot operation. Headlight dimmer function may be provided either as a left foot-operated floor switch or a left hand-operated column-mounted stalk (lever).	
b. Automatic Transmission: The above arrangement shall be followed except that the service brake shall be accesible for either right or left foot operation (in which case, tne brake pedal shall be laterally elongated sufficiently to make it convenient for operation by either foot).	
5.4.5.2.3.4.2 Pedal, Geometric Relationships - Clutch, service brake and accelerator pedals shall be arranged so that the primary contact point of each pedal (i.e., height and distance from the floor, heel-reference point) is approximately the same, to make it convenient for the operator to shift his or her foot from the accelerator to the service brake pedal without having to lift the foot an excessive amount. The pedal contact point should be based on a point on the accelerator pedal that matches a "all-of-the-	New requirements based on best automotive practice.

Table _____ - Foot-Operated Controls

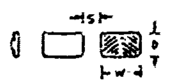
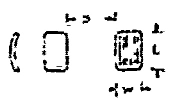
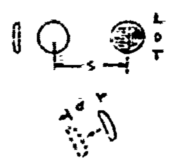
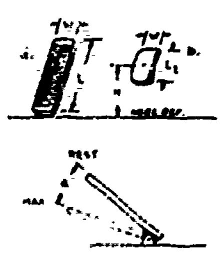
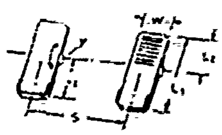
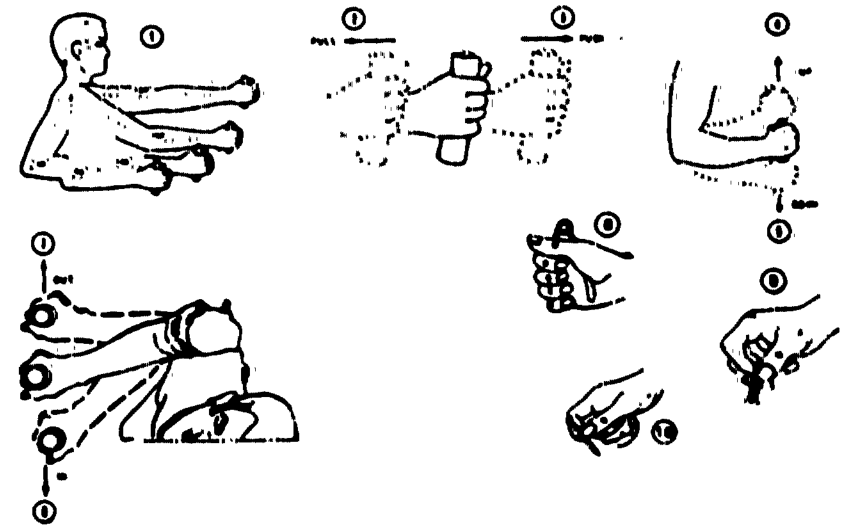
	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	BRAKE PEDAL APPLICATIONS: CLUTCH-BRAKE-CONVEX TREAD SURFACE. FORCE REQUIREMENTS: CLUTCH = 2-20 LBS (8.9-88.9 N) BRAKE = 120 LBS (533.3 N)	W X D - MIN = 3 X 3" (7.6 X 5.1 CM)	—	—	—	S - MIN TO PREVENT FOOT SLIPPING BETWEEN PEDALS = 2.0" (5.1 CM)
	ALTERNATE PEDAL SHAPE & SPACING. CONVEX, TREAD SURFACE.	W + L - MIN = 2 X 3" (5.1 X 7.6 CM)	—	—	—	S - MIN SEPARATION TO ALLOW FOOT TO PASS BETWEEN PEDALS = 5.0" (12.7 CM); 7.0" (17.8 CM) FOR HEAVY BOOTS
	ROUND PEDAL SHAPE ACCEPTABLE. FLAT, TREAD SURFACE.	D - MIN = 2.25" (5.7 CM)	S - COMFORT SEPARATION = 12.0 ± 2.0" (30.5 ± 5.1 CM) MAX = 16.0" (40.6 CM) MIN = 8.0" (20.5 CM)	—	— d - MAX REST TO ACTIVATE = 7.0" (17.8 CM); MIN = 1.0" (2.54 CM) PREFERRED = 2.5"-4.0" (6.4-10.2 CM)	(NOTE: EDGE TO EDGE PEDAL SEPARATIONS OF BETWEEN 2 AND 4.5 INCHES SHOULD GENERALLY BE AVOIDED BECAUSE OF POSSIBILITY OF GETTING FOOT CAUGHT)
	ACCELERATOR PEDAL APPLICATIONS: a. FLOOR-HINGED, FULL PEDAL b. SUSPENDED PEDAL (PEDAL SHOULD BE FREE-SWIVEL ACTION DISPLACEMENT ENVELOPE. NOMINAL CRUISE ANGLE* SHOULD CAUSE LOWER LEG/FOOT, INCLUDED ANGLE TO BE BETWEEN 90-105°. FORCE REQUIREMENTS: MAX = 20 LB (88.9 N) MIN = 10 LB (4.4 N) *NOMINAL CRUISE = LEVEL GRADE, AVG. SPEED FOR APPLICATION	W = 2" (5.1 CM) MINIMUM L_1 = 10 ±2" (25.4 ±5.1 CM) L_2 = 3.5" (8.9 CM) MIN.	W ≥ 6" (15.2 CM) OPTIMUM	—	— d - MAX DISPLACEMENT = 30° (20° WITH HEAVY BOOTS)	—

Table _____ - Foot-Operated Controls (Continued)

	APPLICATION CRITERIA	DESIGN CRITERIA				
		DIMENSIONS			DISPLACEMENT	SEPARATION
	AIRCRAFT RUDDER/BRAKE ASSEMBLY, SHOULD HAVE MIN FOR AFT ADJUSTMENT OF 9.0" (22.9 CM). TOE PRESSURE OPERATES BRAKE, FORE-AFT MOVEMENT OF PEDAL FULCRUM OPERATES RUDDER (RIGHT PEDAL FWD = RIGH .URN). FORCE REQUIREMENTS: SEE MIL-F-8785	W - MIN = 6.0" (15.2 CM)	L_1 - MIN = 10" (25.4 CM) L_2 - MIN = 5.0" (12.7 CM)	—	SEE AFSCM 85.1 HIAD (USAF)	S - MIN = 15" (38 CM) MAX = 21" (53.3 CM)
 ALT. PEDAL	(SEE MIL-B-3584 FOR SPECIFIC DIMENSIONS)					
	FOOT SWITCHES, NORMALLY USE ONLY ONE PER FOOT (MAX. TWO) FORCE REQUIREMENTS: MAX. 10 LB. (4.4 N)	D - MIN DIAM = 1.0" (2.54 CM)	H - DISTANCE FROM HEEL REF = 7-10" (17.8-25.4 CM)	C - CLEARANCE TO OBSTRUCTION MIN = 3.0" (7.6 CM)	MIN = 0.5" (1.27 CM) MAX = 2.5" (6.35 CM) FOR BOOTS, INCREASE MIN TO 1.0" (2.54 CM)	S - MIN = 3.0" (7.5 CM)
	FOOT SWITCHES, STAND OPN'S: NORMAL FREQUENT ACTIVATION, SPEED NOT CRITICAL. FORCE REQUIREMENTS: PREFERRED MAX. 20 LB. (88.9 N)	D - MIN BUTTON DIAM = 1.0" (2.54 CM) (LARGER PREFERRED)	—	—	—	—
	EMERGENCY OPERATION, SPEED IMPORTANT	E - EXTENSION MIN = 4.0" (10.2 CM)	L - ACCESSIBLE TO EITHER FOOT, FULL WIDTH OF THE EXPECTED WORK ENVELOPE	C - CLEARANCE BENEATH UNDEPRESSED BAR FOR TOE, MIN = 2.5" (6.4 CM) OR 3.0" (7.6 CM) WITH BOOTS	—	N/A

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
foot" position when the operator's heel rests normally on the floor, and the accelerator pedal is in the "undepressed" position. Lateral pedal positions should be arranged and spaced so that the total array is approximately centered on the operator's centerline (i.e., so the operator is not required to sit in a skewed position in order to operate certain pedals). For maximum, long-duration comfort, the accelerator pedal should not be more than about 12-inches right of the operator's centerline. 5.4.5.2.3.4.3 Lateral Pedal Array Limits - Lateral spacing of individual pedals shall conform to criteria in Table ____. However, the overall array shall not exceed 30" (76.2 cm) as measured between the outermost pedal centerlines without express approval by the procuring agency.	

ORIGINAL REQUIREMENT	MF-1 COMMENTS
5.4.4 High-Force Controls - 5.4.4.1 Arm, Hand, and Thumb-Finger Controls - Where arm, hand and thumb-finger controls requiring high control forces are to be used, the maximum force requirements shall not exceed those specified in Figure 15. 5.4.4.2 Leg Controls - Where leg controls requiring high control forces are to be used the force push exerted by the leg depends on the thigh angle and the knee angle. Figure 16 specifies the mean maximum push at various knee and thigh angles. The maximum push is at about the 160° angle referred to as the limiting angle.	A general requirement statement is needed.

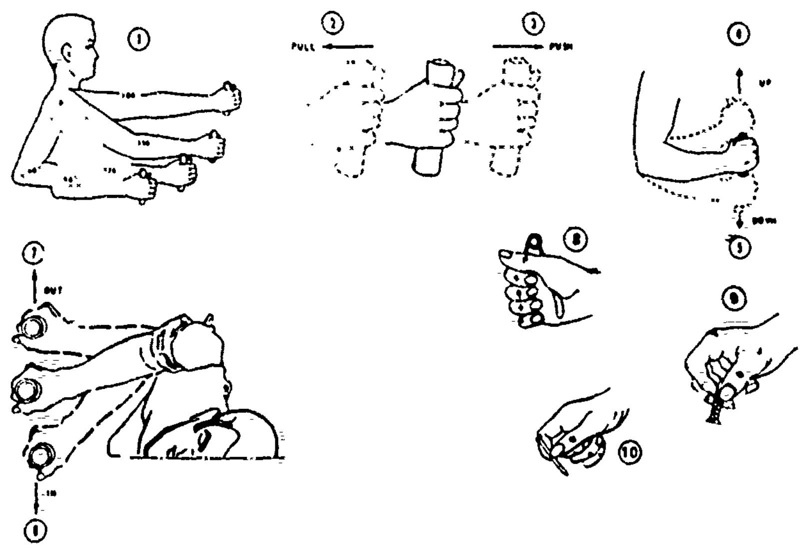


ARM STRENGTH (Lb)												
(1)	(2)		(3)		(4)		(5)		(6)		(7)	
DEGREE OF ELBOW FLEXION (deg)	PULL		PUSH		UP		DOWN		IN		OUT	
	L	R*	L	R	L	R	L	R	L	R	L	R
180	50	52	42	50	9	14	13	17	13	20	8	14
150	42	56	30	42	15	18	18	20	15	20	8	15
120	34	42	26	36	17	24	21	26	20	22	10	15
90	32	37	22	36	17	20	21	26	16	18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

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

*L = LEFT; R = RIGHT

Figure 15. ARM, HAND, AND THUMB-FINGER STRENGTH (5TH PERCENTILE MALE DATA)

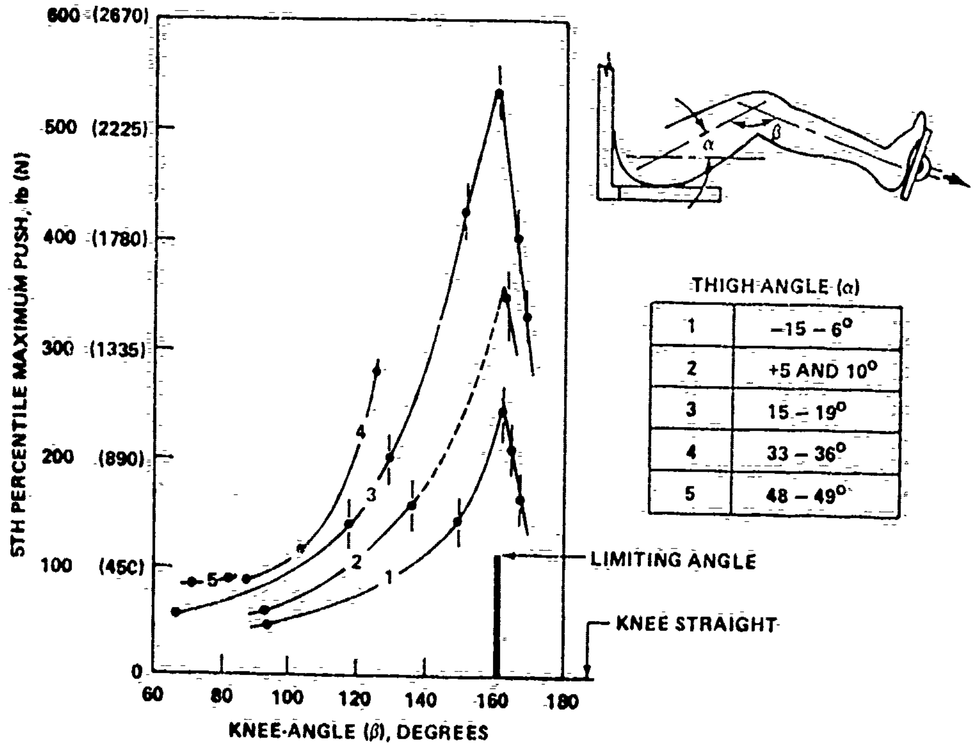


ARM STRENGTH (N)													
(1)	(2)		(3)		(4)		(5)		(6)		(7)	
DEGREE OF ELBOW FLEXION (deg)	PULL		PUSH		UP		DOWN		IN		OUT	
	L	R*	L	R	L	R	L	R	L	R	L	R
180	222	231	187	222	40	62	58	76	58	89	36	62
150	187	249	133	187	67	80	80	89	67	89	36	67
120	151	187	116	160	76	107	93	116	89	98	45	67
90	142	165	98	160	76	89	93	116	71	80	45	71
60	116	107	98	151	67	89	80	89	76	89	53	76

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

*L = LEFT; R = RIGHT.

Figure 15. ARM, HAND, AND THUMB-FINGER STRENGTH (5TH PERCENTILE MALE DATA)(CONCLUDED)

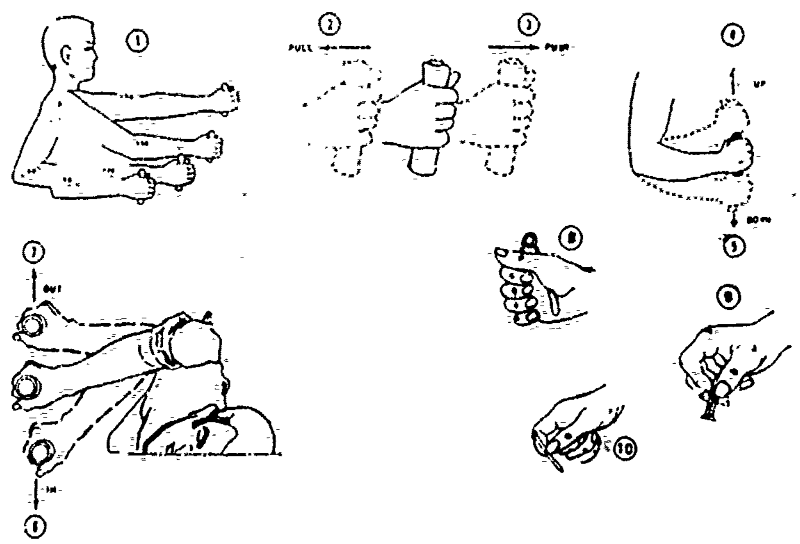


THIGH ANGLE (α)

1	−15 – 6°
2	+5 AND 10°
3	15 – 19°
4	33 – 36°
5	48 – 49°

Figure 16. LEG STRENGTH AT VARIOUS KNEE AND THIGH ANGLES

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.4.5.2.4 High-Force Controls	
5.4.5.2.4.1 Use - In general, controls shall not be used that require operator forces near the strength limits of the weaker segment of the expected user population. In addition, high force controls shall not be used except when the operator's nominal working position provides proper body and/or limb support, i.e., a proper seat backrest, adequate foot support, etc. Sustained high force requirements shall be avoided (e.g., durations longer than 2 or 3 seconds).	Adds a general requirement statement; includes strength limits (as with female operators) not previously recognized; requires proper body support and avoidance of long durations for sustained high force.
5.4.5.2.4.2 Arm, Hand, and Thumb-Finger Controls - [Use original material from par. 5.4.4.1.]	
5.4.5.2.4.3 Foot-Leg Controls - [Use original material from par. 5.4.4.2.]	



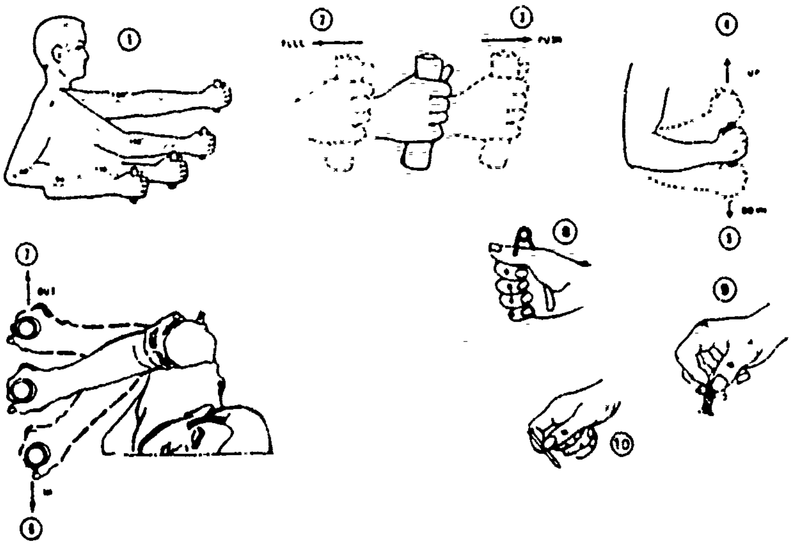
ARM STRENGTH (N)														
(1)	(2)		(3)		(4)		(5)		(6)		(7)	
DEGREE OF ELBOW FLEXION (deg)	PULL		PUSH		UP		DOWN		IN		OUT	
	L	R*	L	R	L	R	L	R	L	R	L	R
180	222	231	187	222	40	62	58	76	58	89	36	62
150	187	249	133	187	67	80	80	89	67	89	36	67
120	151	187	116	160	76	107	93	116	89	98	45	67
90	142	165	98	160	76	89	93	116	71	80	45	71
60	116	107	98	151	67	89	80	89	76	89	53	76

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

*L = LEFT; R = RIGHT.

Figure 15. ARM, HAND, AND THUMB-FINGER STRENGTH (5TH PERCENTILE MALE DATA)(CONCLUDED)

Note: Where female operators are expected, force values should be reduced by 25 percent.



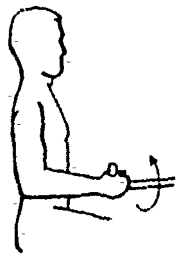
ARM STRENGTH (Lb)													
(1)	(2)		(3)		(4)		(5)		(6)		(7)	
DEGREE OF ELBOW FLEXION (deg)	PULL		PUSH		UP		DOWN		IN		OUT	
	L	R*	L	R	L	R	L	R	L	R	L	R
180	50	52	42	50	9	14	13	17	13	20	8	14
150	42	56	30	42	15	18	18	20	15	20	8	15
120	34	42	26	36	17	24	21	26	20	22	10	15
90	32	37	22	36	17	20	21	26	16	18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

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

*L = LEFT; R = RIGHT

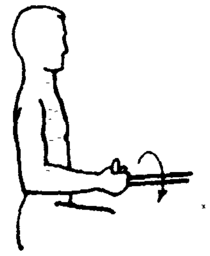
Figure 15. ARM, HAND, AND THUMB-FINGER STRENGTH (5TH PERCENTILE MALE DATA)

Note: Where female operators are expected, force values should be reduced by 25 percent.



A

Supination



B

Pronation

MAXIMUM, ONE-HAND STATIC TORQUE CAPABILITY FOR MEN & WOMEN

	MALE POP, MEAN (STD. DEV.)		FEMALE (5th %-tile)	
	Nm	in-lb	Nm	in-lb
A	13.7 (3.4)	121.5 (30.1)	6.7	60.0
B	17.4 (5.1)	153.9 (45.0)	7.9	70.0

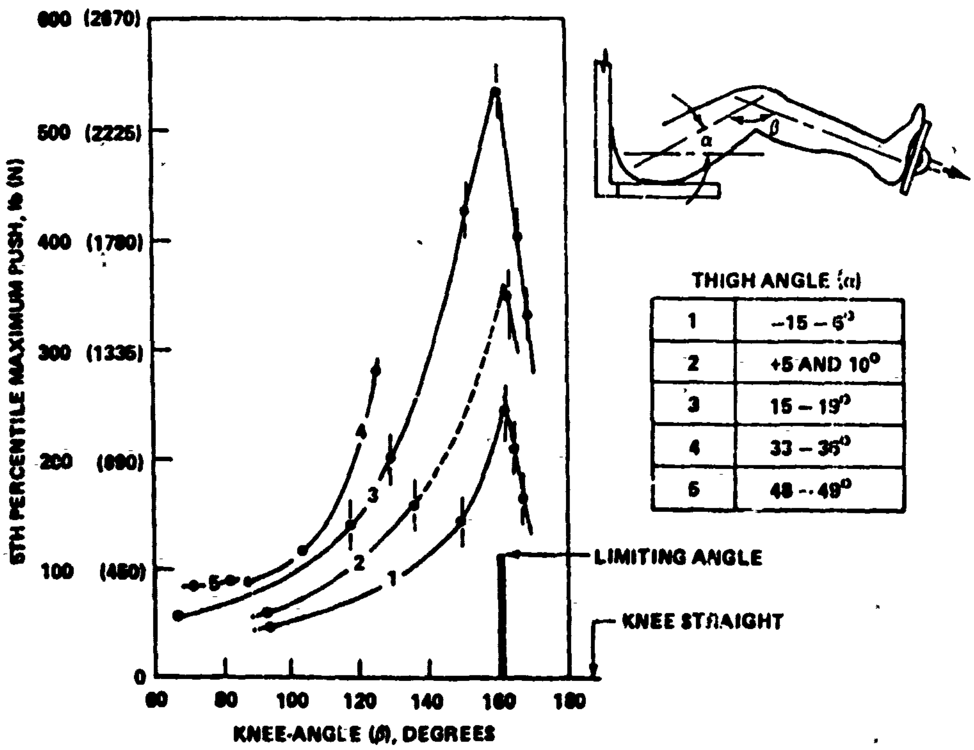


Figure 16. LEG STRENGTH AT VARIOUS KNEE AND THIGH ANGLES

Note: Where female operators are expected, force values should be reduced by 25 percent.

ORIGINAL REQUIREMENT	MFI COMMENTS
5.5 LABELING -	This section needs considerable expansion to broaden coverage to include markings other than labels and to provide more definitive requirements with respect to alphanumeric character design and legibility.

5.5 LABELING -

5.5.1 General -

5.5.1.1 General Requirements - Controls, displays, and any other items of equipment that must be located, identified, read, or manipulated shall be appropriately and clearly labeled to permit rapid and accurate human performance. No label will be required on equipment or controls whose use is obvious to the user (e.g., aircraft control stick).

5.5.1.2 Label Characteristics - The characteristics of the labeling to be used shall be determined by such factors as:

a. The accuracy of identification required

b. The time available for recognition or other responses

c. The distance at which the labels must be read

d. The illumination level and color characteristics of the illuminant

e. The criticality of the function labeled

f. Consistency of label design within and between systems.

5.5.1.3 Prototype and Production Equipment Labels - Labels for both prototype and production equipment shall meet the criteria specified herein. Labels for production equipment shall be designed to meet the criteria specified for the duration of equipment use. Since frequent design changes may be anticipated in prototype equipment, labels for such equipment shall be designed so that they may be simply and easily affixed, altered, and removed.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.5 LABELS, LEGENDS, PLACARDS, SIGNS and MARKING 5.5.1 General 5.5.1.1 General Requirements - Labels, legends, placards, signs and/or markings shall be provided wherever it is necessary for an operator or technician to identify, interpret, follow procedures or avoid hazards in the use of systems, equipment or facilities, except where it is obvious to the observer what an item is and what he or she is to do with it or about it. 5.5.1.2 Basic Characteristics - The characteristics of the label, legend, placard, sign or marking shall be determined by such factors as: a. The accuracy of identification required. b. The time available for recognition or other responses. c. The distance at which the device must be read. d. The illumination level and color characteristics of the illuminant. e. The criticality of the label, legend, placard, sign or marking to satisfactory and safe operator performance. f. Consistency of label, legend, placard, sign or marking within and between systems. 5.5.1.3 Prototype and Production Systems - Labels, legends, placards, signs and markings for both prototype and production systems shall meet the criteria specified herein. They shall meet the requirements specified for the duration of system use. Since frequent design changes may be anticipated in prototype systems, labels, legends, placards, signs and markings should be designed so that they may be simply and easily affixed, altered, and removed or replaced.	This section broadens the original provisions so as to include legends, placards, signs, and markings which need to be covered but are not included elsewhere in the Standard.

ORIGINAL REQUIREMENT	MFI COMMENTS
5.5.2 Orientation and Location -	
5.5.2.1 Orientation - Labels and information thereon should be oriented horizontally so that they may be read quickly and easily from left to right. Vertical orientation shall be used only when labels are not critical for personnel safety or performance and where space is limited. When used, vertical labels shall read from top to bottom.	
5.5.2.2 Location - Labels shall be placed on or very near the items which they identify, so as to eliminate confusion with other items and labels. Labels shall be located so as not to obscure any other information needed by the operator. Controls shall not obscure labels.	Needs expansion.
5.5.2.3 Standardization - Labels shall be located in a consistent manner throughout the equipment and system.	Although desirable, this should not be mandatory because it is not always feasible.
5.5.3 Contents -	
5.5.3.1 Equipment Functions - Labels should primarily describe the functions of equipment items. Secondarily, the engineering characteristics or nomenclature may be described.	
5.5.3.2 Abbreviations - Standard abbreviations shall be selected in accordance with MIL-STD-12, MIL-STD-411, or MIL-STD-783. If a new abbreviation is required, its meaning shall be obvious to the intended reader. Capital letters shall be used. Periods shall be omitted except when needed to preclude misinterpretation. The same abbreviation shall be used for all tenses and for both singular and plural forms of a word.	More specific requirements as to when to use capitals and when to use lower case should be provided.
5.5.3.3 Irrelevant Information - Trade names and other irrelevant information shall not appear on labels or placards.	Some other standards require trade names to appear.
5.5.4 Qualities -	
5.5.4.1 Brevity - Labels shall be as concise as possible without distorting the intended meaning or information and shall be unambiguous. Redundancy shall be minimized. Where the general function is obvious, only the specific function shall be identified (e.g., frequency as opposed to frequency factor).	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.5.4.2 Familiarity - Words shall be chosen on the basis of operator familiarity whenever possible, provided the words express exactly what is intended. Brevity shall not be stressed if the results will be unfamiliar to operating personnel. For particular users (e.g., maintenance technicians), common technical terms may be used even though they may be unfamiliar to nonusers. Abstract symbols (e.g., squares and Greek letters) shall be used only when they have a commonly accepted meaning to all intended readers. Common, meaningful symbols (e.g., % and +) may be used as necessary.	
5.5.4.3 Visibility and Legibility - Labels and placards shall be designed to be read easily and accurately at the anticipated operational reading distances, vibration/motion environment, and illumination levels, taking into consideration the following factors: a. Contrast between the lettering and its immediate background b. Height, width, stroke width, spacing, and style of letters and numerals c. Method of application (e.g., etching, decal, and silk screen) d. Relative legibility of alternative words e. Specular reflection.	
5.5.4.4 Access - Labels shall not be covered or obscured by other units in the equipment assembly.	Needs to be more specific.
5.5.4.5 Label Life - Labels shall be sharp, have high contrast, and be mounted so as to minimize wear or obscurement by grease, grime, or dirt.	
5.5.4.6 Label Background - Label color shall contrast with the equipment background specified in 5.7.9. No special background for the label shall be provided without approval by the procuring activity.	
5.5.5 Design of Label Characters -	
5.5.5.1 Black Characters - Where the ambient illuminance will be above 1 ft-C (11 lux), black characters shall be provided on a light background.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.5.5.2 Dark Adaptation - Where dark adaptation is required, the displayed letters or numerals shall be visible without interfering with night vision requirements. Where possible, markings shall be white on a dark background.	
5.5.5.3 Style - Style of label characters shall conform to MIL-M-18012, where consistent with 5.5.5.4, 5.5.5.5, 5.5.5.7, and 5.5.5.8, herein. Labels shall be prepared in capital letters, except that extended copy (e.g., instructions) shall be in lower-case letters.	This is too limiting.
5.5.5.4 Letter Width - The width of letters shall preferably be 3/5 of the height, except for the "I", which shall be one stroke in width, and the "M" and "W", which shall be 4/5 of the height.	
5.5.5.5 Numeral Width - The width of numerals shall preferably be 3/5 of the height, except for the "4", which shall be one stroke width wider, and the "1", which shall be one stroke in width.	
5.5.5.6 Wide Characters - Where conditions indicate the use of wider characters, as on a curved surface, the basic height-to-width ratio may be increased to 1:1 in accordance with MIL-M-18012.	
5.5.5.7 Stroke Width, Normal - For black characters on a white (or light) background, the stroke width shall be 1/6 of the height.	This does not recognize variations in stroke width for emphasis.
5.5.5.8 Stroke Width, Dark Adaptation - Where dark adaptation is required or legibility at night is a critical factor, and white characters are specified on a black background, the stroke width of the characters shall be from 1/7 to 1/8 of the height (i.e., narrower than specified for normal daytime vision).	
5.5.5.9 Character Spacing - The minimum space between characters shall be one stroke width.	This requirement does not cover variations from the minimum.
5.5.5.10 Word Spacing - The minimum space between words shall be the width of one character.	
5.5.5.11 Line Spacing - The minimum space between lines shall be one-half character height.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.5.5.12 Label Size vs Luminance - The height of letters and numerals shall be determined by the required reading distance and luminance. With a 28-inch (700 mm) viewing distance, the height of numerals and letters shall be within the range of values in Table X for "low" and "high" control-display luminance conditions.	
5.5.5.13 Character Height and Viewing Distance - For general dial and panel design, with the luminance normally above 1 ft-L (3.4 cd/m^2), character height should approximate the values given below for various distances:	
Viewing Distance — Height	
a. 20 inches (510 mm) or less — 0.09 (2.3 mm)	
b. 20 - 36 inches (510 - 910 mm) — 0.17 (4.3 mm)	
c. 36 - 72 inches (910 mm - 1.830 m) — 0.34 (8.6 mm)	
d. 72 - 144 inches (1.830 - 3.660 m) — 0.68 (17 mm)	
e. 144 - 240 inches (3.660 - 6.100 m) — 1.13 (29 mm)	
5.5.6 Equipment Labeling -	
5.5.6.1 Assemblies, Components, and Parts -	
5.5.6.1.1 General Requirements - Each assembly, component, and part shall be labeled with a clearly visible, readable, and meaningful name, number, or symbol.	Not necessarily desirable. The functions of some components are so obvious as to preclude necessity for labeling.
5.5.6.1.2 Location - The gross identifying label on an assembly or major component shall be located: a. Externally in such a position that it is not obscured by adjacent assemblies or components b. On the flattest, most uncluttered surface available c. On a main chassis of the equipment d. In a way to minimize wear or obscurement by grease, grime, or dirt	

TABLE X. LABEL SIZE VERSUS LUMINANCE

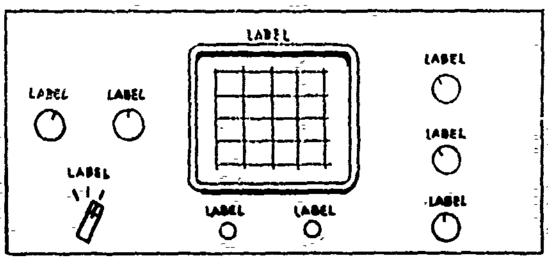
MARKINGS	HEIGHT*	
	BELOW 1 ft-L ($3.4\ cd/m^2$)	ABOVE 1 ft-L ($3.4\ cd/m^2$)
For critical markings, with position variable (e.g., numerals on counters and settable or moving scales):	0.20–0.30" (5 – 7.5 mm)	0.12–0.20" (3 – 5 mm)
For critical markings, with position fixed (e.g., numerals on fixed scales, controls, and switch markings, or emergency instructions):	0.15–0.30" (3.8 – 7.5 mm)	0.10–0.20" (2.5 – 5 mm)
For noncritical markings (e.g., identification labels, routine instructions, or markings required only for familiarization):	0.05–0.20" (1.3 – 5 mm)	0.05–0.20" (1.3 – 5 mm)

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

ORIGINAL REQUIREMENT	MFI COMMENTS
e. In a way to preclude accidental removal, obstruction, or handling damage. 5.5.6.1.3 Terms - Components, circuits, or assemblies shall be labeled with terms descriptive of the test or measurement applicable to their test points (e.g., demodulator rather than crystal detector and power amplifier rather than bootstrap amplifier). 5.5.6.1.4 Other Criteria - In addition to the criteria herein, equipment labels and placards shall conform to MIL-STD-129, MIL-STD-130, MIL-STD-195, MIL-STD-411, MIL-STD-783, and MIL-STD-1247, as applicable. 5.5.6.2 Controls and Displays - 5.5.6.2.1 General Requirements - Controls and displays shall be appropriately and clearly labeled with the basic information needed for proper identification, utilization, actuation, or manipulation of the element. Integrally illuminated panels shall comply with MIL-P-7788. 5.5.6.2.2 Simplicity - Displays and controls shall be labeled in the simplest and most direct manner possible. Abbreviations may be used when they are familiar to operators (e.g., psi, g/cm^2). 5.5.6.2.3 Functional Labeling - Each control and display shall be labeled according to function, and the following criteria shall apply: a. Highly similar names for different controls and displays shall be avoided. b. Instruments shall be labeled in terms of what is being measured or controlled taking into account the user and purpose. c. Control labeling shall indicate the functional result of control movement (e.g., increase) and may include calibration data where applicable. Such information shall be visible during normal operation of the control. d. When controls and displays must be used together (in certain adjustment tasks), appropriate labels shall indicate their functional relationship.	

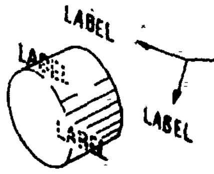
ORIGINAL REQUIREMENT	MFI COMMENTS
5.5.6.2.4 <u>Location</u> - The following criteria shall apply to the location of control and display labels.	
a. Ease of control operation shall be given priority over visibility of control position labels.	
b. Labels should normally be placed above the controls and displays they describe. When the panel is above eye level, labels may be located below if label visibility will be enhanced thereby.	
c. The units of measurement (e.g., volts, psi, meters) shall be located on the panel.	
d. Labels shall be used to identify functionally grouped controls and displays. The labels shall be located above the functional groups they identify. When a line is used to enclose a functional group and define its boundaries, the label shall be centered at the top of the group either in a break in the line or just below the line. When colored pads are used, the label shall be centered at the top within the pad area.	
e. Label location throughout a system and within panel groupings shall be uniform.	Too restrictive.
5.5.6.2.5 <u>Size Graduation</u> - To reduce confusion and operator search time, labels shall be graduated in size. The characters used in group labels shall be larger than those used to identify individual controls and displays. The characters identifying controls and displays shall be larger than the characters identifying control positions. With the smallest character determined by viewing conditions each label shall be at least approximately 25 percent larger than the next smaller label.	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.5.2 <u>Orientation and Location</u>	
5.5.2.1 <u>Orientation</u> - Alphanumeric characters and symbols shall appear "upright" to the observer so they are easily recognized and read in the normal manner left to right. Vertical arrangements of words for labels or signs shall be used only when these are not critical for personnel safety or task performance, and where space is limited. When used, vertical labels shall read from top to bottom.	
5.5.2.2 <u>Location</u> - Labels, legends, placards, signs and markings shall be positioned so that they are visible from the nominal or expected observer's viewpoint reference when he or she needs to see them, i.e., the observer should not have to assume an unusual position in order to see a label, nor should an observer have to wait to get past an obstacle or other persons in order to see a sign. Labels shall be placed on or very near the items which they identify, so as to eliminate confusion with other items and labels. Labels shall be located so as not to obscure other information needed by the operator, and shall be placed where a control or operator's normal hand or arm position will not obscure the label (see Figure______).	Includes normal operator position as a factor in placement of labels.
5.5.2.3 <u>Standardization</u> - Labels, legends, placards, signs and markings should be located in as consistent a manner as practical throughout a system, equipment or facility.	Emphasizes desirability of standard label location but removes mandatory requirement.



Locate labels consistently "above" or "below" a control or display on a given panel ("above" is preferred except when the panel is located considerably above the observer's eye level).

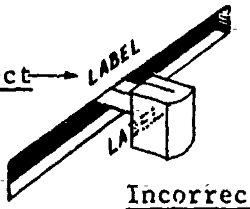
Incorrect



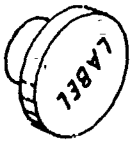
Correct

Locate label so that a control handle will not obscure the label.

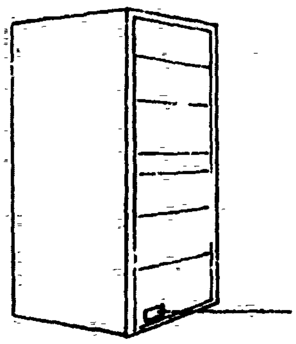
Correct



Incorrect



Do not place label on a control that could rotate the label to an upside-down position.



Poor

Do not place placards near the floor or other positions that preclude the observer from getting his or her eyes in a position adequate for reading the placard.

Figure ____ - Location and Position of Labels

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES

5.5.3 Content

5.5.3.1 Equipment Functions - Labels should primarily describe the functions of equipment items, and in terms that the typical operator, technician or other observer understands. Engineering characteristics, nomenclature or other terminology shall only be used when a commonly-understood term is not available.

5.5.3.2 Abbreviations - Standard abbreviations shall be selected in accordance with MIL-STD-12, MIL-STD-411, or MIL-STD-783 where appropriate. However, when the above references specify the same abbreviation for more than one function, such abbreviation shall not be used for more than one function on the same equipment panel. If a new abbreviation is required, its meaning shall be obvious to the intended observer.

5.5.3.3 Capital vs Lower-Case Letters and Punctuation - The following shall be observed relative to use of capital or lower-case letters and punctuation marks:

a. Labels shall be printed in all caps, and periods shall not be used after abbreviations.

b. Legends shall be printed in all caps, and periods or commas shall not be used.

c. Placards (e.g., instructional material) may employ caps and lower case when the amount of material consists of several lines. However, for short instructional material all-caps are preferred. An acceptable all-cap approach may also include use of larger caps for the initial letter in a paragraph or separate line of instruction or procedural step (see Figure____).

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

Provides the definitive requirements on capitalization and punctuation necessary for consistency of usage.

Ref: Woodson and Conover, Human Engineering Guide for Equipment Designers, 1966, p. 2-39.

TO EJECT

FOR EMERGENCY EJECTION IN FLIGHT JETTISON CANOPY BY PULLING CANOPY JETTISON HANDLE. HOOK HEELS IN STIRRUPS. RAISE BOTH ARM RESTS TO HORIZONTAL POSITION. ASSUME ERECT POSTURE. ACTUATE EJECT HANDLE.

Poor: Too long; procedural steps run together.

TO EJECT

- JETTISON CANOPY
- FEET IN STIRRUPS
- RAISE ARM RESTS
- SIT ERECT
- PULL EJECT HANDLE

Preferred: Short, each step on separate line.

Figure _____ - Example Instruction Placard Formatting and Type Style

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.5.3.4 <u>Irrelevant Information</u> - Non-operational information shall not appear conspicuously on the face of instruments, e.g., trade names, manufacturer specification numbers, etc.; if required, such markings shall be subdued by small size, reduced contrast, and/or inconspicuous location so the operator's attention is not drawn away from critical instrument markings.	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.5.4 Qualities	
5.5.4.1 Brevity - As few words as necessary to convey the intended meaning shall be used on labels, legends, placards and signs. Special marking and/or symbols shall be considered when they will unambiguously convey meaning in a more direct manner than several words, e.g., pictorials, arrows.	Introduces usage of symbols where they may be more clear than words.
5.5.4.2 Familiarity - Words and symbols shall be chosen on the basis of user familiarity whenever possible, provided the words or symbols express exactly what is intended. Engineering or other technical terms shall be used only when such terms are familiar to the specific designated user. (Common technical terms or symbols do not have to be familiar to casual, nonusers.) Common, meaningful symbols (e.g., % and +) may be used as necessary. Abstract symbols (e.g., Greek letters) shall be used only when they have a commonly accepted meaning to all intended users.	
5.5.4.3 Understandability - Extended instructional or procedural information for placards and signs shall be concise, but understandable to the intended user. The following shall be considered a. Omit words that are not absolutely necessary to convey the meaning of the message. b. When procedural steps are implied, place each procedural step on a separate line, and include numbers, dots or other techniques to emphasize the beginning of each step. (See Figure_____.) c. Use acronyms only sparingly, and when it is known that they are familiar to the intended user. d. Avoid use of instructions that require reference to another, perhaps unavailable resource (e.g., technical manual). Such reference may however be used for placards that pertain only to a depot maintenance situation, and where resource materials are typically available.	New requirements needed for placards and signs, based on professional judgment.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.5.4.4 Visibility and Legibility - Labels, legends, placards, signs and markings shall be designed to be read easily and accurately at the anticipated operational reading distances, vibration/motion environment, and illumination levels, taking into consideration the following factors: a. Contrast between the lettering and its immediate background. b. Height, width, stroke width, spacing, and style of letters and numerals, and/or size of detail for other abstract or pictorial symbols. c. Method of application (e.g., etching, engraving, decal, silk screen). d. Relative legibility of alternate words. e. Specular reflection.	
5.5.4.5 Consistency - When function and application is identical words or abbreviations used shall be identical, i.e., slightly different words shall not be used to identify several controls or displays that actually are identical. Conversely, the same words shall not be used to identify two or more controls or displays when these are not functionally identical.	New requirement to ensure consistency throughout the system.
5.5.4.6 Label Background - Label background colors shall contrast visually with equipment background specified in 5.7.9. No special additional background for the label shall be used on the equipment without approval of the procuring activity. Placards or signs that include their own independent background shall provide maximum contrast between the lettering and immediate background. Shiny metallic backgrounds should not be used for operational labels, placards, signs or marking.	Adds a prohibition on use of shiny metallic backgrounds for labels.
5.5.4.7 Label Life - Characters, markings, and symbols on labels, legends, placards, and signs shall remain sharp, have high contrast, and be mounted so as to minimize the degrading effects of wear or obscurement by grease, grime or dirt.	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.5.4.8 Access - Labels shall be placed on the outside of equipment covers to identify control, display or other functions located within a covered compartment. 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 nominal viewing position of the technician, i.e., when labels are attached during bench assembly (as opposed to attachment when lines or cables are assembled on the equipment), labels shall be oriented for the benefit of the eventual field technician, not the factory assembler. Both ends of a cable or line shall be labeled, and the connector elements shall also contain appropriate matching labels.	Adds specific requirements for label access by technicians.
5.5.4.9 Label Surface - Whenever practicable, labels, legends, placards or signs shall be placed on a flat surface. If a label must be placed on a curved surface, lettering or symbols shall be completely visible to the observer from his or her nominal vantage point (i.e., portions of characters or symbols shall not disappear due to the size of the symbols and the curvature of the surface.) When the curvature is such that the lettering would become too small to be read, another mode of labeling shall be used, e.g., attached tag, etc.	Adds requirements about the surface on which the label is mounted.
5.5.4.10 Figure-Ground Contrast - [Use original material from par. 5.5.5.1 and 5.5.5.2.]	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.5.5 Design of Letters, Numerals and Symbols 5.5.5.1 Letter/Numeral Design 5.5.5.1.1 Type Style - Letters and numerals shall be of a simple style without serifs except as may be necessary to distinguish between characters which would otherwise be confused (e.g., I and 1). Acceptable styles are shown in Figures ____ and ____. Other specific styles may be acceptable provided they conform generally with the simple style in the illustrated fonts. Capital letters shall be used for labels, legends and short messages (only a few words). Lower case should be used on placards and signs with long messages (e.g., complete text sentences).	This section presents a much more comprehensive and better organized set of requirements for design of letters, numerals, and symbols. 5.5.5.1.1 Less restrictive than 1472B, in allowing characters of simple style without serifs.
5.5.5.1.2 Letter/Numeral Width - The width-to-height ratio shall be between 3:5 and 1:1 for all characters and styles except for the "I" and "1". (The 1:1 ratio is appropriate for use on curved surfaces such as counter drums, small pipes, and cables.)	Ref: McCormick, Human Factors in Engineering and Design, 1976, p. 90.
5.5.5.1.3 Character Stroke Width - When characters are used on a light background, the stroke width shall be approximately 1/6 the height of the character. When light characters are used on a dark background, the stroke width shall be 1/7 to 1/8 the height of the character. Note: The above 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 should be no less than 1/8 nor the thickest character stroke greater than 1/5 respective character heights.	Includes variation of stroke width on signs for emphasis.
5.5.5.1.4 Stroke Continuity - Continuous stroke characters shall be used where applicable and practical for all equipment labels, legends, placards and signs. (For dot or segment pattern alphanumeric characters, see 5.2.6.2.3). Stencil characters may be used for shipping containers. Stencil characters shall not have stroke breaks greater than 1/2 the character stroke width. Stencil stroke widths should conform to requirements in 5.5.5.1.3.	New requirement for stroke continuity, and limiting the breaks in stencil characters.

A B C D E F G
H I J K L M N
O P Q R S T U
V W X Y Z

0 1 2 3 4 5
6 7 8 9

Figure ____ - Numerals and letters for Aircraft Instruments
(MS 33558 - ASG)

1 2 3 4 5
6 7 8 9 0

(MIL-M-18012)

A B C D
E F G H
I J K L
M N O P
Q R S T
U V W X
Y Z

Maximally legible numeral/letter style based on individual character recognition (available in LeRoy lettering guides)

Equipment that must meet ISO standards, refer to ASCC AIR STD 10/6D "Numerals and Letters for Aircrew Station Displays".

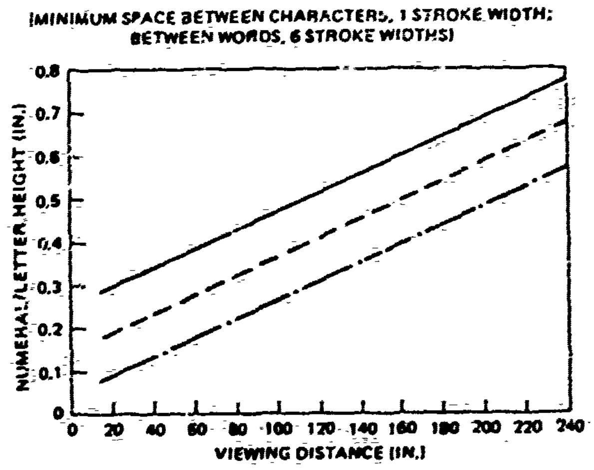
ABCDEFGHIJKLMNOPQRSTUVWXYZ&abcdef
ghijklmnopqrstuvwxyz1234567890$.,"-:;!?"“

News Gothic (Standard printer's type)

ABCDEFGHIJKLMNOPQRSTUVWXYZ&
abcdefghijklmnopqrstuvwxyz 123456789
0$.,-:;'!?

Helvetica (Standard printer's type)

Figure ____ - Examples of Acceptable Letter/Numeral Styles for Use on Instruments, Labels, Legends, Placards, Signs



Letter Height vs Viewing Distance and Illumination Level

(Metric conversion: 1" = 2.54 cm)

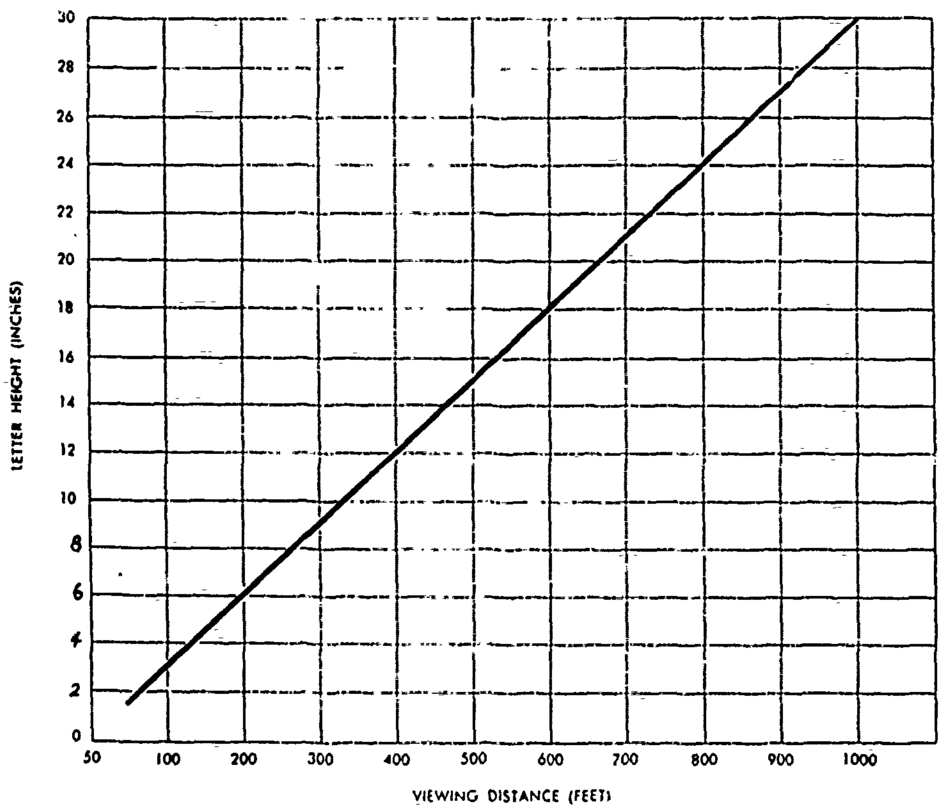
—— FOR INSTRUMENTS WHERE THE POSITION OF THE NUMERALS MAY VARY AND THE ILLUMINATION IS BETWEEN 0.03 AND 1.0 FT-L.

- - - FOR INSTRUMENTS WHERE THE POSITION OF THE NUMERALS IS FIXED AND THE ILLUMINATION IS 0.3-1.0 FT-L OR WHERE POSITION OF THE NUMERALS MAY VARY AND THE ILLUMINATION EXCEEDS 1.0 FT-L.

—·— FOR INSTRUMENTS WHERE THE POSITION OF THE NUMERALS IS FIXED AND THE ILLUMINATION IS ABOVE 1.0 FT-L.

* Note: For Marking of Aircrew Station Displays Ref: MIL-M-18012B.

Figure ____ - Character Height Criteria for Instruments, Panels and Equipment Viewed in Close Proximity



Minimum letter height for 10-foot viewing distance = 0.3 inches. Letter height for longer viewing distances may be computed as follows:

$$\text{Desired letter height} = \frac{\text{Viewing distance (ft)} \times 0.3''}{10}$$

(Metric conversion:
1" = 2.54 cm
1' = 0.3 m)

Figure ____ - Character Height Criteria for Viewing Signs at Extended Distances

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.5.5.2 Character Spacing - The minimum space between characters within a word shall be one stroke width. However, character spacing should be adjusted to provide an appearance of "open area balance" within single words, i.e., when adjacent vertical strokes between adjoining characters are compared to adjacent characters in which vertical components are far apart the word will appear to be properly spaced. In such cases it is recommended that the space between adjacent vertical strokes be slightly wider than between vertical/horizontal or horizontal/horizontal strokes.	Clarifies the criteria for character spacing. Ref: Woodson, Handbook of Human Factors Engineering Data, Ch. 3, p. 44, (in press).
5.5.5.3 Word Spacing - The preferred space between words is the width of one character (except for "I" or "1"). Minimum spacing between words shall be 1/2 the width of one character.	
5.5.5.4 Confusion Between 'I', '1' and 'L' and Between '0' and 'O' When a label, legend, placard or sign contains characters which might be confused between one another, they should be made distinguishably different as follows: a. The lower case letter 'L' should have a tab at the lower end extending to the right. b. The numeral '1' should have a tab at the upper end extending to the left. c. The numeral zero should appear narrower than the letter 'O' of a given font.	New requirements to preclude confusion between certain character pairs.
5.5.5.5 Line Spacing - [Use original material from par. 5.5.5.11]	
5.5.5.6 Character Height - Character height for labels, legends, and signs shall be determined on the basis of criteria in Figures ______ and ______.	
5.5.5.7 Pictorials - Pictorial symbols may be used in place of certain, one- or two-word labels, and/or in addition to a word label when the pictorial provides quicker operator response (i.e., the observer can grasp the meaning faster than would occur in reading a word or words). Pictorials shall be completely unambiguous under the expected visual operating environments (i.e., the	Introduces coverage of pictorials, not included in 1472B.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
size provides sufficient descrimination of symbol detail, and adequate ambient or internal illumination is provided). Pictorials should not be used on a control that may rotate and thus position the symbol so that it may be confusing. Pictorials for automotive equipment shall conform to requirements in Federal Motor Vehicle Standard (FMVSS-101). Other pictorials shall be subject to approval by the procuring activity.	FMVSS-101 "Control Location, Identification and Illumination". Standards established by SAE Driver Controls Standardization Committee.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.5.5.8 Borders - There shall be sufficient clear space between characters and words used for labeling or signing to prevent the label from appearing crowded and in some cases difficult to read. The minimum clearance around a character or word shall be 1/2 character height, preferably more. On the other hand clearance around a character or word or set of words should not make the label appear "lost" within a large expanse of background, i.e., the label should be appropriately framed to aid the observer in focusing on the character or words. No performance limits have been established for maximum clearance around a label.	New material on requirements for clearance around labels.
5.5.6 Equipment Labeling 5.5.6.1 Assemblies, Components, and Parts 5.5.6.1.1 General Requirements - Each assembly, component, and part shall be labeled with obvious exceptions (i.e., carrying handles, panel fasteners, equipment locks, door handles, and/or vehicle steering wheel, aircraft joystick, etc.). All labels shall conform to requirements herein with regard to visibility, readability and meaningfulness. 5.5.6.1.2.1 Cabinets - When several equipment cabinets are located in a single work area, each cabinet should be labeled to aid the operators and other personnel in quickly identifying what each equipment cabinet is, i.e., radar unit, communications unit, computer, etc. Such identification labels shall be located in a conspicuous position considering the typical observation points from which each equipment should be identifiable. Primary cabinet labels should be located in as consistent a manner as practicable so that observers do not have to hunt for the label. The size of the material on each label shall be consistent with viewing distance requirements. 5.5.6.1.2.2 Panels - Where applicable, each panel within a given equipment or console shall be labeled if the panel must be identified from others, i.e., when a given panel integrates a specific operating function as distinct from another panel, a general system or subsystem identification label shall be provided.	Systematically covers requirements for labeling for typical applications such as parts, panels, cabinets, etc.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.5.6.1.2.3 Sub Functions - When sub-function areas on a single panel must be easily and quickly differentiated from other areas on the panel, the sub-function area should have a label approximately "centered" above the sub-function area. When the shape of the components within the sub-function area is not uniform, consideration should be given to surrounding the area with a suitable border to define the limits of the sub-function area. 5.5.6.1.2.4 Cabinet, Panel, Sub-Function and Component Label Differentiation - Labels for identifying a prime equipment cabinet vs panels, sub-functions on a panel, and individual panel components should be differentiable in terms of the label size (e.g., letter height). The size encoding should progress as follows: a. Largest label size for the prime equipment. b. Next largest label for individual panels. c. Next largest label for sub-function areas within a panel. d. Smallest label for individual components, e.g., displays, controls. Note: Label sizes shall be compatible with expected viewing distances. However, to provide discriminable differences among label sizes, each label character height should be at least 20 percent (25 percent is preferred) larger or smaller than the next function level. (Refer to example, Figure _____).	

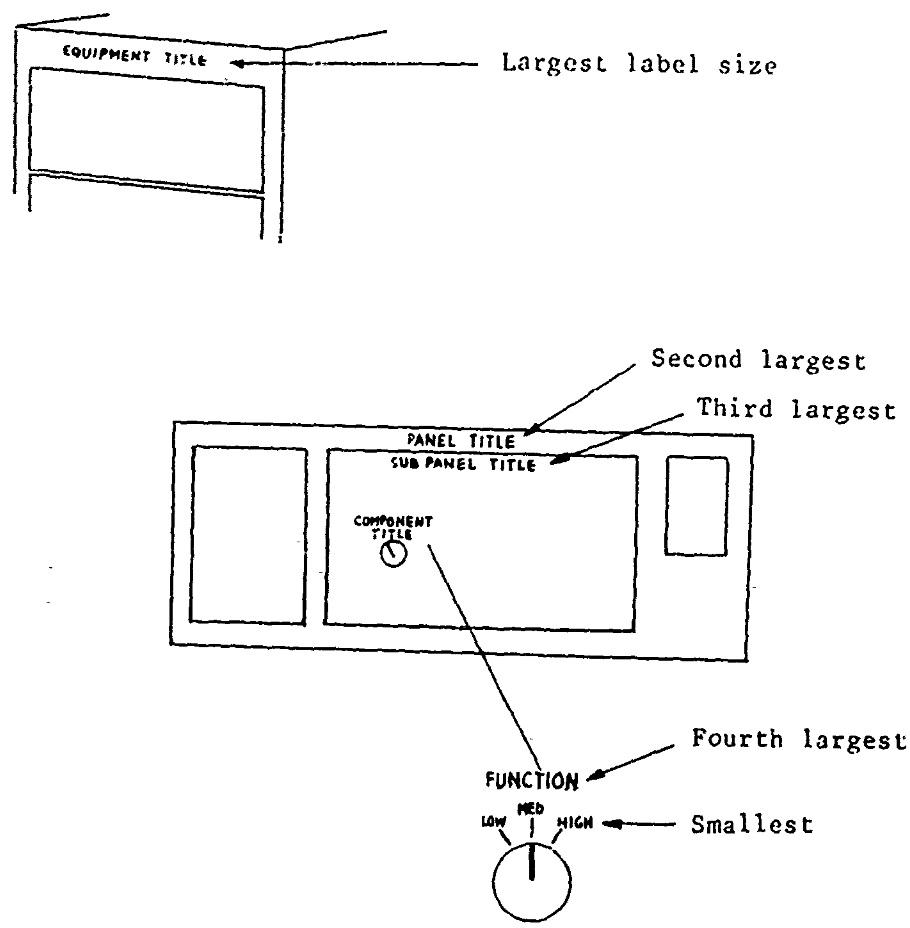


Figure ____ - Label Size-Hierarchy Example for Equipment, Panel, Subpanel and Component Identification

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.5.7 <u>Control-Display Labeling</u>	
5.5.7.1 <u>General Requirements</u> - [Use material from original par. 5.5.6.2.1.]	
5.5.7.2 <u>Simplicity</u> - [Use material from original par. 5.5.6.2.2.]	
5.5.7.3 <u>Functional Labeling</u> - [Use material from original par. 5.5.6.2.3.]	
5.5.7.4 <u>Location</u> - The following shall apply to the location of control and display labels.	
a. Ease of control operation shall be given priority over visibility of control position labels.	
b. Labels may be located either on the control or display and/or on the panel adjacent and above the control or display as appropriate. However, consideration shall be given to an alternate label position relative to the control if the control and/or the operator's hand will obscure the label, i.e., if the display or control is above the operator's eye level it may be more appropriate to locate a particular label below the display or control. (See also 5.5.2.2 and 5.5.2.3.)	
c. The units of measurement (e.g., volts, psi, meters) associated with a display should be located on the face of display; but for a control they should be on the panel adjacent to the control.	
d. [Use original material from par. 5.5.6.2.4 (d).]	
e. Label location throughout a system and within panel groupings shall be as uniform as is practicable.	Recognizes that there may be exceptions to absolutely uniform locations.
5.5.7.5 <u>Size Graduation</u> - Size graduation should be used when a control has both an identifying label and sub-labels and/or numerical graduations (see 5.5.6.1.2.4).	The size graduations were specified as part of the requirements for labeling different sizes of equipment items in 5.5.6.1.2.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.5.8 Hazard Signing and Marking - Appropriate signing and marking of all potential hazards to personnel shall be provided. The following shall be considered: a. Fixed physical obstructions (i.e., low overheads, open hatches or manholes, posts, guard rails, etc.). b. Moving hazards (i.e., conveyor belts, chains, gears, loaders, cranes, booms, etc.). c. Equipment contact hazards (i.e., high voltage, high temperature, etc.). d. Radiation hazards (i.e., electromagnetic, nuclear). e. Laser beam. f. Toxic contaminants (substances and gases). g. Flash or high intensity light. h. Requirement for safety glasses. i. High noise or blast. j. Requirements for hard hats. k. Explosives. l. High pressure containers, hose, etc. m. Slipping and falling hazards. n. Other (i.e., Fire, First Aid, rescue, e.g., "cut-here" aircraft fuselage marking, "NO STEP", etc.).	New material covering signs for hazardous situations.
5.5.8.1 Color Coding - Surface colors selected for identification of physical hazards shall conform to criteria in Table ____.	Ref: Woodson, Handbook of Human Engineering Data, Ch. 3, p. 88, (in press).

Table____ Surface Colors for Identification Coding

Application	Color*
Red is the basic color for fire (e.g., alarm boxes, extinguishers, buckets, etc.), danger (e.g., cans with flammable contents, safety pin streamers, signs, etc.), "stop" (bars on hazardous machinery, switches, signs, etc.), and emergency (equipment shut-down switches, police lights, etc.).	Red - 11105
Orange is also used for dangerous conditions; e.g., hazardous moving parts of machines, starting switches, machinery, levers inside of guards for gears, chains, cutting edges, and pulleys, starting buttons, etc.	Orange - 12246
Yellow is the basic color used for designating caution and marking physical hazards that might cause a person to stumble, trip, fall, collide, etc. Yellow and black stripes are usually recommended for mobile equipment, covering on guy wires, unguarded platforms, pillars and columns, and emergency controls used with red lighting (e.g., landing gear emergency handles, ejection seat handles, etc.).	Yellow - 13655
Green is the basic color used for designating safety and first-aid equipment (survival kits, first-aid kits, stretchers, etc.).	Green - 14187
Blue is another color used to designate caution; it is generally limited to warning against starting or using equipment under repair (barrier flags or signs for elevators, ovens, boilers, etc.).	Blue - 15102
Purple is the basic color used to designate radiation hazards. Yellow should be used with purple for tags, labels, and signs for rooms and containers storing radioactive material or for containers and areas contaminated with radioactivity.	Purple - 17142

*FED-STD-595

ORIGINAL REQUIREMENT	MFI COMMENTS
5.7 GROUND WORKSPACE DESIGN REQUIREMENTS -	
5.7.1 General -	
5.7.1.4 Panel Slope - For normal console operation, the slope of the control-display panel surface shall begin at the level of the console shelf.	This is not the most important criterion for establishing departure point for the panel slope.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.7.1.4 Panel Slope - Visual display panels should be oriented to position displays in a convenient orientation for comfortable and parallax-free viewing. The following factors shall be considered in determining the most appropriate panel orientation:	Provides criteria for establishing the departure point for the display panel and its slope.
a. The normal eye reference level.	Professional judgment.
b. The typical head slump angle (see Figure 1).	
c. Whether both a standing and seated observer must have visual access to the display(s).	
d. Whether controls have to be mounted on the same panel.	
e. Whether the panel slope will position displays so that ambient light reflections and/or reflection of the operator in the face of a display will obscure display details.	
f. How far the operator must be away from the panel due to desk area requirements, i.e., for writing, a keyboard or other controls. For typical console-panel orientation and dimensions see Figures 24, 25 and 26.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.7.2 Standing Operations - 5.7.2.1 Work Surface - Convenient work surfaces to support job instruction manuals, worksheets, etc., shall be provided for standing operators. Work benches and other work surfaces shall be 36 ±0.5 inches (915 ±15 mm) above the floor, unless otherwise specified. 5.7.2.2 Display Placement, Normal - Visual displays mounted on vertical panels and used in normal equipment operation shall be placed in an area between 41 inches (1.040 m) and 74 inches (1.880 m) above the standing surface. 5.7.2.3 Display Placement, Special - Indicators that must be read precisely and frequently shall be placed in an area between 50 inches (1.270 m) and 69 inches (1.750 m) above the standing surface. 5.7.2.4 Control Placement, Normal - All controls mounted on a vertical surface and used in normal equipment operation shall be located in an area between 34 and 74 inches (860 mm and 1.880 m) above the standing surface. 5.7.2.5 Control Placement, Special - Controls requiring precise or frequent operation and emergency controls shall be mounted between 34 and 57 inches (860 mm and 1.450 m) above the standing surface and no further than 22 inches (560 mm) laterally from the centerline.	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.7.2.2 <u>Display Placement, Typical</u> - Visual displays mounted in standard equipment racks shall be located between 104.1 cm (41 inches) and 188.0 cm (74 inches) above the standing surface.	We assume standard equipment racks would be the typical situation for stand operation.
5.7.2.3 <u>Control Placement, Typical</u> - Controls mounted in standard equipment racks shall be located between 86.4 cm (34 inches) and 188.0 cm (74 inches) above the standing surface.	Conforms to generally to the preferential ranges in MIL-HDBK 759, but allows somewhat greater tolerance from the optimum.
5.7.2.4 <u>Special Applications</u> - Controls requiring precise or frequent operation and/or emergency controls shall be mounted between 86.4 to 144.8 cm (34 to 57 inches) above the standing surface and no further than 55.9 cm (22 inches) laterally from the normally-positioned operator's centerline. Displays requiring precise, frequent readout shall be placed between 127 to 175 cm (50 to 69 inches above the standing surface.	

ORIGINAL REQUIREMENT	MFI COMMENTS
5.7.3 <u>Seated Operations</u> -	
5.7.3.1 <u>Work Surface Width</u> - A lateral workspace of at least 30 inches (760 mm) wide and 16 inches (400 mm) deep shall be provided whenever practicable.	
5.7.3.6 <u>Display Placement, Normal</u> - Visual displays mounted on vertical panels and used in normal equipment operation shall be placed in an area between 6 and 48 inches (150 mm and 1.220 m) above the sitting surface.	
5.7.3.7 <u>Display Placement, Special</u> - Indicators that must be read precisely and frequently shall be placed in an area between 14 and 37 inches (360 and 940 mm) above the sitting surface, and no further than 22 inches (560 mm) laterally from the centerline.	
5.7.3.8 <u>Warning Displays</u> - For "sit" consoles requiring horizontal vision over the top, critical visual warning displays shall be mounted at least 22.5 inches (570 mm) above the sitting surface.	
5.7.3.9 <u>Control Placement, Normal</u> - All controls mounted on a vertical surface and used in normal equipment operation shall be located in an area between 8 and 35 inches (200 and 890 mm) above the sitting surface.	
5.7.3.10 <u>Control Placement, Special</u> - Controls requiring precise or frequent operation shall be mounted between 8 and 30 inches (200 and 760 mm) above the sitting surface.	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.7.3.1 Work Surface Width 5.7.3.1.1 Writing - A minimum area 61 cm wide by 41 cm deep (24 by 16 inches) should be provided when a writing surface is required (the preferred area is greater, i.e., 76 by 51 cm (30 by 20 inches)).	Breaks out writing area as a separate requirement.
5.7.3.1.2 Special Requirements - When a horizontal work space must accommodate keyboards, other controls, and/or controls plus writing area, spatial dimensions and configuration shall provide the best compromise for the multi-task roles considering the following: a. Relationships between desk-mounted controls and other displays mounted on forward, vertical and/or sloping panels. b. Convenience requirements for operating certain desk-mounted controls (e.g., joystick, track ball). c. Convenience for writing, considering both left and right-handed operators.	Introduces special requirements where the operator station must accommodate multiple tasks.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.7.3.6 Display Placement, Typical - Console or rack-mounted displays viewed from a seated position shall be located between 15 to 122 cm (6 to 48 inches) above the sitting surface.	
5.7.3.7 Control Placement, Typical - Console or rack-mounted controls operated from a sitting position shall be located between 20 89 cm (8 to 35 inches) above the sitting surface.	
5.7.3.8 Special Applications	
5.7.3.8.1 Precision Requirements - When display readout accuracy and continuous or frequent monitoring is required, such displays shall be located between 36 to 94 cm (14 to 37 inches) above the sitting surface. Controls requiring precise or frequent opertion shall be located between 20 to 76 cm (8 to 30 inches) above the sitting surface.	
5.7.3.8.2 Over-the-Top Viewing and Warning Display Location - For "sit" consoles requiring horizontal vision over the top (i.e., to monitor displays external to the console), the top of the console shall not be more than 73.7 cm (29 inches) above the seat surface, and/or less if the external display cannot be located so that its lowest display element can be placed high enough to be viewed under the above specification. Critical warning displays mounted on the console shall be located at least 57 cm (22.5 inches) above the sitting surface.	Adds requirements for over-the-top viewing for the seated operator, based on anthropometric data.

ORIGINAL REQUIREMENT	MFI COMMENTS
5.7.6 Special-Purpose Console Design -	
5.7.6.1 Horizontal Wrap-Around (Figure 25) -	
5.7.6.1.1 Panel Width - When requirements for preferred panel space for a single seated operator exceed a panel width of 44 inches (1.120 m), a flat-surface, segmented, wrap-around console should be provided, so as to place all controls within the reach of the 5th percentile stationary operator.	
5.7.6.1.2 Panel Angle - The left and right segments should be placed at an angle, measured from the frontal plane of the central segment, such that they can be reached by the 5th percentile stationary operator.	
5.7.6.2 Vertical/Stacked Segments (See Figure 26 for example.) -	
5.7.6.2.1 Panel Division - Where direct forward vision over the top of the console is not required by a seated operator, and when lateral space is limited, the panel shall be divided into three vertical/stacked segments whose surfaces should be perpendicular to the operator's line of sight with little or no head movement.	There seems to be no reason to specify three surfaces as opposed to some other number
5.7.6.2.2 Height - The center of the central segment should be 31.5 inches (800 mm) above the seat reference point. The height of this segment shall not exceed 21 inches (530 mm).	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.7.6.1.1 <u>Panel Width</u> - When requirements for preferred panel space for a fixed, seated operator exceed a width of 44 inches (111.6 cm), a "wrap-around" console configuration should be provided so that all controls are within reach of a 5th percentile male and/or female operator.	Specifies female as well as male operator.
5.7.6.1.2 <u>Panel Angle</u> - Viewing angles for wrap-around configurations should be approximately "normal" as the operator turns his or her head to view each panel, and in no case shall vary more than 45° from the normal.	Relates panel angle for the wrap-around to normal viewing angle.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.7.6.2.1 Panel Division - Where direct forward vision over the top of a console is not required by a seated operator, and when space is limited, a vertical "wrap-around" configuration should be used. Individual panel segments should provide an approximately "normal" viewing angle as the operator raises or lowers his or her head to view each panel, and in no case shall vary more than 45° from the normal.	Requires that panel segments accommodate approximately normal viewing angle, but removes the limitation of three different panel surfaces.
5.7.6.2.2 Height - The center of the central segment should be approximately 28 inches (71 cm) above the seat reference point.	Changes the criterion value to 28 inches to allow for female population and the normal depression of the viewing angle from the horizontal.

ORIGINAL REQUIREMENT	MFI COMMENTS
5.9.3 Adjustment Controls -	
5.9.3.1 Calibration Adjustments - Knobs should be selected in preference to screwdriver adjustments whenever frequent adjustment must be performed.	
5.9.3.2 Screwdriver Adjustments - If screwdriver adjustments must be made without the aid of vision, mechanical guides for the screwdriver shaft shall be provided or the screws shall be mounted so that the screwdriver will not move out of position.	Should be made explicit that screwdriver adjustments are for technician only.
5.9.3.3 Reference Scale for Adjustment Controls - A reference scale or any other appropriate feedback shall be provided for all adjustment controls and be readily visible to the person making the adjustment.	
5.9.3.4 Control Limits - Calibration or adjustment controls which are intended to have a limited degree of motion should be provided with adequate mechanical stops to prevent damage.	
5.9.3.5 Sensitive Adjustments - Sensitive adjustment points shall be located or guarded so that adjustments will not be disturbed inadvertently. Suitable hand or arm support shall be provided near the location to facilitate making the adjustment in all cases where the operator is subjected to disturbing vibrations or acceleration during the adjustment operation.	
5.9.3.6 Hazardous Locations - Internal controls should not be located close to dangerous voltages, rotating machinery, or any other hazards. If such location cannot be avoided, the controls shall be appropriately shielded and labeled.	Should be more explicit.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.9.3 Adjustment Controls - Controls required for maintenance purposes shall comply with basic control design requirements in 5.4 and labeling requirements in 5.5.	Adds the important provision that adjustment controls must conform with basic requirements stated earlier in the standard.
5.9.3.1 Calibration Adjustments - [Use original material from 5.9.3.1.]	
5.9.3.2 Screwdriver Adjustments - Screwdriver adjustments should be used when the particular adjustment should not be made except by specifically designated maintenance technicians. When screwdriver adjustment controls are used, the control shall be located where it is visible for mating the screwdriver with the screw. If the adjustment control cannot be made visible, it shall be mounted so that the screwdriver can be maintained firmly in the screw slot by means of a mechanical guide or other aid to hold the screwdriver in the proper position while it is being turned.	Limits use of screwdriver adjustments to those made exclusively by maintenance technician. Clarifies wording.
5.9.3.3 Adjustment Feedback - A reference scale or other appropriate feedback shall be provided, i.e., visual or auditory indication of adjustment changes.	
5.9.3.4 Control Limits - [Use original material from 5.9.3.4 but add:] Screwdriver control slots should be deep enough to minimize screwdriver slippage and slot damage.	Shallow screwdriver slots must be prohibited because of tool slippage and eventual wear-down of the slot.
5.9.3.5 Sensitive Adjustments - [Use original material from 5.9.3.5.]	
5.9.3.6 Hazardous Locations - Internal controls should not be located close to dangerous voltages, rotating components such as gears, belts or chains, or near extremely hot components. When adequate separation cannot be maintained, appropriate shielding shall be provided, and conspicuous warning labels posted where they are readily visible to the technician before he or she inadvertently contacts the hazard.	Provides more explicit requirements for hazardous location of controls.

ORIGINAL REQUIREMENT	MFI COMMENTS
5.9.14.10 Drawer Modules - Drawer modules designed for "remove and replace" maintenance shall be provided with connectors mounted on the back of the drawer and mated with connectors in the cabinet to accomplish electrical inter-connection between the drawer, other equipment in the rack and external connectors, where feasible. Guide pins or equivalent devices shall be provided to aid in alignment.	This overlooks the hazard if the drawer could be pulled out completely and dropped.

ORIGINAL REQUIREMENT	MFI COMMENTS
5.11.2.2 <u>Crank Size</u> - The size of tracking cranks, where used, shall be a function of rotation speed required. Within the parameters of Figure 7, a. Maximum speed should be between 140 to 200 RPM. b. Crank radius should be between 2.25 inches (57 mm) and 4.5 inches (115 mm): (1) High RPM requirement: smaller crank radius (2) Low RPM requirement: larger crank radius.	No change is recommended for this paragraph except if the referenced Figure 7 changes number.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.9.14.10 Drawer Modules -[Use original material from 5.9.14.10, but add the following:] When practicable, drawer modules should be mounted on glide tracks that incorporate mechanical stops to prevent the drawer or chassis from being accidentally pulled all the way out and dropped. Provide handles on the front panel of drawers and chassis modules that have sufficient panel area for securing such handles. Where appropriate consider use of latch-type handles so that the act of unlatching for removal of the drawer and withdrawal can be accomplished without requiring change of hand position.	This adds a very necessary safety requirement for mechanical stops to prevent accidental drawer withdrawal from the slides.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.9.19 Printed Circuit Boards - Printed circuit boards shall be designed and mounted for ease of removal and replacement considering such factors as finger access, gripping aids and resistance created by the mounting device. Appropriate feedback shall be provided to insure that the technician knows when the board is securely connected.	NEW

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.12.9.4.6 <u>Driver Station Design</u> - Requirements for operator workstations described herein shall generally be applied to automotive driver stations. In addition, the following factors shall be considered: a. External visibility shall be adequate to observe the necessary reference extremities of the vehicle to safe-steer the vehicle, to observe clearances between the vehicle and other objects, and to observe key elements necessary for making steering and braking decisions i.e., traffic lights, road signs and markings. When the vehicle will be used on public roads, it shall be be designed in compliance with Federal Motor Vehicle Standards pertaining to exterior visibility. b. All internal visual displays shall be designed and located for easy access by the operator when his or her eyes are positioned for normal roadway observation. c. All controls that may be operated while the vehicle is in motion shall be easily accessible from the operator's normal operating position, and it shall not be necessary for the operator to reach to the extent that his or her eye reference is drawn to a position in which the operator cannot maintain adequate eye contact with the road. d. Driver controls and displays shall be as consistent as practicable among similar vehicles in terms of basic design and location i.e., the common elements shall be similar (e.g., brake, clutch and accelerator, ignition/starter, lights, windshield washer/wiper, turn signal, horn, speedometer, fuel, oil and temperature displays, etc.).	NEW

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.13.5.6 <u>Moving Equipment</u> - Auditory warning devices shall be provided on all large equipments and/or vehicles to indicate when they are in motion, i.e., backing alarm for large vehicles in which the operator may be unable to see directly to the rear, operator controlled signalling device to warn persons in the path of a machine (when the general noise environment makes it difficult to know that a machine is about to move toward an individual who may not be facing it), etc.	NEW

ORIGINAL REQUIREMENT	MFI COMMENTS
5.14 AEROSPACE VEHICLE COMPARTMENT DESIGN REQUIREMENTS -	
5.14.1 General - Aerospace vehicle compartments shall be designed to optimize human efficiency, safety, and comfort within the constraints imposed by system requirements.	
5.14.1.1 Windows, Canopies, and Windshields -	
5.14.1.1.1 Visual Performance - Transparent areas shall be designed to be free from color, distortion, or any other factors that would degrade visual performance below the level required for mission accomplishment.	
5.14.1.1.2 Multilayered Windows - Visual performance shall not be degraded below the level required for mission accomplishment by loss of light transmission or by multireflections resulting from multilayered windows.	
5.14.1.1.3 Angle of Incidence - When undistorted external vision is required, the angle of incidence (see 3.3) shall not exceed 60 degrees.	
5.14.1.1.4 Unobstructed Vision - Windows and canopies shall be designed for optimum unobstructed vision. Width of structural members in the line of vision should not exceed 2.2 inches (56 mm).	
5.14.1.2 Instrument Location - Instruments shall be located so that, with glare shields and bezels in place, they can be easily read by appropriate crew members.	Too general.
5.14.2 Crew Stations and Passenger Compartments (All Aerospace Vehicles)	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.14.1.2 Instrument Location - Cockpit instruments and integrally-illuminated knobs and panels shall be located to optimize pilot(s) viewing angle and minimize effects of sun glare on instruments and/or reflection of display surfaces on windshield, canopy or side windows at night. Glare shields and bezels shall not obstruct complete view of all critical display detail on instruments, legend switches or controls, considering the complete range of operator sizes and potential seat adjustments the operator may have made.	Adds specificity to the requirement for glare shielding of cockpit instruments.

ORIGINAL REQUIREMENT	MFI COMMENTS
5.14.2 Crew Stations and Passenger Compartments (All Aerospace Vehicles) 5.14.2.1 Pilot and Copilot Stations (Aeronautical) - Specific design requirements for pilot and copilot stations are contained in MIL-STD-203, MIL-STD-250, MIL-STD-411, MIL-STD-783, MIL-STD-850, MIL-STD-1333, MIL-L-5667, MIL-P-7788, and MIL-M-18012. Human Engineering design of pilot and copilot stations not covered in the above documents or other contractual documents (e.g., handbooks and manuals) shall be in accordance with the criteria in this standard.	Add reference MIL-C-81774 to this paragraph and also to the list in the front of the document.

ORIGINAL REQUIREMENT	MFI COMMENTS
5.14.2.4 Seating and Restraint -	
5.14.2.4.1 General - Seats contours, positions, and restraints should be adjustable to individual anthropometric dimensions of shirtsleeve, pressure suit, survival equipment, armor, and to foreseeable conditions and levels of g-loading. Seating or restraints shall provide an adequate supporting framework for the body relative to the activities that must be performed. Seats shall be designed for maximum protection under g-loading and for comfort, ease of adjustments, and minimum weight.	
5.14.2.4.2 Vertical and Horizontal (Fore and Aft) Adjustments - Seats shall have vertical and horizontal adjustments sufficient to accommodate suitably clothed and equipped users with relevant body dimensions varying between 5th and 95th percentile (see 5.6), without degrading their performance capability.	
5.14.2.4.3 Swivel Adjustments - Seats capable of being rotated shall contain at least eight locking positions equally spaced through 360°. The seat shall be capable of being swiveled freely, when unlocked, while supporting a load of 250 pounds (113 kg).	
5.14.2.4.4 Height - The sitting surface shall be designed to provide a minimum of 9 inches (230 mm) between the sitting surface and the bottom of the work surface or shelf. (See Figure 24.)	
5.14.2.4.5 Access to Foot Controls - When seated, the operator shall have free access to, and activation of, foot-operated controls.	Does not cover adjustable foot controls.
5.14.2.4.6 Backrest - Backrest angle shall vary between 5° and 15° aft of the vertical for the work position and to a maximum of 50° for the rest position. The rest angle shall not exceed an included angle between seat and backrest of 136°.	

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.14.2.4.2 Vertical and Horizontal (Fore and Aft) Adjustments - Use original material, but add the following: Seat adjustment controls should be located so that the pilot can operate such controls without modifying his or her normal operating body position (i.e., without leaning forward or to the side, thus removing his or her eyes from the designated "operational" eye reference position.)	Adds the important requirement that the pilot must be able to make seat adjustment without shifting his body or diverting attention from his visual tasks.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.14.2.4.5 Access to Foot Controls - [Use original material, but add the following:] When adjustable foot controls are provided, they shall be located so that the pilot can operate the control without modifying his or her normal body position (i.e., without leaning forward or to the side, thus removing his or her eyes from the designated "operational" eye reference position.)	Adds a requirement that foot control adjustments be made without postural shift or distraction of visual attention.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.14.4.2.6 <u>Exit Signs and Marking</u> - All emergency exits shall be clearly marked with signs reading EMERGENCY EXIT. Such signs shall be located so that there will be no confusion as to the location of the exit and/or so that the sign could be inadvertently obscured by persons or articles stowed or sitting near the exit. Such signs shall be visible both day and night. Lettering on such signs shall be fluorescent RED with contrasting background of at least 80 percent or more. When practicable, a red line or tape should be used to outline the actual exit opening.	NEW

ORIGINAL REQUIREMENT	MFI COMMENTS
5.14.4.3 Ejection Systems - Where ejection systems are specified, the following criteria, and those contained in MIL-S-9479 for USAF, or MIL-S-18471 for USN, shall apply.	
5.14.4.3.1 Clearance - The vehicle shall be designed to provide adequate clearance for egress of either the ejection seat and occupant or the escape capsule as applicable.	
5.14.4.3.2 Safety Harnesses - Personnel safety harnesses shall be easily adjusted and removed and shall be designed to preclude interference with safe ejection.	Needs more specificity.
5.14.4.3.3 Ejection Controls - Ejection controls shall be readily accessible and activation shall be possible with either hand.	
5.14.4.3.4 Control Protection - Provision shall be made to guard against accidental activation of ejection controls.	Not strong enough!

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.14.4.3.2 Safety Harnesses - Personnel safety harnesses shall be easily adjusted and removed, and shall be designed to preclude interference with safe ejection. A single-action response shall release all belt elements necessary for the occupant to quickly remove the safety harness. The belt release control shall be accessible to either hand. The release device shall be designed so that inadvertent contact will not release the belt accidentally. The force to release the buckle shall be compatible with limitations that any high G-force maneuver may place on the occupant's ability to reach for and/or manipulate the release device.	Adds requirements for quick release of safety harness and for prevention of accidental release.

MFI RECOMMENDED MODIFICATION	RATIONALE/REFERENCES
5.14.4.3.3 Ejection Controls - Ejection controls shall be accessible and activation shall be possible with either hand under the highest G-force conditions expected.	Adds important requirement that release must be possible under highest G-force.
5.14.4.3.4 Control Protection - Ejection controls shall be designed and/or located so that accidental activation is precluded. Ejection control handles shall be appropriately marked with alternate yellow and black striping to denote CAUTION.	Strengthens the requirement to prevent accidental ejection.