

**(R) Minimum Performance Standard for
Airborne Multipurpose Electronic Displays**

RATIONALE

The original AS8034 document specified minimum performance standards for Electronic Displays which, at the time of publication, included only Cathode Ray Tube (CRT) displays. The AS8034A revision updated the minimum performance standards to include specific performance standards for Liquid Crystal Displays (LCD) not covered in the originally published document. The current revision, AS8034B, contains clarification on the scope of applicable types of electronic displays, updated references as well as specific updates to the general minimum performance standards for electronic displays identified in Section 3, specific performance standards for LCDs in Section 4.5, and some clarification to CRT specific minimum performance standards in Section 4.4. This document was developed by the SAE A-4 Electronic Display committee and supersedes AS8034 and AS8034A.

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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 flightcrew 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 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 section 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 flightcrew 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.
- 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 AS8055.

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 only to the extent that they are explicitly invoked by the requirements within this Aerospace Standard. The latest issue of all SAE publications shall apply except in cases where referring documents call out specific versions. In the event of conflict between these documents and this standard, the contents of this standard shall govern.

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 724-776-4970 (outside USA), www.sae.org.

ARP1782	Photometric and Colorimetric Measurement Procedures for 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 Direct View Flat Panel Displays
ARP5583A	Guide to Certification of Aircraft in a High Intensity Radiated Field (HIRF) Environment
AS8055	Minimum Performance Standard for Airborne Head Up Display (HUD)

2.1.2 CIE (Commissions Internationales de l'Eclairage) Publications

Available from Commission Internationale de l'Eclairage, CIE Central Bureau, Kegelgasse 27, A-1030 Wien, Austria, Tel: +43-1-714-31-87-0, www.cie.co.at.

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

2.1.4 EIA Publications

Available from Electronic Industries Alliance, 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 Radio Technical Commission for Aeronautics Inc., 1828 L Street, NW, Suite 805, 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, 860 Hillview Court, Suite 150, Milpitas, CA 95035.

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

2.2 Related Publications

The following documents are provided for reference only and do not form requirements for this specification.

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 724-776-4970 (outside USA), www.sae.org.

- AIR1093 Numeral, Letter and Symbol Dimensions for Aircraft Instrument Displays
- ARP4032 Human Engineering Considerations in the Application of Color to Electronic Aircraft Displays
- ARP4101 Core Document, Flight Deck Layout and Facilities
- ARP4102 Core Document, Flight Deck Panels, Controls and Displays
- ARP4103 Flight Deck Lighting and Visual Interface
- ARP4105 Nomenclature and Abbreviations for Use on the Flight Deck
- AMS2521B Reflection Reducing Coatings for Instrument Glasses

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 25-11A 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 Radio Technical Commission for Aeronautics Inc., 1828 L Street, NW, Suite 805, Washington, DC 20036, Tel: 202-833-9339, www.rtca.org.

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

2.2.4 U. S. Government Publications

Available from the Document Automation and Production Service (DAPS), Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-9495, <https://assist.daps.dla.mil/quicksearch/>.

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 flightcrew 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.
- The Society of Automotive Engineers, Inc, (SAE International), Aerospace Recommended Practice (ARP) 4761 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 vs Arc mode, which does not require a mode indication.

NOTE: Examples of modes on a moving map display include head-up vs. 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 kilogram (tenth of a pound)
- g. Environmental categories per DO-160GF/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 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 section 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) 25.853 and 25.1359 (d) and Appendix F thereto, with the exception that materials tested may be configured in accordance with paragraph (b) of Appendix F or may be configured as used.

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 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 flightcrew alerted to the failure.

4. MINIMUM PERFORMANCE STANDARDS UNDER STANDARD CONDITIONS

The 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.

4.2 Viewing Characteristics

The following requirements apply to the instrument in its installed position and as viewed under all flight deck light conditions from the 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.

4.2.1 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).

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).

4.2.2 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.

4.2.3 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 .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° with respect to the values provided by the position and database sources.

4.2.4 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.

4.2.5 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.

4.2.6 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 milliradians peak-to-peak when viewed within the design eye position viewing envelope as specified by the instrument manufacturer. Jitter of 0.3 milliradians peak-to-peak from any point within the viewing envelope is a suggested upper limit, but that may not be acceptable in some instances.

4.2.7 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.

4.2.8 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 ARP 4260A.

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.

4.2.8.1 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 moire 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.

4.2.8.2 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.

4.2.9 Crosstalk

Crosstalk shall not be readily apparent or distracting.

4.2.10 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.

4.2.11 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.

4.2.11.1 Failed-ON Row/Columns (Matrix Display)

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

4.2.11.2 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 flightcrew.

4.2.11.3 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.

4.2.12 Multiple Images

When illuminated with light not normal to the display surface, for example sun shafting illumination, transfective 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 86 100 lx (8000 ft-c) incidence on the face of the display and provide rapid eye adaptation for transitions from forward field of view luminance levels of up to 34 300 cd/m² (10 000 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 overlaid.
- 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 manufacturers shall specify the ambient illumination level and illuminate characteristic for which this requirement is met. The minimum ambient illumination requirement is specified in section 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 nine percent 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. $\pm 30\%$ when located within the useful display area, or
- b. $\pm 20\%$ 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 milliradians, whichever is greater, when viewed from within the 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 flightcrew 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/m² (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/m² (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 milliradians 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 milliradians 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 flightcrew'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/m² (0.1 fL) for 0.6 milliradians 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:

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

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 $\pm 30\%$.

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

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

where:

A is the 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:

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

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 transfective/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 transfective/reflective displays when subjected to point source illumination levels up to 86,100 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/m² (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 the equation below, 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 86 100 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 (see also 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 (reference 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.

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 paragraph 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 manufacturer wishes to qualify the equipment for the particular environmental condition. These tests are identified by the phrase "when required." If the 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.

5.1 Requirements

The following performance requirements (paragraphs 5.1.1 through 5.1.6) shall be met for the environmental conditions as required in paragraphs 5.4- 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 & Operating Low Temperature Test)

Under the environmental temperature conditions, the 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 of the requirements of Section 5.1 of this document shall be met.
- c. Systems which require cooling air shall meet all of the requirements of Section 5.1 of this document

5.4.3 In-Flight Loss of Cooling Test

When the display system is subjected to this test, all of 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 of the requirements of Section 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 of the requirements of Section 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 of the requirements of Section 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 of 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 of 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 of 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 of 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 of 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 of 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 of 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 of 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 of 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 of 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 of the requirements of section 4 of this document.

5.17.2 Category B Test (When Required)

- a. Following the application of Intermittent Transients, all of 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 of 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 of 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 of 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 of 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 of 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 in) 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: $0.05 \times 10^{-6} \text{ W/cm}^2$
- b. In the wavelength from 315 to 400 nm: $0.05 \times 10^{-3} \text{ W/cm}^2$

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 section 5.4.2 of this document and also section 4 of DO-160G) and the low operating temperature (see section 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.