AEROSPACE STANDARD

AS8034™	REV. C

Issued 1982-12
Reaffirmed 1993-05
Revised 2018-07

Superseding AS8034B

(R) Minimum Performance Standard for Airborne Multipurpose Electronic Displays

RATIONALE

The current revision, AS8034C, now includes the minimum performance standards for touch screen enabled electronic displays. This document was developed by the SAE A-4 Electronic Display committee and supersedes AS8034, AS8034A and AS8034B.

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http://standards.sae.org/AS8034C

1. SCOPE

This SAE Aerospace Standard (AS) specifies minimum performance standards for all types of electronic displays and electronic display systems that are intended for use in the flight deck by the flight crew in all 14 CFR Part 23, 25, 27, and 29 aircraft. The requirements and recommendations in this document are intended to apply to all installed electronic displays and electronic display systems including those that have a touch screen interface within the flight deck, regardless of intended function, criticality, or location within the flight deck, but may also be used for non-installed electronic displays. This document provides baseline requirements and recommendations (see 2.3 for definitions of "shall" and "should"). This document primarily addresses hardware requirements, such as electrical, mechanical, optical, and environmental. It does not address system specific functions. It does not contain an exhaustive or comprehensive list of requirements for specific systems or functions, such as TCAS, ADS-B, GPS, weather, or shared display considerations (e.g., when should alerts be inhibited on a display system that simultaneously depicts navigation data integrated with terrain data or traffic alerting). This document is intended to be used in combination with other guidance material contained in current system specific, TSOs, Advisory Circulars (ACs), and other Federal Aviation Administration (FAA)-approved guidance material.

The requirements and recommendations in this document are intended to apply to, but are not limited to, the following types of display functions:

- Primary flight and primary navigation which include vertical situation, horizontal situation, and moving map displays.
- Systems display and displays that have alerting functions which may include engine instrument, aircraft systems information/control, pilot or flight crew alerting, and documentation displays.
- Control displays including communication, navigation, and system control displays.
- Information displays which may include navigation displays used for situation awareness only, supplemental data displays, and maintenance displays.

Electronic displays can include one or more of the following interconnected components. Other configurations are possible.

- Symbol Generator/Processor Unit (SG) containing display processing and symbol generation processing and symbol generation capability, power supplies, interface logic/buffer circuits and display unit interface capability. The SG receives data from external sources, produces symbols as electronic signals, and transmits the symbols to the display units(s).
- Control Panel (CP) is an optional component providing the means for manually selecting display symbology options/modes, selections, settings, brightness, etc.
- Touch Screen (TS) is an optional component providing the means for manually selecting display symbology options/modes, selections, settings, brightness, etc.
- Display Unit (DU) providing the visual display of SG symbology.

Head up displays are out of scope for this document. The minimum performance standards for head up displays are provided in AS8055A.

NOTE: This document is expected to be used by the FAA as the basic requirement for a Technical Standard Order (TSO) for multipurpose electronic displays. While not required, ARP1874 and ARP4067 give recommended means, but not the only means, of compliance to this standard for CRT based displays. In addition, while not required, ARP4256 gives recommended means, but not the only means, of compliance to this standard for Part 25 LCD displays. That document is subject to change to keep pace with experience and technical advances. A similar document for Part 23 aircraft does not exist at this time, however these documents may be used as the basis for electronic displays intended to be installed in Part 23, 27, and 29 aircraft, realizing that additional requirements may also apply.

2. REFERENCES

The documents listed in 2.1 are referenced in this document. The documents listed in 2.2 are provided for information purposes only and do not form a part of the requirements of this document.

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

ARP1782	Photometric and Colorimetric Measurement Procedures for Airborne Direct View CRT Displays
ARP1874	Design Objectives for CRT Displays for Part 25 (Transport) Aircraft
ARP4067	Design Objectives for CRT Displays for Part 23 Aircraft
ARP4102/7	Electronic Displays
ARP4256	Design Objectives for Liquid Crystal Displays for Part 25 (Transport) Aircraft
ARP4260	Photometric and Colorimetric Measurement Procedures for Airborne Electronic Flat Panel Displays
ARP5583	Guide to Certification of Aircraft in a High-Intensity Radiated Field (HIRF) Environment
AS8055	Minimum Performance Standard for Airborne Head Up Display (HUD)
ARP4761	Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment

2.1.2 CIE (Commissions Internationale de l'Eclairage) Publications

Available from CIE Central Bureau, Babenbergerstrasse 9/9A, 1010 Vienna, Austria, Tel: +43 1 714 31 87, www.cie.co.at.

Supplement No. 2 to CIE Publication No. 15	Recommendations on Uniform Color Spaces Color Difference Equations - Psychometric Color Terms

2.1.3 Code of Federal Regulations (CFR)

Available from the United States Government Printing Office, 732 North Capitol Street, NW, Washington, DC 20401, Tel: 202-512-0000, www.gpoaccess.gov.

14 CFR 23	Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes
14 CFR 25	Airworthiness Standards: Transport Category Airplanes
14 CFR 27	Airworthiness Standards: Normal Category Rotorcraft
14 CFR 29	Airworthiness Standards: Transport Category Rotorcraft

Advisory Circular 20-136A Protection of Aircraft and Electrical/Electronic Systems against the Indirect Effects of Lightning

Advisory Circular 20-155 SAE Documents to Support Aircraft Lightning Protection Certification

Advisory Circular 20-158 The Certification of Aircraft Electrical and Electronic Systems for Operation in the High-Intensity Radiated Fields (HIRF) Environment.

The new Part 23 rule went into effect August 30, 2017. However, the former Part 23 regulations may still be used. In the NPRM, the FAA noted that "under the proposed rule, applicants may choose to use an industry consensus standard, the former Part 23 standards (available at no cost), or its own means of compliance accepted by the Administrator".

2.1.4 EIA Publications

Available from Electronic Component Association (ECA), 2500 Wilson Boulevard, Arlington, VA 22201-3834, Tel: 703-907-7500, www.eia.org.

EIA RS-503a Recommended Practice for Measurement of X-Radiation from Direct View Display Cathode Ray Tubes

2.1.5 FAA Publications

FAA AC-( ) documents are available from the U.S. Department of Transportation, Subsequent Distribution Office M-30, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785, www.faa.gov/regulations_policies.

2.1.6 RTCA/EUROCAE Publications

Available from RTCA, Inc., 1150 18th Street, NW, Suite 910, Washington, DC 20036, Tel: 202-833-9339, www.rtca.org.

RTCA DO-160G/EUROCAE ED-14G Environmental Conditions and Test Procedures for Airborne Equipment

2.1.7 VESA Publications

Available from VESA, 1754 Technology Drive, Suite 238, San Jose, CA 95110, Tel: 408-982-3850, www.vesa.org.

Flat Panel Measurements Standard, Version 2.0, June 1, 2001

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Aerospace Technical Report.

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AMS2521 Coating, Reflection-Reducing for Instrument Glasses

AIR1093 Numeral, Letter and Symbol Dimensions for Aircraft Instrument Displays

ARP4032 Human Engineering Considerations in the Application of Color to Electronic Aircraft Displays

ARP4101 Flight Deck Layout and Facilities

ARP4102 Flight Deck Panels, Controls, and Displays

ARP4103 Flight Deck Lighting for Commercial Transport Aircraft

ARP4105 Abbreviations, Acronyms, and Terms for Use on the Flight Deck

2.2.2 FAA Publications

FAA AC-( ) documents are available from the U.S. Department of Transportation, Subsequent Distribution Office M-30, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785, www.faa.gov/regulations_policies.

FAA AC 25-11B Electronic Flight Deck Displays

FAA AC 23-1311-1B Installation of Electronic Display Instrument Systems in Part 23 Airplanes

FAA AC 27-1 Certification of Normal Category Rotorcraft

FAA AC 29-2 Certification of Transport Category Rotorcraft

FAA AC 20-158 The Certification of aircraft Electrical and Electronic Systems for Operation in the High-Intensity Radiated Fields (HIRF) Environment

2.2.3 RTCA/EUROCAE Publications

Available from RTCA, Inc., 1150 18th Street, NW, Suite 910, Washington, DC 20036, Tel: 202-833-9339, www.rtca.org.

RTCA DO-178C~~B~~/EUROCAE ED-12B Software Considerations in Airborne Systems and Equipment Certification

2.2.4 U. S. Government Publications

Copies of these documents are available online at http://quicksearch.dla.mil.

MIL-HDBK-87213 Military Handbook: Electrically/Optically Generated Airborne Displays

2.3 Definitions

Definitions used in this document shall be as noted in the Glossary of Terms defined in Section 7.

The word “shall” is used to express an essential requirement where compliance is mandatory.

The word “should” is used to express a recommendation. Deviation from the specified recommendation shall require justification.

The word “must” is used to express an essential (mandatory) requirement that is required by a specific regulation.

3. GENERAL STANDARDS

3.1 Material

Material shall be of a quality which experience and/or tests have demonstrated to be suitable and dependable for use in aircraft instruments.

3.2 Workmanship

Workmanship shall be consistent with high quality aircraft electromechanical and electronic instrument manufacturing practices.

3.3 Compatibility of Components

If a display system component is individually acceptable but requires calibration adjustments or matching to other components in the aircraft for proper operation, it shall be identified in a manner that will insure performance to the requirements of this document.

3.4 Interchangeability

Display system components which are identified with the same manufactured part number shall be completely interchangeable.

3.5 Accessibility of Controls

Controls which are not normally adjustable in flight shall not be readily accessible to flight personnel when the instrument is installed in accordance with the instrument manufacturer's instructions.

3.6 Self-Test Capability

If the equipment contains integral arrangements to permit pre-flight and/or in-flight self-test checks on the operation of the equipment in combination with other aircraft sub-systems, such tests shall not adversely affect any associated subsystem.

In-flight, self-test activation features shall include a means to warn the pilot or appropriate flight crew member of this mode of operation.

3.7 Effect of Tests

Unless otherwise stated, the application of all prescribed in-service testing shall not produce a subsequent condition which would be detrimental to the continued performance of the instrument.

3.8 Malfunctions/Failure Indications

3.8.1 Malfunction Indication

Means shall be provided to indicate malfunctions or failures to the appropriate crew member. A blank display or a “X” across the display are examples of acceptable means of indicating failure.

3.8.2 Power Failure Indication

Means shall be provided to indicate when electrical power (voltage and/or current of all required phases), is not sufficient for proper operation of display and/or display system. A blank display is an example of acceptable means of indicating failure.

3.8.3 Fail Safe Provision

No single failure or malfunction of the display system shall introduce unsafe conditions to interconnected equipment.

- Unsafe conditions include the probability of failure of the article that could lead to an unsafe condition, based upon the design assurance level.
- A Failure Modes and Effects Analysis (FMEA) shall be performed to identify, isolate, and mitigate individual failures of the display. This is needed to be used in a System Safety Assessment (SSA) for aircraft airworthiness determination.
- ARP4761 Table 1 shows a means of evaluating the failure condition severity as related to probability objectives and assurance levels for components and systems in aircraft.

3.9 Multiple Mode Indications

When a display and/or display system has more than one mode each mode of operation shall be indicated on the display. One example of an acceptable exception is the depiction of the Horizontal Situation Indicator (HSI)-Full Compass versus Arc mode, which does not require a mode indication.

NOTE: Examples of modes on a moving map display include head-up versus track up. In contrast, a vertical profile display portion of the display screen would be considered a function, not a mode, and thus would not be required to be indicated (e.g., labeled).

3.10 Identification

The following information shall be legible and permanently marked on the equipment or nameplate attached thereto.

a. Name of equipment

b. Manufacturer's part number

c. Manufacturer's serial number or date of manufacture

d. AS8034 or equivalent approval identification

e. Manufacturer's name or trademark

f. Weight to the nearest 0.05 kg (tenth of a pound)

g. Environmental categories per DO-160G/ED-14G

3.11 Display

The information being displayed should functionally conform to the applicable SAE Aerospace Recommended Practice.

3.11.1 Discernibility

Appropriate means shall be incorporated to prevent obscuration or confusion of task essential information. Task essential information shall be identified and defined by the applicant (e.g., typically the equipment manufacturer or OEM).

3.11.2 Critical Information

Means shall be provided to prevent the removal of information deemed critical to safe aircraft operation.

3.11.3 Information Limit Indication

A means shall be provided to identify when critical displayed information exceeds display format functional limits.

3.11.4 Scale Indications

The display scaling, graduations, and numeration shall be appropriate for the level of reading accuracy and dynamic range required (e.g., familiar units of measure are not as significant as the values and may be smaller font, but still must be discernible). The display should indicate if display items are not drawn to scale (e.g., TAWS displays).

3.11.5 Ambiguity

Appropriate means shall be provided to prevent ambiguous indications within the operating range of the display system.

3.11.6 Lighting

Per regulation 14 CFR 2X.1543, all instrument markings shall be clearly visible to the appropriate crewmember. All display, control labels, and markings shall be clearly visible and easily readable in all flight deck lighting conditions.

When integral lighting is provided, it shall, under normal flight deck ambient illumination conditions as defined in 4.3.1, make all indices within the required viewing envelope readily discernible.

3.12 Resistance to Dust and Moisture

Optics shall be designed to prevent contamination of surfaces by dust or moisture under all operating and test conditions of this standard.

When hermetically sealed, the case shall be filled with an inert gas, free of dust particles, and sufficiently dry so that fogging of the indicator glass does not occur during the low temperature and fogging tests of this document.

3.13 Mechanical Hazard System Protection

The display should be so designed that no hazard will result from implosion, or other mechanical failures.

3.14 Fire Resistance

Except for small parts (e.g., fasteners, grommets, knobs, seals, small electrical parts) that would not contribute significantly to the propagation of a fire, all materials used must be self-extinguishing when tested in accordance with the requirements of 14 Code of Federal Regulations (CFR).

3.15 Supplemental Heating/Cooling

Where supplemental heating or cooling is required by the equipment to ensure conformance with this standard, it shall be the responsibility of the equipment manufacturer to specify such requirements. If the loss of supplemental heating or cooling during normal system operation could lead to hazardously misleading information, the heating or cooling sources shall be monitored, and the flight crew alerted to the failure.

3.16 Touch Screen Displays

The information being displayed and the manipulation of the information on the display should consider the recommendations of the applicable SAE Aerospace Recommended Practice.

3.16.1 Touch Screen Disablement

If a touch screen is part of the electronic display unit and intentionally disabled via a user-controlled aircraft mechanism there shall be an indication to the user. One type of user-controlled aircraft mechanism might include the position or state of a switch, but this is not the only possible mechanism.

If a touch screen is part of the electronic display unit and can be disabled or limited via a non-user-controlled mechanism these limitations to operation shall be documented in the system safety analysis and in the installation or operating instructions. One type of non-user-controlled aircraft mechanism might be a HIRF event where the touch screen may temporarily lock out or limit (e.g., degraded mode) the touch screen usage until the event has passed. During this lock out or limitation time, an indication shall be made to the user.

The applicant can consider conditions before annunciating to the user (e.g., time duration, task performed) in such scenario the conditions shall be documented in the installation or operating instructions. After the event has cleared the system shall fully operate without intervention by the user and the annunciation removed unless this conflicts with other operational or functional requirements of the system.

3.17 Touch Screen Input

3.17.1 Touch Screen Interface

Document in the Installation or operating instructions the key operating characteristics and any known limitations. The following are a list of possible items but not necessarily the entire list.

Examples:

- Input Devices: Document if there are known limitations on type or size of input devices used to make touch screen inputs. Some examples could be limitations with the use of glove or stylus. If there are limitations with the size of the input device being too small to be recognized or too large such that it gets rejected these are also to be documented.

- Activation Method: The method in which a touch is detected is to be documented. If a minimum force is required, this value is to be documented. If no minimum force is required or no contact is required, this is to be documented. If, on the same touch screen, there are different levels of force for different tactile commands, for instance a minimum force for a secured command and no minimum force for a non-secured command, this is to also be documented.

- Single/Multi Touch: If the number of simultaneous touches that are allowed is limited, the maximum number allowed and what happens when the maximum number of input touches allowed is exceeded is to be documented. If the interface allows more than one simultaneous touch, the minimum distance between touch points that indicate more than one touch has been received is to be documented.

- Maintenance: Document if any maintenance is necessary (e.g., touch screen calibration its periodicity and methodology that is required).

4. MINIMUM PERFORMANCE STANDARDS UNDER STANDARD CONDITIONS

The equipment manufacturer shall conduct sufficient tests to prove compliance with this aerospace standard. The applicable standard test conditions are given in RTCA DO-160G/EUROCAE ED-14G. The applicable measurement procedures for LCDs are in ARP4260. The applicable measurement procedures for CRTs are in ARP1782.

4.1 Equipment Functions and Mechanical Operation

Equipment shall display information with contents as specified by the appropriate standard document. All equipment functions and mechanical devices shall perform their intended function.

4.1.1 Viewing Characteristics

The following requirements apply to the instrument in its installed position and as viewed under all flight deck light conditions from the equipment manufacturer's design eye position viewing envelope.

The instrument manufacturer shall specify the instrument's design eye position viewing envelope. This information shall be documented in the TSO data package (qualification test report), and in the limitations section of the installation instructions. This information shall contain, as a minimum, the viewing angles in both the horizontal and vertical planes measured normal to the plane of the display surface, and the minimum and maximum distances from the center of display surface for which the instrument complies with this minimum standard.

4.2 Viewing Angle

All indicating means displayed (indicia, pointers, symbols, etc.) shall be completely visible from any eye position within the viewing envelope(s) as specified by the equipment manufacturer. Text and symbology shall be readily discernible and should be legible and readable within the specified viewing envelope(s). The viewing envelope requirement includes any specialized bezels/hand grips that may be used for stabilization.

NOTE: It is the responsibility of the equipment installer to determine that the required aircraft viewing envelope is within the specified display viewing envelope(s).

4.2.1 Symbol Alignment

Symbols which are interpreted relative to each other (e.g., cursors on scales, command bars against reference points, etc.) including mechanically produced symbols that are interpreted relative to electronically produced symbols, shall be aligned, including parallax effects throughout the design eye position viewing envelope, to preclude misinterpretation of information.

4.2.2 Positional Accuracy

The display absolute positional accuracy shall be better than 5% of the maximum diagonal dimension of the display. In no case shall the absolute positional error cause erroneous data to be presented. All displayed symbols and graphics on moving map displays shall be positioned (i.e., drawn or rendered) accurately relative to one another such that placement errors are less than 0.013 inches on the map depiction or 1% of the shortest axis (i.e., horizontal and vertical dimension) of the map depiction, and orientation errors are less than 3 degrees with respect to the values provided by the position and database sources.

4.2.3 Drift

Dimensional and positional stability of display system presentations shall be sufficient to ensure the requirements of 4.2.1, 4.2.2, and 4.2.3 are met. Drifts shall in no case cause an erroneous interpretation of the information presented.

4.2.4 Line Width

Line widths shall be of sufficient size and optimal sharpness to display the intended information with no distracting visual artifacts or ambiguities that could result in an unsafe condition. When viewed from within the design eye position viewing envelope (DEP-VE), lines of a specified color and luminance should appear uniform in width at all rotational or translational orientations of the line. Line width variation should not be readily apparent. Narrow or thin lines with a minimum line width less than 70% of the maximum line width, of that particular line, may produce an undesirable visual “roping” effect.

4.2.5 Jitter

There should be no discernible display jitter when viewed within the viewing envelope. In no case shall the display jitter be objectionable. Display jitter shall be no greater than 0.6 mrad peak-to-peak when viewed within the design eye position viewing envelope as specified by the instrument manufacturer. Jitter of 0.3 mrad peak-to-peak from any point within the viewing envelope is a suggested upper limit, but that may not be acceptable in some instances.

4.2.6 Flicker

The display shall not exhibit an unacceptable level of flicker under the full range of ambient environment up to the maximum ambient illumination level specified by 4.3.1 when viewed from any viewing angle defined in 4.2 and 4.2.1, with both foveal and full peripheral vision.

4.2.7 Symbol Quality and Distortion

Lines, symbols, and characteristics shall not have distracting gaps, geometric distortions (such as tails, squiggles, skews), or motion anomalies discernible from the design eye position viewing envelope which cause erroneous interpretation. Any distorted dimension should not exceed one half the local line width in the area of the distortion. Measurement techniques are included in ARP4260A.

Image distortion should not compromise image interpretation. Images meant to provide information about depth (for example, 3-dimensional type perspective displays) should provide adequate depth information to meet the intended function.

4.2.7.1 Matrix Anomalies

Displays generated by an array of discrete elements, displayed information may have visible spatial and color anomalies. Stair stepping, line width variation, and moiré are examples of spatial anomalies; color banding and color fringing are examples of color anomalies. Anomalies are especially visible in dynamic images and may not be visible in static images. The extent of the anomaly is dependent on many factors including the size, shape, and arrangement of the display shall have no matrix anomalies which cause distraction or erroneous interpretation. This shall be assessed with both static and dynamic formats.

4.2.7.2 Symbol Motion

Display symbology that is in motion (translation and/or rotation) should not have distracting jitter, jerkiness, or ratcheting effects. Dynamic symbols should maintain luminance (per 4.3.2), contrast, color, line width, and symbol quality characteristics independent of their rate of motion. Pointers and bar graphs should be designed with built in hysteresis or smoothing of the displayed value such that when a constant or near constant value of a parameter is to be displayed, objectionable motion is eliminated.

4.2.8 Crosstalk

Crosstalk shall not be readily apparent or distracting.

4.2.9 Image Retention

Undesired afterimages that persist on the display should not be readily discernible day or night, should not be distracting, and shall not cause an erroneous interpretation of the display.

4.2.10 Defects

Visible defects on the display surface (such as failed-ON or failed-OFF elements, rows, or columns, etc.) should not be distracting and shall not cause an erroneous interpretation of the display. Defects which are not visible with any operational format from the minimum viewing distance are acceptable.

4.2.10.1 Failed-ON Row/Columns (Matrix Display)

No failed-ON row/columns shall be allowed on the display.

4.2.10.2 Failed-OFF Row/Columns (Matrix Display)

Depending on resolution, mode, color, and format, there may be failed-OFF row/column defects which are neither distracting nor cause erroneous interpretation. In no case shall a failed-OFF row/column cause any loss of expected information or erroneous interpretation. If a failed-OFF row/column is in an unused area (format dependent) or is orthogonal to other depicted lines, it may never be detected by the flight crew.

4.2.10.3 Element Failures

Beyond the requirements of 4.2.11, 4.2.11.1, and 4.2.11.2, the number of acceptable element failures is an aesthetic issue not a safety of flight issue. Failed-OFF elements and failed-ON blue elements are much less objectionable than failed-ON red, green, or white elements. Clusters of failed elements are more objectionable than those widely separated. The number of acceptable defects is dependent on the format. Any segment failure on a segmented display shall constitute an unacceptable display (unless there are redundant segments). Section 7.37 defines segmented display.

4.2.11 Multiple Images

When illuminated with light not normal to the display surface, for example sun shafting illumination, transflective or reflective liquid crystal displays can produce multiple images of displayed information. The multiple images formed should not be distracting and shall not cause erroneous interpretation of displayed data.

4.3 General Photocolorimetric Characteristics

4.3.1 Ambient Illumination Characteristics

The display symbology shall be readable and/or discernible throughout the viewing envelope under all ambient illumination levels ranging from 1.1 lx (0.1 ft-c) to sun-shafting illumination of 86100 lx (8000 ft-c) incidence on the face of the display and provide rapids eye adaptation for transitions from forward field of view luminance levels of up to 34300 cd/m^2 (10000 fL).

4.3.2 Luminance Characteristics

Luminance: The display luminance shall be sufficient to provide a usable display under the maximum ambient illumination.

4.3.2.1 Manual Luminance Control

The display system shall have capability for manual luminance control.

4.3.2.2 Automatic Luminance Control

If the display system has automatic luminance compensation, the operation of this compensation shall function so that the system meets the requirements of 4.3.1 under changing flight deck ambient light levels. Manual luminance control shall not be adversely affected by failure of the automatic luminance control.

4.3.2.3 Luminance Tracking

When the luminance of the display is varied between maximum and minimum, the relative luminance of all displayed information shall remain visually consistent. In no case shall any critical symbols or characters become invisible at the minimum luminance setting while other characters or symbols are visible.

4.3.2.4 Luminance Uniformity

The luminance uniformity of the display shall be sufficient to prevent hazardously distracting conditions or erroneous interpretation of information.

4.3.3 Luminance and Color Discrimination

Under the conditions in 4.2.1 displayed information shall have sufficient luminance contrast and/or color difference to discriminate between the following as applicable:

a. Between symbols (including characters and/or lines) and the background (ambient or generated) on which they are overlayed.

b. Between various symbols, characters, and lines. This shall also include when they overlay ambient or generated backgrounds.

c. Between the generated backgrounds and ambient backgrounds.

d. Between the generated backgrounds of various specified colors.

In all cases the luminance contrast and/or color differences between all symbols, characters, lines, or all backgrounds shall be sufficient to preclude confusion or ambiguity as to information content of any displayed information. When operationally relevant, the color of the information shall be identifiable (e.g., if colors are used for alerting). The equipment manufacturers shall specify the ambient illumination level and illuminate characteristic for which this requirement is met. The minimum ambient illumination requirement is specified in 4.3.1.

NOTE: It is not recommended to place a symbol on a background of equal luminance regardless of color differences. Saturated colors are not recommended to be used for background; saturated colors should be saved for smaller items such as symbols, icons, targets, etc.

4.3.4 Color

Where multiple colors are used to enhance discrimination, the use of color shall result in no erroneous or ambiguous interpretation of the displayed information. In no case should colors be selected which conflict with the requirements of 4.3.3.

In general, color should not be used as the only coding dimension. Other coding dimensions such as shape, location, bold, boxed, or highlighting should be used as redundant coding.

Displays intended to be installed in all types of aircraft (Part 23, 25, 27, and 29) shall meet the requirements in 14 CFR 25.1322 and the guidance in AC 25.1322. Displays intended to be installed in only in Part 23, 27, or 29 aircraft may not be required to meet 14 CFR 25.1322 and the associated AC but shall meet the requirements in 14 CFR 2X.1322 and shall have appropriate wording in the limitations section of the installation instructions.

NOTE: Approximately 9% of the population has some sort of color vision deficiency (what is commonly called “color blindness”). It should also be noted that the FAA does not test for all potential color deficiencies.

4.3.4.1 Color Uniformity

The color difference between any symbols of the same color located at any position within the useful display area (see definition section) shall result in no ambiguity or an incorrect identification of an assigned color over the entire range of luminance control.

4.4 CRT

This section applies only if the display is a CRT.

4.4.1 Luminance Uniformity

The luminance of a given symbol, line, character, or generated background shall not vary more than:

a. ±30% when located within the useful display area, or

b. ±20% when located within the central 80% of the useful display area.

These requirements apply for any luminance control setting.

Under night lighting conditions with the display brightness set at the lowest usable level for flight all symbology, all flags, and annunciations shall be adequately visible.

NOTE: The lowest usable level is not the same as the lowest level on some display systems.

4.4.2 Convergence

When a display element is a composite of multiple traces (such as multiple guns of a shadow mask CRT, or alternate fields of a beam penetration CRT), the beam centers shall be converged. This convergence value at any point shall be within the average of the line widths of the respective traces at that point. This requirement applies over the useful display area for all symbol intensity settings.

When a display element is comprised of two or more closely spaced traces (such as raster generated symbology) the primary gun beam centers shall be converged. This convergence value shall be within one display line width or 0.7 mrad, whichever is greater, when viewed from within the equipment manufacturer's specified design eye position viewing envelope.

In no case shall misconvergence cause a line, symbol, or character color or form to be ambiguous.

4.5 LCD

This section applies only if the display is an LCD.

4.5.1 Luminance

Information should be readable over a wide range of ambient illumination under all foreseeable conditions relative to the operating environment, including but not limited to:

- Direct sunlight on the display
- Sunlight through a front window illuminating white shirts (reflections)
- Sun above the forward horizon and above a cloud deck in a flight crew member's eyes
- Night and/or dark environment

4.5.1.1 Maximum Luminance, Transmissive Displays

With manual and automatic luminance controls at maximum, the average white symbol luminance across the useful display area shall be at least 257 cd/m^2 (75 fL) when measured from within the design eye position viewing envelope in a dark ambient. The maximum white symbol luminance shall be at least 171 cd/m^2 (50 fL) anywhere on the useful display area under static conditions (e.g., when the display is not changing) and dynamic conditions (e.g., when the display is changing such as when the compass card is rotating). This luminance requirement is based on a 0.6 mrad line width. Larger line widths and filled areas will require less luminance to provide the same apparent brightness. Conversely, smaller line widths will require more luminance for the same apparent brightness. Refer to ARP4256, 4.2.2.1 for additional guidance on apparent brightness as a function of line width.

Maximum luminance required for a given display to be considered usable is also a function of the display installation location. The above luminance requirements are based on requirements for primary instrumentation located under the glare shield and are minimum performance requirements. Other installation positions that are closer to the forward-field-of-view ambient luminance, such as on the glare shield, may require greater luminance levels for equal readability and will need to be evaluated for basic readability per 4.3.1 and 4.3.2.

4.5.1.2 Maximum Luminance, Transflective/Reflective Segmented Displays

Transflective or reflective segmented liquid crystal displays shall have the values given in Table 2 for the following maximum total white segment luminance (self-luminance plus reflected illumination with any integral lighting or gray scale controls set to maximum luminance) when measured from within the design eye position viewing envelope. These luminance requirements are based on a 1.2 mrad line width and are minimum performance requirements. Refer to ARP4256, 4.2.2.1 for additional guidance on apparent brightness as a function of line width.

4.5.2 Minimum Luminance

For low ambient conditions, the display should be dimmable to levels that allow for the flight crew's adaptation to the dark, permitting visibility of out of the window. Under these low ambient conditions, with the display brightness set at the lowest usable level for flight or ground operations all essential symbology, flags, and annunciations shall be discernable. In dark conditions, the minimum white symbol luminance when measured in a dark ambient shall be no greater than 0.343 cd/m^2 (0.1 fL) for 0.6 mrad wide lines. A narrower line could have higher luminance. Refer to ARP4256, 4.2.2.1 for additional guidance on apparent brightness as a function of line width.

NOTE: These minimum luminance values have been established for dark-adapted flight conditions.

4.5.2.1 Design Eye Position Viewing Envelope Luminance Uniformity (Matrix Displays)

Display areas of a specified color (excluding the dark or OFF state) and luminance should have a luminance uniformity of less than 0.6 across the utilized display surface when measured from each DEP within the DEP-VE.

where:

$$\text{Luminance Uniformity} = \frac{L_{max} - L_{min}}{L_{mean}}$$

and:

L_{max} = maximum luminance measured anywhere on the utilized display surface from each DEP within the DEP-VE

L_{min} = minimum luminance measured anywhere on the utilized display surface from each DEP within the DEP-VE

L_{mean} = mean luminance of the utilized display surface as measured from each DEP within the DEP-VE

NOTE: This requirement is comparable to the CRT requirement of ±30%.

The measurement technique used to determine L_{mean} should produce a value as close as possible to that given by:

$$\frac{\int L \, dA}{A} \qquad \text{(Eq. 1)}$$

where:

A = utilized display surface area

Care should be taken to sufficiently sample luminance over the utilized display surface to produce this result.

4.5.2.2 Viewing Envelope(s) Luminance Uniformity (Matrix Displays)

Display area luminance should not vary more than 0.6 when measured from any eye position within each viewing envelope as specified by the equipment manufacturer and with the display set to its maximum gray scale (full-on).

where:

$$\text{FOV Luminance Uniformity} = \frac{L_{max} - L_{min}}{L_{mean}}$$

and:

L_{max} = maximum area luminance of a specified area measured from any eye position within each viewing envelope

L_{min} = minimum area luminance of a specified area measured from any eye position within each viewing envelope

L_{mean} = mean area luminance within each viewing envelope

4.5.3 Contrast Ratio (CR)

The contrast ratio shall be sufficient to provide a promptly discernible, readable image under all conditions of flight deck illumination.

4.5.3.1 Dark Ambient Contrast Ratio

The average saturated white contrast ratio over the usable display surface shall be a minimum of 20:1 within the design eye position viewing envelope and 10:1 for any eye position within the entire viewing envelope. This requirement shall apply to self-luminous displays (e.g., CRTs, LCDs) in a dark ambient or to transflective/reflective displays subjected to dark ambient conditions up to 1080 lx (100 ft-c).

4.5.3.2 High Ambient Contrast Ratio

The average saturated white contrast ratio over the usable display surface shall be a minimum of 3:1 when viewed from any eye location within the viewing envelope. This requirement shall apply to both self-luminous (e.g., CRTs, LCDs) and transflective/reflective displays when subjected to point source illumination levels up to 86100 lx (8000 ft-c). This requirement does not apply to specular reflections from point source illuminations.

4.5.4 Viewing Envelope(s) Color Tolerance

Over the useful luminance range (0.343 cd/m^2 (0.1 fL) to max brightness saturated white) each color displayed shall be identifiable as that same color, regardless of the field of view or viewing angle.

4.5.5 Gray Scale

Gray scale luminance level deviations throughout the viewing envelope shall not cause erroneous or misleading information.

4.5.6 Specular Reflections

As identified in Equation 2, the total photopic specular reflectivity (in %) of LCD displays installed where specular reflections (direct solar or pilot's white shirt) are within the instrument's viewing envelope shall be equal to or less than the LCD display maximum white luminance times the line width normalizing factor, K_n (refer to ARP4256, 4.2.2.1 for additional guidance), divided by 100:

$$\text{Specular Reflectivity (\%)} \leq \frac{K_n \times L_{max}}{100} \quad \text{(Eq. 2)}$$

For viewing angles of 30 degrees or less from the display normal, and L_{max} in fL.

In no case shall the level of reflectivity or mirror like reflection be sufficient to be hazardously distracting or cause erroneous interpretation.

4.5.7 Inactivated Segments

In segmented displays, when segments are not electrically activated, there shall be no obtrusive difference between the normal background luminance, color, or texture and the inactivated segments or the area surrounding them. In no case where the contrast ratio exceeds the range of 1 to 1.15 shall the data be misleading. Contrast ratios (between inactivated segments and the background) outside of the range of 1 to 1.15 measured within the design eye position viewing envelope under a point source ambient illumination of up to 86100 lx (8000 ft-c) result in visibility of the inactive segments and should be avoided.

4.5.8 Response Time

The display response time shall meet the following requirements.

- < 60 ms for total range, i.e., sum of full-off to full-on plus full-on to full-off (as measured from 10% maximum gray level to 90% maximum gray level plus 90% max to 10% max).
- < 200 ms between any intermediate levels of gray with a luminance change of at least 10%.
- In addition to the above for subjective evaluation, no tunneling (i.e., dimming) or objectionable smearing of critical or essential dynamic symbology or video shall be observable.
- This level of response time performance is required after the warm-up period ends, as defined in the environment section.

Verification Method:

Performance test (optical/time measurement, see the VESA Flat Panel Measurements Standard, Version 2.0, June 1, 2001, section 305.1) and subjective evaluation of dynamic symbology, both graphical and tactical video, under normal operating temperatures.

4.6 Operating Time

4.6.1 Start-Up

Under standard ambient conditions, a display shall present statically correct and non-misleading information within 1 minute of receiving valid data. Full dynamic and other detailed performance requirements should be met within 10 minutes. Segmented displays shall have a test, which may be done during start-up or when the test is initialized, to verify that the segments are properly displayed.

4.6.1.1 Power Transient Recovery

For power interruptions up to 200 ms in duration, recovery time should not exceed 1 second. In no case shall power transients cause any steady erroneous display or output (refer to section 16 of DO-160G).

4.6.2 Lag Time

The lag time between pilot selection of a format and display of the format should not exceed 1 second. The lag between pilot selection of primary flight data and display of the data should not exceed 0.25 second (refer to ARP4102/7, 6.1.3).

4.6.3 Data Update

Display data shall be updated at sufficient frequency to meet symbol motion (4.2.8.2) requirements. In particular for pitch and roll the update rate should be a minimum of 15 Hz.

4.7 Touch Screen Displays Operational Considerations Under General Conditions

4.7.1 Latency

The maximum amount of latency induced by the touch display system shall be appropriate to the intended function and shall not cause an unacceptable level of work load, flight crew misinterpretation or lead to an unsafe condition.

The equipment manufacturer shall document, in the operating procedures and/or in the installation instructions, the unit level latency. The latency value in milliseconds (ms) shall be a unit value. The equipment manufacturer shall also document in the TSO data package procedure, the associated avionics system configuration, the laboratory system configuration as appropriate, and the assumptions that have been made, to make such an assessment possible. Where the visual or other feedback for a touch activation is part of the unit under test (UUT), then the latency should be determined by method 1 below. If the processing of feedback is not only performed by the UUT (such as a graphics processor remote from the display), then method 2 is appropriate:

1. The time from touch screen user selection to user feedback.

2. The feedback time involving the UUT can be made of:

2a. The time from touch screen user selection until the user selection information is sent out of the UUT.

2b. The time between the UUT receiving information from the externally processed feedback and the UUT finally providing the user with the result.

NOTE: Depending on the configuration of the system, either 2a or 2a plus 2b are applicable. If the latency value is only from case 2a it is because the feedback is somewhere else in system and not on the UUT.

The following requirements apply to both 1 and 2 above.

- The equipment manufacturer may choose to perform analysis to provide an estimated latency instead of performing a measurement procedure.

- Precision of the measurement or analysis shall be documented.

- In regards to timing and predictability, expected worst case execution time condition scenarios shall be evaluated, independent of the methodology chosen by the equipment manufacturer, to determine how the latency value is affected by these condition scenarios.

- Each time that there is a major design change to the display unit, the latency value shall be reassessed to confirm if this number has changed or not.

NOTE: The latency of the touch display unit would be part of the overall display lag time described in 4.6.2, if the touch interface is used for functionalities specified in 4.6.2.

4.7.2 Cleaning

The use of the touch interface will require objects to come in contact with the front surface at a much higher rate than current displays that do not have a touch interface. This may cause the front surface of the display to become contaminated with foreign materials. These materials may reduce the ability of the pilot to see the display under all lighting conditions and therefore may require cleaning of the front surface of the display.

If cleaning is required, the display shall meet all requirements of section 4 after using prescribed cleaning methods as stated in the installation or operating instructions. There shall be a documented procedure in the installation or operating instructions to ensure during cleaning no unintended actions shall occur.

NOTE: Equipment manufacturers may choose to implement a "cleaning mode" that is accessed exclusively via touch screen. However, screen contaminates may render this function inoperable, if this mode is accessed exclusively via the touch screen that is being cleaned.

4.7.3 Touch Screen Selection Accuracy

The required alignment accuracy between the actual touched location and the detected touch location is greatly dependent on the required functionality. The equipment manufacturer shall document, in the operating procedures and/or in the installation instructions, the unit level alignment accuracy and how it was measured or analyzed.

4.8 Touch Screen Displays Operational Characteristics Under Specific Conditions

4.8.1 Performance Under Operational Lighting Conditions

The touch function shall perform as intended under all required ambient illumination levels ranging from 1.1 lx (0.1 ft-c) to sun-shafting illumination of 86100 lx (8000 ft-c) incident on the face of the display (see 4.3.1). Its operational characteristics shall be documented in the installation or operating instructions.

4.8.2 Operational Performance Under Liquid Spillage Conditions

The touch function shall perform as intended by the equipment manufacturer when a liquid comes in contact with the touch screen and its operational characteristics while the liquid remains on the touch screen shall be documented in the installation or operating instructions. The unit is expected to return to full operation after liquid is removed.

4.8.3 Operational Performance When Object is Dropped onto Touch Screen Surface

The touch function shall perform as intended by the equipment manufacturer when an object normally expected to be found on the flight deck (e.g., paper charts, cups, pens, pencils, tablet devices, food trays, headsets) falls on the touch screen and its operational characteristics after the object has contacted the touch screen surface shall be documented in the installation or operating instructions.

4.8.4 Operational Performance When Object is Placed on Touch Screen Surface and Then Removed

The touch function shall perform as intended by the equipment manufacturer when an object normally expected to be found on the flight deck (e.g., paper charts, cups, pens, pencils, tablet devices, food trays, headsets) is placed on the surface of the touch screen and its operational characteristics while the object remains on the touch screen shall be documented in the installation or operating instructions. The unit is expected to return to full operation after object is removed.

5. MINIMUM PERFORMANCE STANDARDS UNDER ENVIRONMENTAL CONDITIONS

To demonstrate compliance with this document, the tests of this section shall be conducted (where applicable). All equipment, displays, display systems, and components shall meet the applicable sections of DO-160G. Unless otherwise specified, the environmental measurement procedures applicable to a determination of performance under environmental conditions are set forth in RTCA DO-160G/EUROCAE ED-14G. Performance tests which are made after subjection to test environments may be conducted after exposure to several environmental conditions. The order of tests shall be in accordance with 3.2 of Section 3 of DO-160G/ED-14G. Unless otherwise specified in this document, the environmental test procedures contained in RTCA DO-160G/ED-14G will be used to demonstrate equipment compliance.

The environmental tests and performance requirements described in this subsection are intended to provide a laboratory means of determining the overall performance characteristics of the equipment under conditions representative of those that may be encountered in actual operations. Some of the environmental tests contained in this subsection need not be performed unless the equipment manufacturer wishes to qualify the equipment for the particular environmental condition. These tests are identified by the phrase "when required." If the equipment manufacturer wishes to qualify the equipment to these additional environmental conditions, then these "when required" tests will be performed.

The environmental performance requirements identified in this section shall be met for all equipment, displays, display systems, and components. At the conclusion of all environmental tests, the requirements of Section 4 of this document shall be met.

The following applies to displays with touch screens:

- When the unit is fully operational during testing no false positive touches shall be received.
- During specified testing (5.5, 5.20) it is up to the applicant to prove the touch screen functions as intended during the test and no false positive touches are received. Touch screen compliance may be demonstrated by testing during DO-160G, outside of the DO-160G testing, analysis or some combination thereof. Software simulation cannot be used in lieu of physical activation.
- The methodology used to prove that no false positives are received during testing shall be fully documented in the final test acceptance report.
- In 5.5 physical activation only needs to be verified at the low end operating and high end operating requirements. No false positive activations should be received during the entirety of 5.5 testing.

5.1 Requirements

The following performance requirements (5.1.1 through 5.1.6) shall be met for the environmental conditions as required in 5.4 through 5.30 of this document. Compliance may be demonstrated by testing, analysis or combination thereof.

5.1.1 Display Characteristics

The display system shall meet the display characteristics of the following paragraphs:

a. 4.2.3 Symbol Position Accuracy (External)

b. 4.2.4 Display Drift

c. 4.2.5 Display Line Width

d. 4.2.6 Display Jitter

e. 4.2.7 Display Flicker

f. 4.2.8 Symbol Quality

5.1.2 Luminance

The display luminance shall be sufficient for the display to perform its intended function.

5.1.3 Color

Where multiple colors are used, any change in color shall not cause ambiguous or erroneous information to be presented.

5.1.4 Color registration for multicolor displays, color misregistration shall not cause symbol color to be ambiguous or erroneous information to be presented.

5.1.5 Display Response Time

The display response time shall be sufficient for the display to perform its intended function. The display response time shall be less than 1 second. The requirement could be shorter for displays intended for more critical functions.

5.1.6 Mechanical Operation

All mechanical devices shall perform their intended function in a clear and unambiguous manner.

5.2 Definition of Terms

The definition of environmental general terms, including temperature stabilization, control, and test category are given in DO-160G/ED-14G Section 2.

5.3 Conditions of Tests

The equipment connection, air temperature measurement, environmental test condition tolerances and test equipment requirements are given in DO-160G/ED-14G Section 3.

5.4 Temperature and Altitude Tests (Section 4.0, DO-160G/ED-14G)

When the display system is subjected to this test, the requirements of 5.1 shall be met

5.4.1 Low Temperature Test (including Ground Survival Low Temperature Test and Short-Time Operating Low Temperature Test and Operating Low Temperature Test)

Under the environmental temperature conditions, the equipment manufacturer shall specify the time required to meet full performance. The maximum time to meet full performance shall be equal to or less than 10 minutes. The requirement could be shorter for displays intended for more critical functions.

5.4.2 High-Temperature Test (including Ground Survival High Temperature Test and Short-Time Operating High Temperature Test and Operating High Temperature Test)

a. When subjected to the high short-time operating temperature, the equipment shall function both electrically and mechanically.

b. When the equipment is operated at the high operating temperature, all the requirements of 5.1 of this document shall be met.

c. Systems which require cooling air shall meet all the requirements of 5.1 of this document.

5.4.3 In-Flight Loss of Cooling Test

When the display system is subjected to this test, all the requirements of 5.1 shall be met.

5.4.4 Altitude, Decompression and Overpressure Tests (When Required) (Section 4.6, DO-160G)

5.4.4.1 Altitude Test

When subject to this test, all the requirements of 5.1 shall be met. The instrument shall be so designed as to safeguard against hazards to the aircraft and crew, and/or malfunction of the instrument due to outgassing of organic or inorganic compounds when subjected to the altitude conditions of DO-160G/ED-14G, paragraph 4.6.

5.4.4.2 Decompression Test

When installed in accordance with the equipment manufacturer's instructions, the equipment shall function properly as intended and not be adversely affected following by exposure to the decompression test conditions of DO-160G/ED-14G, paragraph 4.6.2. When subjected to the decompression test(s), all the requirements of 5.1, along with the following shall be met.

5.4.4.3 Overpressure Test

When the equipment is subjected to the overpressure test, the requirements of 5.1 shall be met.

5.5 Temperature Variation Test (Section 5.0, DO-160G/ED-14G)

When the equipment is subjected to this test, all the requirements of 5.1 of this document shall be met.

5.6 Humidity Test (Section 6.0, DO-160G/ED-14G)

After being subjected to this test, the following shall apply:

a. Within 15 minutes after primary power is applied, the equipment shall operate at a level of performance which indicates that no significant failures of components or circuitry have occurred.

b. Within 4 hours after primary power is applied, all the requirements of Section 4 of this document shall be met.

5.7 Operational Shocks and Crash Safety Tests (Section 7.0, DO-160G/ED-14G)

a. After being subjected to the operational shock test, all the requirements of Section 4 of this document shall be met.

b. After being subjected to the crash safety shocks, the equipment shall remain in its mounting and no parts of the equipment or its mounting shall have become detached.

5.8 Vibration Tests (Section 8.0, DO-160G/ED-14G)

a. When subjected to this test, the display shall not distort either dimensionally or in visual characteristics to the extent that it presents misleading or erroneous information.

b. At the conclusion of vibration testing, the requirements of Section 4 shall be met.

5.9 Explosive Atmosphere Test (When Required) (Section 9.0, DO-160G/ED-14G)

After being subjected to this test, all the requirements of Section 4 of this document shall be met.

5.10 Waterproofness Test (When Required) (Section 10.0, DO-160G/ED-14G)

After being subjected to this test, all the requirements of Section 4 of this document shall be met.

5.11 Fluids Susceptibility Test (When Required) (Section 11.0, DO-160G/ED-14G)

After being subjected to this test, all the requirements of Section 4 of this document shall be met.

5.12 Sand and Dust Test (When Required) (Section 12.0, DO-160G/ED-14G)

After being subjected to this test, all the requirements of Section 4 of this document shall be met. External glass surfaces may be covered during the sand and dust test.

5.13 Fungus Resistance Tests (When Required) (Section 13.0, DO-160G/ED-14G)

After being subjected to this test, all the requirements of Section 4 of this document shall be met.

5.14 Salt Fog Test (When Required) (Section 14.0, DO-160G/ED-14G)

After being subjected to this test, all the requirements of Section 4 of this document shall be met.

5.15 Magnetic Effect Test (Section 15.0, DO-160G/ED-14G)

When the equipment is subjected to this test, it shall meet all the requirements of DO-160G/ED-14G for the DO-160G equipment category of installations for which it is intended.

5.16 Power Input Test (Section 16.0, DO-160G/ED-14G)

The display shall meet the requirements of Section 16.0 of DO-160G/ED-14G for power interruptions.

5.16.1 Normal Operating Conditions

When the equipment is subjected to this test, the requirements of Section 4 of this document shall be met.

5.16.2 Abnormal Operating Conditions

When the equipment is subjected to these conditions, it shall continue to operate after being turned on. Degradation of performance is tolerable providing ambiguous, erroneous, or unsafe information is not displayed, and that the equipment will return to normal operating conditions when the normal power is restored.

5.17 Voltage Spike Test (Section 17.0, DO-160G/ED-14G)

5.17.1 Category A Test (When Required)

After testing to Category A test requirements, the equipment shall meet all the requirements of Section 4 of this document. After interruption of displayed information, if it occurs, the display shall return to normal operation and meet all the requirements of Section 4 of this document.

5.17.2 Category B Test (When Required)

a. Following the application of intermittent transients, all the requirements of Section 4 of this document shall be met.

b. During the application of repetitive transients, the display may distort momentarily, however, critical data shall be readable and not hazardously misleading. After interruption of display information, if it occurs, the display shall return to normal operation and meet all the requirements of Section 4 of this document.

5.18 Audio Frequency Conducted Susceptibility - Power Inputs (Closed Circuit Test) (Section 18.0, DO-160G/ED-14G)

The display shall not distort either dimensionally or in visual characteristics to the extent that it presents ambiguous or erroneous presentation of information. After momentary distortion the display shall return to normal operation and meet all the requirements of Section 4 of this document.

5.19 Induced Signal Susceptibility Test (Section 19.0, DO-160G/ED-14G)

The display shall not distort either dimensionally or in visual characteristics to the extent that it presents ambiguous or erroneous presentation of information. After momentary distortion the display shall return to normal operation and meet all the requirements of Section 4 of this document.

5.20 Radio Frequency Susceptibility Test (Radiated and Conducted) (Section 20.0, DO-160G/ED-14G)

After being subjected to the tests in this section, the equipment shall meet all the requirements of Section 4 of this document. The tests levels from DO-160G/ED-14G Section 20 shall be specified by the equipment manufacturer. The levels should be consistent with those expected in the aircraft locations where the equipment and wiring will be installed. Additional guidance on selecting test conditions for installations is given in ARP5583. During application of the tests, the display shall not distort either dimensionally or in visual characteristics to the extent that it presents ambiguous or erroneous information. The equipment manufacturer shall define acceptable performance. After the aircraft is exposed to HIRF, each affected system that performs these functions shall automatically recover normal operation, unless this conflicts with other operational or functional requirements of that system.

NOTE: For installation related conditions, see Advisory Circular 20-158, The Certification of Aircraft Electrical and Electronic Systems for Operation in the High-Intensity Radiated Fields (HIRF) Environment.

5.21 Emission of Radio Frequency Energy Test (Section 21, DO-160G/ED-14G)

When the equipment is subjected to this test, it shall meet requirements for the appropriate category as specified in Section 21 of DO-160G.

5.22 Lightning Induced Transient Susceptibility (Section 22, DO-160G/ED-14G)

After being subjected to the tests in this section, the equipment shall meet the requirements of Section 4. The tests levels from DO-160G/ED-14G Section 22 shall be specified by the equipment manufacturer. The levels should be consistent with those expected in the aircraft locations where the equipment and wiring will be installed. Additional guidance on selecting test levels for installations is given in ARP5413 and AC 20-136. During application of the tests, the display shall not present ambiguous or erroneous information. The equipment manufacturer shall define acceptable performance. For example, displays should not display hazardously misleading primary flight data, and operation should be quickly recoverable after exposure.

NOTE: For installation related conditions, see Advisory Circular 20-136A Protection of Aircraft and Electrical/Electronic Systems against the Indirect Effects of Lightning.

5.23 Lightning Direct Effects (When Required) (Section 23, DO-160G/ED-14G)

If this section is required by DO-160G, then after being subjected to the tests in this section, the equipment shall meet all the requirements of Section 4 of this document.

5.24 Icing (When Required) (Section 24, DO-160G/ED-14G)

This section is not applicable to display systems installed inside the aircraft.

5.25 Electrostatic Discharge (ESD) (Section 25, DO-160G/ED-14G)

After being subjected to this test, the equipment shall meet the requirements of Section 4.

5.26 X-ray Radiation

This section only applies to display and display systems using CRTs. LCDs and other systems that do not emit X-ray radiation do not need to document compliance to this section nor deviations to the requirements in this section. The display system should be so designed so as to safeguard against hazard to the aircraft and crew due to X-ray radiation. Radiated energy measured 5 cm (2.0 inches) from the unit surface in the direction of the design eye, in a worse case operating condition, shall not exceed 0.1 milliroentgen per hour as measured in accordance with procedures specified in EIA RS-503a. X-ray radiation analysis may be submitted in lieu of testing.

5.27 UV Radiation

This section only applies to display and display systems using CRTs. LCDs and other systems that do not emit UV radiation do not need to document compliance to this section nor deviations to the requirements in this section. Radiation emitted by display systems shall not result in radiation on exposed skin or eyes exceeding the following values:

a. In the wavelength from 200 to 315 nm: 0.05×10^{-6} W/cm^2

b. In the wavelength from 315 to 400 nm: 0.05×10^{-3} W/cm^2

UV radiation shall be measured using a radiometer positioned as close to the display unit is feasible.

5.28 Fogging (Hermetically Sealed or Desiccated Display Units Only)

The display unit, while operating, shall be exposed to the high operating ambient temperature for a minimum of 30 minutes. While at this temperature, the external face of the cover glass shall be reduced to a temperature of not more than 20 °C. No moisture or other material shall be deposited on the internal face of the cover glass or filter.

5.29 Thermal Shock (When Required)

The operating unit shall be subjected to temperature extremes between the high operating temperature (see 5.4.2 of this document and also Section 4 of DO-160G) and the low operating temperature (see 5.4.1 of this document of and also Section 4 of DO-160G) without evidence of damage or operating failure. The unit shall operate in a high temperature test chamber at the high operating temperature until the unit temperature stabilizes. At the end of this time period, the temperature change (e.g., moving the unit to another chamber) shall be done as rapidly as possible but per the procedures and requirements specified in Section 5 of DO-160G, to a cold chamber with an internal chamber temperature at the low operating temperature.

5.30 Dielectric Test

This section is applicable to the cathode ray tube of CRT displays and planar gas discharge displays as well as any other display or display system component that has a high voltage circuit internal to the equipment.

The requirements in this section are intended to ensure that the dielectric of insulation is sufficient to keep any high voltage from causing a hazard. After completion of all other qualification tests, the display system shall meet the following dielectric test. In the performance of this test, any internal and/or external components or wires connected between the circuits and equipment case or frame shall be disconnected. The insulation resistance measured at a minimum of 200 VDC for 5 seconds shall not be less than 5 MΩ.

6. TEST PROCEDURES

6.1 Test Conditions

Where not otherwise defined by applicable CFRs, display system sampling required to demonstrate compliance with the requirements of this document shall be determined by the equipment manufacturer. The complete systems shall meet the requirements of the equipment manufacturer's recommended test procedure before qualification testing is started.

Unless otherwise specified below, equipment meeting the requirements of this standard shall be tested under the conditions specified in Section 3 of RTCA document DO-160G, ARP1782, and/or sections of this document.

6.2 Ambient Room Conditions

When tests are conducted with the atmospheric pressure or temperature values substantially different from those specified in DO-160G, allowance shall be made for these variations.

6.3 Power Conditions

Except as otherwise specified herein, all tests shall be conducted at the power rating (supplied voltage, frequency, etc.) recommended by the equipment manufacturer.

7. GLOSSARY OF TERMS

7.1 Ambient Background

Background other than generated background (i.e., the optically off state of the display).

7.2 Ambiguous or Erroneous Information

Information that is capable of being understood in a different sense than intended.

7.3 Central 80% of Useful Display Area

Area within the locus of points 80% of the distance from display center to the edge of the useful display area.

7.4 Chromaticity

A measure of the hue and purity of a color; it is defined as x,y (CIE 1931), or u',v' (CIE 1976) coordinates (refer to ARP4260).

7.5 Color Banding (Matrix)

Non-uniform distribution of color within a line or symbol (see Figure 1).

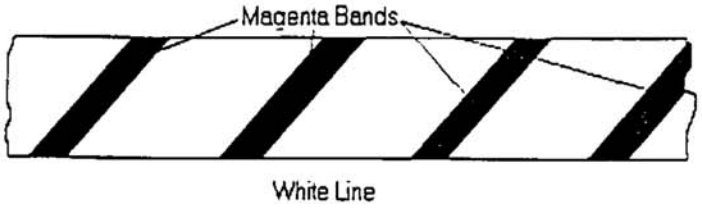

Figure 1 - Enlarged schematic depiction of color banding

7.6 Color Fringing (Matrix)

Color distortion along the edge of a line or symbol due to the interaction of line or symbol orientation with pixel pattern geometry (see Figure 2).

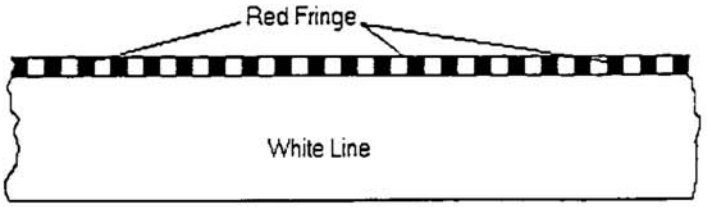

Figure 2 - Enlarged schematic depiction of color fringing

7.7 Contrast Ratio (CR)

$$CR = \frac{L_t}{L_b}$$

where:

L_t = Total luminance of the symbol or image, including any transmitted and reflected light as measured in the specified lighting conditions.

L_b = Luminance of the background, or dimmer area, including any transmitted and reflected light and any stray display emissions measured in the specified lighting conditions. Refer to ARP1782 for a full discussion on this and related definitions.

7.8 Crosstalk

Unwanted luminance modulation in display elements which is caused by the cross coupling of electrical signals addressed to other elements or rows, columns, or blocks of other elements.

7.9 Design Eye Position (DEP)

A point fixed in relation to the aircraft structure (neutral seat reference point) at which the midpoint of the pilot's eyes should be located when seated at the normal position. The DEP is the principal dimensional reference point for the location of panels, controls, displays, and external vision (refer to Figure 1 of ARP4101).

7.10 Design Eye Position Viewing Envelope (DEP-VE)

The volume in space defined by, as a minimum, the range of design eye positions in both the horizontal and vertical planes measured normal to the plane of the display surface, and the minimum distance from the center of display surface for which the instrument complies with this document. This envelope is a subset of the total viewing envelope.

7.11 Display Center

The center of the useful display area.

7.12 Display Element

The smallest addressable entity of the display. In the case of an active matrix LCD, the smallest addressable shutter of an individual color. In the case of a segmented display, any of the shapes, or symbols made up of only one individual addressable entity.

NOTE: Other commonly used terms are "dot" in matrixed displays and "segment" in segmented displays.

7.13 Failed-ON

A display element, row, or column which is failed permanently or sporadically in the "bright" or emitting state.

7.14 Failed-OFF

A display element, row, or column which is failed permanently or sporadically in the "dark" or non-emitting state.

7.15 Flashing

A desired and usually controlled variation in the luminance of a symbol or group of symbols.

7.16 Flicker

Flicker is an undesired rapid temporal variation in display luminance of a symbol, or a group of symbols, or a luminous field. Flicker can cause fatigue and reduced crew efficiency.

7.17 Flight Deck

Flight deck refers to the pilot compartment of all types of aircraft and is the generic term for "flight deck" and "cockpit."

7.18 Flightcrew

Flightcrew refers to a pilot, flight engineer, or flight navigator assigned to duty in an aircraft during flight time (refer to 14 CFR Part 1)

7.19 Generated Background

Internally generated imagery upon which symbology may be superimposed.

7.20 Gray Scale

The incremental levels of display element light transmission which exist between fully off (dark) and fully on (bright).

7.21 Image Retention

Image retention is an undesired afterimage (residual pattern) that persists on the display.

7.22 Industry Standards

A standard which has been adopted by industry which will be useful to industry for the design and procurement of equipment.

7.23 Input/Output

The interface to a unit that provides data or signals used or generated by that unit.

7.24 Instrument

The word "instrument" shall be considered to mean the specific unit or complete system for which this document is written.

7.25 Jitter

Unintended rapid movement discernible to a human eye located within the design eye position viewing envelope.

7.26 Line Width

Width at 50% of peak luminance of the line luminance distribution when measured from within the DEP-VE.

7.27 Luminance

A measure of luminous intensity per unit area; units are cd/m^2 or foot-lamberts (fL) (refer to ARP4260).

7.28 Milliradian (mrad)

An angular measurement equal to 0.0573 degrees defined as one thousandth of an arc whose length equals the circle radius. Table 1 converts milliradians to linear dimensions (inches and millimeters) for a viewing distance of 762 mm (30 inches).

7.29 Minimum Performance Standard

A standard which specifies the minimum instrument design requirements as established by the operational and environmental conditions encountered during normal flight (taxi, take off, climb, cruise, descent, landing, and taxi). It also specifies the minimum instrument performance necessary for safe operation of the aircraft during normal flight.

7.30 Moiré

A pattern seen when two out of phase spatially periodic patterns are superimposed.

7.31 Orientation Errors

This refers to angular errors associated with the depiction of symbols and other graphics that have a particular compass orientation, such as runways.

7.32 Pixel

In a matrix display, the smallest group of display elements which provides the color capability of the display.

NOTE: Be careful with the word “pixel”; it is sometimes erroneously used to refer to a single “display element” on a color matrix display (see 7.12).

7.33 Ratcheting

Discontinuous (jerky) movement or rotation of a dynamic display feature caused by excessively large quantization steps in the translation or rotation of the particular feature.

7.34 Redundancy

Multiple data paths and processing to allow a system to be failure tolerant.

7.35 Response Time

Time for pixel to react to a single input stimulus or a sequence of input stimuli (e.g., alignment of LC to change “levels of gray”).

7.36 Roping

Periodic luminance modulation along a line producing a “rope-like” appearance.

7.37 Segmented Display

A display in which the individual addressable display elements (segments) are of varying shape and/or orientation such that they are dedicated to the display of a specific type or specific types of symbolic or pictorial information.

7.38 Service Limits

An end of life condition under which the unit shall be removed from the aircraft.

7.39 Self-Luminous Displays

Self-luminous displays have the ability to emit light. Examples of Self-luminous displays include LCDs with backlights, Organic Light Emitting Devices and CRTs.

7.40 Shall Function

The instrument shall not exceed the given tolerances.

7.41 Shall Not Be Adversely Affected

The instrument shall not exhibit characteristics or sustain damage which precludes proper functioning and/or use.

7.42 Specular Reflections

Specular reflectivity is defined as the percent of light reflected from the display at an angle exactly opposite the angle of light incident to the display.

7.43 Stair Stepping

Discrete steps occurring along edges of a line or symbol caused by quantization phenomena.

7.44 Stylus

Any object that can be used to cause activation on an electronic display equipped with a touch screen. Examples of a stylus could be a finger, writing utensil, etc.

7.45 Touch Screen Activations

The act of touching a touch screen interactive display and causing a feedback response in the system.

7.46 Touch Screen Display

An electronic display that has a touch interface as part of the display surface. At a minimum a touch interface display would have a sensor integrated into the display and a controller that interprets touches on the screen and provides the appropriate x and y coordinate locations and allows input via a secondary device (e.g., finger, stylus, etc.) to cause an action on the display device. The most basic form of this would be to replace a bezel push button with a button on the display surface

7.47 Touch Screen False Activation

A registered touch screen response that happens when there is not an input stimulus to the touch screen interface.

7.48 Touch Screen Interface

The front surface of an electronic display that allows physical interaction.

7.49 Touch Screen Physical Activation

To select a touch screen function through a physical device such as a finger or stylus.

7.50 Touch Screen Software Simulated Activation

A recorded touch input on a touch screen that is not caused by a physical activation or a false activation.

7.51 Useful Display Area

That portion of the display surface on which symbology is presented.

NOTE: This does not include the bezel or surrounding area that may also be used to depict information.

7.52 Viewing Envelope

The volume in space defined by, as a minimum, the total viewing angles in both the horizontal and vertical planes measured normal to the plane of the display surface, and the minimum distance from the center of display surface for which the instrument complies with this document.

7.53 Worse Case Execution Time

The maximum length of time the task could take to execute on a specific platform. One example might be a display with heavy graphical content being displayed.

8. NOTES

8.1 Revision Indicator

A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

Table 1 - Angle conversions

angle (α) mrad	angle (α) deg	h in	h mm	angle (α) mrad	angle (α) deg	h inch	h mm
0.10	0.3'	0.0030	0.08	5.5	18.9'	0.165	4.29
0.15	0.5'	0.0045	0.11	6.0	20.6'	0.180	4.57
0.20	0.7'	0.0060	0.15	6.5	22.3'	0.195	4.95
0.25	0.9'	0.0075	0.19	7.0	24.1'	0.210	5.33
0.30	1.0'	0.0090	0.23	7.5	25.8'	0.225	5.72
0.35	1.2'	0.0105	0.27	8.0	27.5'	0.240	6.10
0.40	1.4'	0.0120	0.30	8.5	29.2'	0.255	6.48
0.45	1.5'	0.0135	0.34	9.0	30.9'	0.270	6.86
0.50	1.7'	0.0150	0.38	9.5	32.7'	0.285	7.24
0.55	1.9'	0.0165	0.42	10	34.4'	0.30	7.60
0.60	2.1'	0.0180	0.46	15	51.6'	0.45	11.4
0.65	2.2'	0.0195	0.50	20	1°9'	0.60	15.2
0.70	2.4'	0.0210	0.53	25	1°26'	0.75	19.1
0.75	2.6'	0.0225	0.57	30	1°43'	0.90	22.9
0.80	2.8'	0.0240	0.61	35	2°1'	1.05	26.7
0.85	2.9'	0.0255	0.65	40	2°17'	1.20	30.5
0.90	3.1'	0.0270	0.69	45	2°35'	1.35	34.3
0.95	3.3'	0.0285	0.72	50	2°52'	1.50	38.1
1.0	3.4'	0.0300	0.76	55	2°9'	1.65	41.9
1.5	5.2'	0.0450	1.14	60	3°26'	1.80	45.7
2.0	6.9'	0.0600	1.52	65	3°43'	1.95	49.5
2.5	8.6'	0.0750	1.91	70	4°1'	2.10	53.3
3.0	10.3'	0.0900	2.29	75	4°18'	2.25	57.2
3.5	12.0'	0.1059	2.67	80	4°35'	2.40	61.0
4.0	13.8'	0.1200	3.05	85	4°52'	2.55	64.8
4.5	15.5'	0.1350	3.43	90	5°10'	2.70	68.6
5.0	17.2'	0.1500	3.81	100	5°44'	3.00	76.0

NOTES:

1. Milliradians and degrees (α) to inches and millimeters (h) at the display surface for a viewing distance (d) of 762 mm (30 inches) which is a typical viewing distance for a design eye position.

2. $h = \alpha \times d$

   where: α = angle subtended (radians)
   d = viewing distance
   h= width or height of symbology

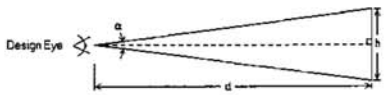

Figure 3 - Depiction of variables used to define symbol size

3. This conversion table is for an assumed viewing distance of 762 mm (30 inches) and may not satisfy performance criteria.

Table 2 - Luminance requirement versus flight deck location

Flight deck Location	Luminance Level	Diffuse Source Flight deck Illumination
Glare Shield	≥240 cd/m² (70 fL)	= 2160 lux (200 fc)
Front Panel and Side Console	≥171 cd/m² (50 fL)	= 1620 lux (150 fc)
Aisle Stand and Overhead Panel	≥120 cd/m² (35 fL)	= 1080 lux (100 fc)

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