

AEROSPACE STANDARD

SAE AS8034

**REV.
A**

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Superseding AS8034

(R) Minimum Performance Standard for Airborne Multipurpose Electronic Displays

TABLE OF CONTENTS

1.	SCOPE	6
2.	REFERENCES.....	7
2.1	Applicable Documents	7
2.1.1	SAE Publications.....	7
2.1.2	U.S. Government Publications	8
2.1.3	RTCA/EUROCAE Publications	8
2.1.4	CIE Publications.....	8
2.1.5	Electronic Industry Association (EIA) Publications.....	8
2.1.6	VESA Publications	8
2.2	Applicable References	9
2.2.1	SAE Publications.....	9
2.2.2	U.S. Government Publications	9
2.2.3	RTCA/EUROCAE Publications	9
2.3	Definitions	10
3.	GENERAL STANDARDS.....	10
3.1	Material	10
3.2	Workmanship.....	10
3.3	Compatibility of Components	10
3.4	Interchangeability	10
3.5	Accessibility of Controls	10
3.6	Self-Test Capability	10
3.7	Effect of Tests	11
3.8	Malfunctions	11
3.8.1	Malfunction Indication	11
3.8.2	Fail Safe Provision	11

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SAE AS8034 Revision A

3.9	Multiple Mode Indications.....	11
3.10	Identification	11
3.11	Display	11
3.11.1	Discernibility	12
3.11.2	Critical Information	12
3.11.3	Information Limit Indication	12
3.11.4	Scale Readability	12
3.11.5	Ambiguity	12
3.11.6	Integral Lighting.....	12
3.12	Resistance to Dust and Moisture	12
3.13	Mechanical Hazard System Protection	12
3.14	Fire Resistance	12
3.15	Supplemental Heating/Cooling.....	13
4.	MINIMUM PERFORMANCE STANDARDS UNDER STANDARD CONDITIONS	13
4.1	Equipment Functions and Mechanical Operation	13
4.2	Viewing Characteristics.....	13
4.2.1	Viewing Angle	13
4.2.2	Symbol Alignment	13
4.2.3	Positional Accuracy.....	14
4.2.4	Drift.....	14
4.2.5	Line Width	14
4.2.6	Jitter	14
4.2.7	Flicker.....	14
4.2.8	Symbol Quality	14
4.2.9	Crosstalk	15
4.2.10	Image Retention.....	15
4.2.11	Defects	15
4.2.12	Multiple Images.....	16
4.3	General Photocolorimetric Characteristics.....	16
4.3.1	Ambient Illumination Characteristics	16
4.3.2	Luminance Characteristics.....	16
4.3.3	Luminance and Color Discrimination	17
4.3.4	Color.....	17
4.4	CRT.....	17
4.4.1	Luminance Uniformity	17
4.4.2	Convergence.....	18
4.5	LCD	18
4.5.1	Maximum Luminance, Transmissive Displays	18
4.5.2	Contrast Ratio (CR).....	20
4.5.3	Viewing Envelope(s) Color Tolerance	21
4.5.4	Gray Scale	21
4.5.5	Specular Reflections	21
4.5.6	Inactivated Segments.....	21
4.5.7	Response Time	22

SAE AS8034 Revision A

4.6	Operating Time	22
4.6.1	Start-Up.....	22
4.6.2	Lag Time	22
4.6.3	Data Update	22
5.	MINIMUM PERFORMANCE STANDARDS UNDER ENVIRONMENTAL CONDITIONS.....	23
5.1	Requirements.....	23
5.1.1	Display Characteristics.....	23
5.1.2	Luminance.....	23
5.1.3	Color.....	23
5.1.4	Color Registration	23
5.1.5	Response Time	23
5.1.6	Mechanical Operation	23
5.2	Definition of Terms	24
5.3	Conditions of Tests	24
5.4	Temperature and Altitude Tests (Section 4.0, DO-160D/ED-14D)	24
5.4.1	Low-Temperature Test.....	24
5.4.2	High-Temperature Test	24
5.4.3	Altitude Test	24
5.4.4	Decompression Test (When Required).....	24
5.4.5	Overpressure Test (When Required).....	25
5.5	Temperature Variation Test (Section 5.0, DO-160D/ED-14D)	25
5.6	Humidity Test (Section 6.0, DO-160D/ED-14D).....	25
5.7	Shock Tests (Section 7.0, DO-160D/ED-14D).....	25
5.8	Vibration Tests (Section 8.0, DO-160D/ED-14D).....	25
5.9	Explosion Test (When Required) (Section 9.0, DO-160D/ED-14D).....	25
5.10	Waterproofness Test (When Required) (Section 10.0, DO-160D/ED-14D)	26
5.11	Fluids Susceptibility Test (When Required) (Section 11.0, DO-160D/ED-14D).....	26
5.12	Sand and Dust Test (When Required) (Section 12.0, DO-160D/ED-14D).....	26
5.13	Fungus Resistance Tests (When Required) (Section 13.0, DO-160D/ED-14D).....	26
5.14	Salt Spray Test (When Required) (Section 14.0, DO-160D/ED-14D).....	26
5.15	Magnetic Effect Test (Section 15.0, DO-160D/ED-14D)	26
5.16	Power Input Test (Section 16.0, DO-160D/ED-14D).....	26
5.16.1	Normal Operating Conditions.....	26
5.16.2	Abnormal Operating Conditions	26
5.17	Voltage Spike Conducted Test (Section 17.0, DO-160D/ED-14D)	27
5.17.1	Category A Test	27
5.17.2	Category B Test	27
5.18	Audio Frequency Conducted Susceptibility Test (Section 18.0, DO-160D/ED-14D) ...	27
5.19	Induced Signal Susceptibility Test (Section 19.0, DO-160D/ED-14D)	27
5.20	Radio Frequency Susceptibility Test (Radiated and Conducted) (Section 20.0, DO-160D/ED-14D).....	27

SAE AS8034 Revision A

5.21	Emission of Radio Frequency Energy Test (Section 21, DO-160D/ED-14D).....	28
5.22	Lightning Induced Transient Susceptibility (Section 22, DO-160D/ED-14D)	28
5.23	Lightning Direct Effects (When Required) (Section 23, DO-160D/ED-14D)	28
5.24	Icing (When Required) (Section 24, DO-160D/ED-14D).....	28
5.25	Electrostatic Discharge (ESD) (Section 25, DO-160D/ED-14D)	28
5.26	X-ray Radiation	28
5.27	UV Radiation	29
5.28	Fogging (Hermetically Sealed or Desiccated Display Units Only)	29
5.29	Thermal Shock (When Required).....	29
5.30	Dielectric Test	29
6.	TEST PROCEDURES.....	30
6.1	Test Conditions	30
6.2	Ambient Room Conditions	30
6.3	Power Conditions	30
7.	GLOSSARY OF TERMS.....	30
7.1	Ambient Background.....	30
7.2	Ambiguous or Erroneous Information	30
7.3	Central 80% of Useful Display Area.....	30
7.4	Chromaticity	30
7.5	Color Banding (Matrix)	31
7.6	Color Fringing (Matrix)	31
7.7	Contrast Ratio (CR).....	31
7.8	Crosstalk	31
7.9	Design Eye Position (DEP).....	32
7.10	Design Eye Position Viewing Envelope (DEP-VE).....	32
7.11	Display Center.....	32
7.12	Display Element	32
7.13	Failed-On	32
7.14	Failed-Off	32
7.15	Flashing.....	32
7.16	Flicker.....	33
7.17	Generated Background	33
7.18	Gray Scale	33
7.19	Image Retention.....	33
7.20	Industry Standards	33
7.21	Input/Output	33
7.22	Instrument	33
7.23	Jitter	33
7.24	Line Width	33
7.25	Luminance.....	34
7.26	Milliradian (mrad)	34
7.27	Minimum Performance Standard	34
7.28	Moire	34

SAE AS8034 Revision A

7.29	Pixel	34
7.30	Racheting	34
7.31	Redundancy	34
7.32	Response Time	34
7.33	Roping	35
7.34	Segmented Display	35
7.35	Service Limits	35
7.36	Shall Function	35
7.37	Shall Not Be Adversely Affected	35
7.38	Specular Reflections	35
7.39	Stair Stepping	35
7.40	Useful Display Area	35
7.41	Viewing Envelope	35
8.	NOTES	36

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1. SCOPE:

This SAE Aerospace Standard (AS) specifies minimum performance standards for Electronic Displays which are intended for use in the cockpit by the pilot or other flight personnel under standard and other environmental conditions. The four basic types of displays based on function and criticality are covered as follows:

- Type I Primary Flight and Primary Navigation which include vertical and horizontal situation displays.
- Type II Systems & Crew Alerting displays which include engine instrument, aircraft systems information/control, crew alerting, and documentation displays.
- Type III Control Displays, including communication, navigation and system control displays.
- Type IV Information Displays which may include navigation displays used for situational awareness only, supplemental data displays, and maintenance displays.

Airborne 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. In the case of Head Up Displays, this information is combined with a view of the real world. The minimum performance standards for Head Up Displays given in AS8055 are applicable.

Electronic display systems covered by this document are displays whose failure may lead to loss of critical displayed information. System design or installation must recognize this characteristic and include appropriate redundancy criteria where applicable.

NOTE: This document is expected to be used by the FAA as the basic requirement for a Technical Standard Order (TSO) for Electronic Display types listed above. ARP1874 and ARP4067 give recommended means, but not the only means, of compliance to this standard for CRT based displays.

SAE AS8034 Revision A

1. (Continued):

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.

2. REFERENCES:

The documents listed in 2.1 are referenced for guidance 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 documents are referenced for guidance and form a part of this document to the extent specified herein. The latest issue of all SAE Technical Reports shall apply. 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, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

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
ARP5413	Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning
ARP5583	Guide to Certification of Aircraft in a High Intensity Radiated Field (HIRF) Environment
AS8055	Minimum Performance Standard for Airborne Head Up Display (HUD)

SAE AS8034 Revision A

2.1.2 U.S. Government 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.

FAR 23 Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes

FAR 25 Airworthiness Standards: Transport Category Airplanes

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

2.1.3 RTCA/EUROCAE Publications: Available from RTCA Inc., 1828 L St. NW, Suite 805, Washington, DC 20036-5133.

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

2.1.4 CIE (Commissions Internationale de l'Eclairage) Publications: Available outside of the U.S. from Bureau Centrale De La CIE, 52, Boulevard Malesherbes, 75008 Paris, France and inside the U.S. from United States National Committee of the Commission Internationale De L'Eclairage, c/o Thomas Lemons, TLA-Lighting Consultants, Inc., 7 Pond Street, Salem, MA 01970-4893.

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

2.1.5 Electronic Industry Association (EIA) Publications: Available from Electronic Industries, 2500 Wilson Boulevard, Arlington, VA 22201.

EIA-503-9 Recommended Practice for Measurement of X-Radiation from Direct View Display Cathode Ray Tubes

2.1.6 VESA Publications: Available from VESA, 860 Hillview Ct., Suite 150, Milpitas, CA 95035.

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

SAE AS8034 Revision A

2.2 Applicable References:

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

2.2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AIR1093	Numerals, Letter and Symbol Dimensions for Aircraft Instrument Displays
ARP4032	Human Engineering Considerations in the Application of Color to Electronic Aircraft Displays
ARP4067	Design Objectives for CRT Displays for Part 23 Aircraft
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
AMS 2521B	Reflection Reducing Coatings for Instrument Glasses

2.2.2 U.S. Government 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.

MIL-HDBK-87213 is available from Document Automation and Production Service, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

Advisory Circular 25-11	Transport Category Airplane Electronic Display Systems
Advisory Circular 23-1311-1A	Installation of Electronic Display Instrument Systems in Part 23 Airplanes
MIL-HDBK-87213	Military Handbook: Electrically/Optically Generated Airborne Displays

2.2.3 RTCA/EUROCAE Publications: Available from RTCA Inc., 1828 L St. NW, Suite 805, Washington, DC 20036-5133.

RTCA DO-178B/EUROCAE ED-12B	Software Considerations in Airborne Systems and Equipment Certification
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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 (mandatory) requirement. Conformance requires that there be no deviation. The word "should" is used to express a recommendation. Deviation from the specified recommendation may require justification.

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 must 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:

3.8.1 Malfunction Indication: Means shall be provided to indicate malfunctions or failures to the appropriate crew member, unless the failure is obvious, such as loss of the display.

3.8.2 Fail Safe Provision: No single failure or malfunction of the display system shall introduce unsafe conditions to interconnected equipment.

3.9 Multiple Mode Indications:

When a display system has more than one mode, each mode of operation shall be identified by the display system unless the mode is obvious, such as Horizontal Situation Indicator (HSI)-Full Compass and Arc mode.

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-160D/ED-14D

3.11 Display:

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

SAE AS8034 Revision A

- 3.11.1 Discernibility: Appropriate means shall be incorporated to prevent obscuration or confusion of critical information.
- 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 Readability: The display scaling, graduations, and numeration shall be appropriate for the level of reading accuracy and dynamic range required.
- 3.11.5 Ambiguity: Appropriate means shall be provided to prevent ambiguous indications within the operating range of the display system.
- 3.11.6 Integral Lighting: When integral lighting is provided, it must, under normal cockpit lighting conditions, make all indices within the required viewing envelope easily readable.

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 that causes an unsafe condition.

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 Federal Aviation Regulation 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 flight crew alerted to the failure.

4. MINIMUM PERFORMANCE STANDARDS UNDER STANDARD CONDITIONS:

The manufacturer shall conduct sufficient tests to prove compliance with this standard. The applicable standard test conditions are given in RTCA DO-160D/EUROCAE ED-14D. 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 or as specified by the manufacturer for that display information. All mechanical devices shall perform their intended function, as defined by the appropriate standard document or the manufacturer, in a clear and unambiguous manner.

4.2 Viewing Characteristics:

The following requirements apply to the instrument in its installed position and as viewed under all cockpit 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 limitation shall contain, 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 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.

4.2.2 Symbol Alignment: Symbols which are interpreted relative to each other, (i.e., 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.

SAE AS8034 Revision A

- 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.
- 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 sharpness to display the intended information with no unsafe distracting visual effects or ambiguities. 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. Lines with a minimum line width less than 70% of the maximum line width may produce an undesirable visual "roping" effect.
- 4.2.6 Jitter: 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. There should be no discernible display jitter when viewed within the viewing envelope. 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: 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.
- 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 elements, construction of the symbol, rate, direction, and increment of motion and luminance control of the elements. 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 should 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 erroneous interpretation. If a failed-OFF row/column is in an unused area (format dependent) or is orthogonal to symbol lines, it may never be detected.
- 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. 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).
- 4.2.11.4 Defect Service Limits: Defects should not constitute a service limit unless they are distracting or could cause an erroneous interpretation. Even though failed-ON row/columns are not acceptable at acceptance testing, they might be tolerated in service for a time if safe flight is not threatened by distraction or erroneous interpretation. Dispatch capability can and should be enhanced by designing the display hardware/software system to be as tolerant of failures as practical; an example is designing symbols with displayed lines that are at least three elements wide so that no single failed row/column can cause an erroneous interpretation.

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 (Type I and II) and should (Type III and IV) be clearly readable throughout the viewing envelope under all ambient illumination levels ranging from 1.1 lux (0.1 fc) to sun-shafting illumination of 86,100 lux (8000 fc) 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 level appropriate to the display type (as defined in 4.3.1) and application.

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 cockpit 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 hazarding 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, characters and/or lines and overlaid background (ambient or generated).
- b. Between individual symbols, characters and lines including when they overlay ambient or generated backgrounds.
- c. Between generated backgrounds and ambient backgrounds.
- d. Between generated background 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 required, the color of the information shall be identifiable. The manufacturers shall specify the ambient illumination level and illuminate characteristic for which this requirement is met.

4.3.4 Color: Where multiple colors are used to enhance discrimination, the use of color shall not result in the 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 for critical information.

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 shall not be sufficient to cause an ambiguity or an incorrect identification of an assigned color over the entire range of luminance control.

4.4 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.

- 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:

- 4.5.1 Maximum Luminance, Transmissive Displays: With manual and automatic luminance controls at maximum, the average white symbol luminance across the usable display surface should 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 should be at least 171 cd/m^2 (50 fL) anywhere on the usable display surface under static or dynamic conditions. 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 is also a function of the display flight deck location. The above luminance requirement is 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.

- 4.5.1.1 Maximum Luminance, Transflective/Reflective Segmented Displays: Transflective or reflective segmented liquid crystal displays should have 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.

4.5.1.1 (Continued):

NOTE: The total luminance requirements stated above have been deemed sufficient by pilot evaluations. The cockpit ambient illumination levels which contribute to these total luminance values, however, are installation dependent and depend on cockpit configuration.

- 4.5.1.2 Minimum Luminance: Under night lighting, with the display brightness set at the lowest usable level for flight with normal symbology, all flags and annunciators shall be adequately visible. To achieve acceptable viewing in dark conditions, the minimum white symbol luminance when measured in a dark ambient should be no greater than 0.343 cd/m^2 (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.

- 4.5.1.3 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: 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

4.5.1.3 (Continued):

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.

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

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

4.5.2 Contrast Ratio (CR): The contrast ratio (total saturated white luminance/total black luminance) shall be sufficient to provide a promptly discernible, easy to read image under all conditions of cockpit illumination and under all conditions of eye adaptation to the external visual scene.

4.5.2.1 Dark Ambient Contrast Ratio: The average saturated white contrast ratio over the usable display surface should 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 in a dark ambient or to transfective/reflective displays subjected to a cockpit illumination of dark ambient up to 1080 lux (100 fc).

- 4.5.2.2 High Ambient Contrast Ratio: The average saturated white contrast ratio over the usable display surface should be a minimum of 3:1 when viewed from any eye location within the viewing envelope. This requirement shall apply to self-luminous or transfective/reflective displays when subjected to point source illumination levels up to 86,100 lux (8000 fc). This requirement does not apply to specular reflections from point source illuminations.
- 4.5.3 Viewing Envelope(s) Color Tolerance: The color difference between any symbols of the same color located at any position within the viewing envelope shall not be sufficient to cause an ambiguity or an incorrect identification of an assigned color over the useful luminance range (0.343 cd/m² (0.1 fL) to max brightness saturated white).
- 4.5.4 Gray Scale: Gray scale luminance level deviations throughout the viewing envelope shall not cause erroneous or misleading information.
- 4.5.5 Specular Reflections: 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 should 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° or less from the display normal, and $L_{\max}$ in fL.

In addition, the crispness or clarity of the reflected image may need to be degraded to prevent a mirror-like reflection. In no case shall the level of reflectivity and resulting loss of contrast be sufficient to be hazardously distracting or cause erroneous interpretation.

- 4.5.6 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. 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 lux (8000 fc) result in visibility of the inactive segments and should be avoided. In no case where the contrast ratio exceeds the range of 1 to 1.15 shall the data be misleading.

4.5.7 Response Time: The display response time shall meet the following requirements.

- ≤ 60 msec 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 msec 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. During the allowable warm-up period a degraded level of performance is expected.

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 should present statically correct and nonmisleading information within 1 minute of the initial turn-on. Full dynamic and other detailed performance requirements should be met within 10 minutes.
 - 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.
- 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). Unless otherwise specified, the environmental measurement procedures applicable to a determination of performance under environmental conditions are set forth in RTCA DO-160D/EUROCAE ED-14D. Performance tests which must be made after subjection to test environments may be conducted after exposure to several environmental conditions. The order of tests must be in accordance with paragraph 3.2, of Section 3 of DO-160D/ED-14D.

5.1 Requirements:

The following requirements shall be met for the environmental conditions as required in the applicable paragraph. 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 Response Time: The display response time shall be sufficient for the display to perform its intended function.

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-160D/ED-14D 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-160D/ED-14D Section 3.

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

5.4.1 Low-Temperature Test:

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

5.4.1.2 Under the environmental temperature conditions, the manufacturer shall specify the time required to meet full performance.

5.4.2 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, the requirements of 5.1 shall be met.
- c. Systems which require cooling air shall meet 5.1 when subjected to the temperature of the loss of cooling test requirements with a cooling air failure.

5.4.3 Altitude Test: When subject to this test, the requirements of 5.1 shall be met.

5.4.4 Decompression Test (When Required): When subjected to this test, the requirements of 5.1 shall be met.

5.4.4.1 Decompression: When installed in accordance with the equipment manufacturer's instructions, the equipment shall function and not be adversely affected following exposure to the decompression test conditions of DO-160D/ED-14D, paragraph 4.6.2.

SAE AS8034 Revision A

5.4.4.2 Outgassing: 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-160D/ED-14D, paragraph 4.6.

5.4.5 Overpressure Test (When Required): When the equipment is subjected to this test, the requirements of 5.1 shall be met.

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

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

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

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

5.6.1 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.

5.6.2 Within 4 hours after primary power is applied, the requirements of Section 4 shall be met.

5.7 Shock Tests (Section 7.0, DO-160D/ED-14D):

a. After being subjected to the operational shock test, the requirements of Section 4 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-160D/ED-14D):

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 Explosion Test (When Required) (Section 9.0, DO-160D/ED-14D):

During this test, the equipment shall not cause detonation of the explosive mixture within the test chamber.

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

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

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

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

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

After being subjected to this test, the requirements of Section 4 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-160D/ED-14D):

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

5.14 Salt Spray Test (When Required) (Section 14.0, DO-160D/ED-14D):

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

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

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

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

As a minimum, the display shall meet the requirements of Section 16.0 of DO-160D/ED-14D for power interruptions. Note, however, that the requirements for operating through power interruptions specified in Section 16 may not be sufficient for some display applications, specifically during critical phases of flight.

5.16.1 Normal Operating Conditions: When the equipment is subjected to this test, the requirements of Section 4 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 operation when the power is returned to normal operating conditions.

5.17 Voltage Spike Conducted Test (Section 17.0, DO-160D/ED-14D):

5.17.1 Category A Test: After testing to Category A test requirements, if applicable, the equipment shall meet the requirements of Section 4.

5.17.2 Category B Test:

- a. Following the application of Intermittent Transients, the requirements of Section 4 shall be met.
- b. During the application of Repetitive Transients, the display may distort momentarily, however, critical data must be readable and not hazardously misleading.

5.18 Audio Frequency Conducted Susceptibility Test (Section 18.0, DO-160D/ED-14D):

The display shall not distort either dimensionally or in visual characteristics to the extent that it presents ambiguous or erroneous information.

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

The display shall not distort either dimensionally or in visual characteristics to the extent that it presents ambiguous or erroneous information.

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

After being subjected to this test, the equipment shall meet the requirements of Section 4. The tests levels from DO-160D/ED-14D 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 levels 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. For example, Type I displays should not display hazardously misleading primary flight data, and operation should be quickly recoverable after exposure. Note: As an installation requirement for critical functions with multiple systems, loss of a system or systems during exposure of the aircraft to High Intensity Radiated Fields (HIRF) shall not result in permanent loss of the function. 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. For Type II, III and IV displays, equipment fault or loss of display may be acceptable as long as normal operation is recovered in a timely manner with no pilot action required.

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

When the equipment is subjected to this test, it shall meet requirements for the appropriate category as specified by the manufacturer.

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

After being subjected to this test, the equipment shall meet the requirements of Section 4. The tests levels from DO-160D/ED-14D 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 AC20-136. During application of the tests, the display shall not present ambiguous or erroneous information. The equipment manufacturer shall define acceptable performance. For example, Type I displays should not display hazardously misleading primary flight data, and operation should be quickly recoverable after exposure.

NOTE: As an installation requirement for critical functions with multiple systems, loss of a system or systems during exposure of the aircraft to lightning shall not result in permanent loss of the function. After the aircraft is exposed to lightning, each affected system that performs these functions shall automatically recover normal operation, unless this conflicts with other operational or functional requirements of that system. For Type II, III and IV displays, equipment fault or loss of display may be acceptable as long as normal operation is recovered in a timely manner with no pilot action required.

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

After being subjected to this test, the equipment shall meet the requirements of Section 4. This section is not applicable to display systems installed inside the aircraft.

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

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

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

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

5.26 X-ray Radiation:

The display system should be so designed 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-503-a. X-ray radiation analysis may be submitted in lieu of testing.

5.27 UV Radiation:

Radiation emitted by display systems shall not result in radiation falling 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. UV analysis may be submitted in lieu of testing.

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 ambient temperature extremes between the high operating temperature (5.4.2) and the low operating temperature (5.4.1) 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 unit shall be transferred, as rapidly as possible but in no more than 5 minutes, to a cold chamber with an internal chamber temperature at the low operating temperature. The unit shall continue to operate at this low temperature until the unit temperature stabilizes, but the stabilization time shall not exceed 1 hour.

5.30 Dielectric Test:

After completion of all other qualification tests, the display system must meet the following dielectric test. Any internal and/or external components or wires connected between the circuits and equipment case shall be disconnected. The insulation resistance measured at a minimum of 200 V DC for 5 seconds shall not be less than 5 megohms.

6. TEST PROCEDURES:

6.1 Test Conditions:

Where not otherwise defined by applicable FARs, display system sampling required to demonstrate compliance with the requirements of this document shall be determined by the manufacturer. The complete systems shall meet the requirements of the 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-160D, 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-160D, 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 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 (reference ARP4260).

7.5 Color Banding (Matrix):

Nonuniform distribution of color within a line or symbol (see Figure 1).

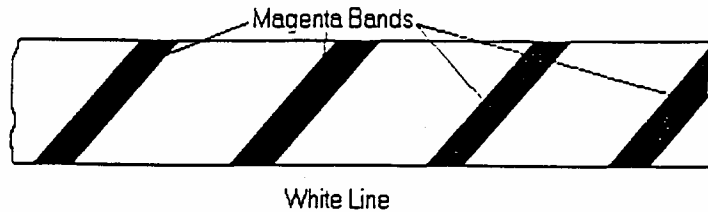


FIGURE 1

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).

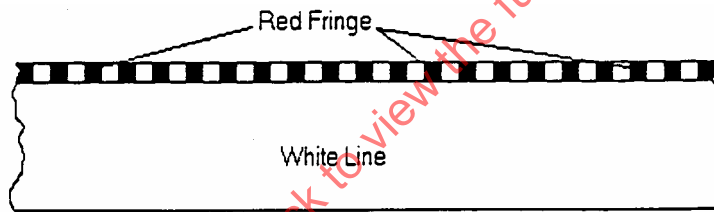


FIGURE 2

7.7 Contrast Ratio (CR):

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

L_t is the total luminance of the symbol or image, including any transmitted and reflected light as measured in the specified lighting conditions. L_b is the luminance of the background, or dimmer area, including any transmitted and reflected light and any stray display emissions measured in the specified lighting conditions. See 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.