



AEROSPACE RECOMMENDED PRACTICE

ARP4103

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Superseding ARP4103

(R) Flight Deck Lighting for Commercial Transport Aircraft

RATIONALE

This SAE Aerospace Recommended Practice (ARP) is revised to update and improve specification of technical requirements. This document recommends flight deck lighting design and performance criteria to ensure prompt and accurate readability and visibility, color identification and discrimination of needed information under all expected ambient lighting and electrical power conditions.

INTRODUCTION

This document is part of a family of documents relating to flight deck lighting as a whole. The family of documents consists of AS264, ARP1048, and ARP1161. It is the intent of the A-20A Aircraft Crew Station Lighting Committee to consolidate these documents into ARP4103 over time.

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1. SCOPE

This document recommends design and performance criteria for aircraft lighting systems used to illuminate flight deck controls, luminous visual displays used for transfer of information, and flight deck background and instrument surfaces that form the flight deck visual environment. This document is for commercial transport aircraft except for applications requiring night vision compatibility.

1.1 Purpose

The criteria specified herein are intended to provide guidance to equipment manufacturers, flight deck designers, and certification personnel in managing such factors as brightness, contrast, and color selection to create a flight deck environment that supports effective human visual perception in all the expected range of ambient illumination conditions. The factors to be managed include those that are known to affect sensory coding, spatial organization, visual search time, and visual information processing; the goal is to optimize visual interface of the flight crew to promote safe operation of the airplane. The purpose is to satisfy the end user and obtain certification.

The desired system for aircraft flight deck lighting and display optics is one that will furnish light of adequate intensity and distribution under all conditions of internal and external lighting so that the crew may read instrumentation, placards, check lists, manuals, maps, instrument color coding, distinguish controls, etc., without undue interference with their vision outside of the aircraft.

1.2 Mandating and Recommending Phrases

"Shall" - The word "shall" indicates a mandatory criterion for compliance to this ARP.

"Should" - The word "should" indicates a criterion for which an alternative, including non-compliance, may be applied if it is documented and justified.

1.3 Application

This ARP should be used in conjunction with ARP4101 and ARP4102.

ARP4103 includes general lighting and display optics requirements for all expected lighting conditions and in all expected electrical power conditions and pilot tasks. This document defines the recommended design and performance requirements for component and system level lighting. The document is organized as follows.

Section 3 provides general system level requirements and guidance for flight deck lighting design and certification. The flight deck lighting needs to be designed for the following top level system considerations:

- a. Normal lighting systems
- b. Non-normal lighting, back up, standby, and battery systems
- c. Emergency evacuation
- d. Service and maintenance

System level design considerations discussed include:

- a. Human visual performance
- b. Ambient lighting environment
- c. The visual geometrical considerations include the pilot viewing angle and distance to the lighted components, window and display location for direct sun angles and night reflections.

- d. The light source and display type, technology affects the reliability and visibility and must be considered for the following factors: luminance, illuminance, chromaticity, temporal characteristics, thermal characteristics, aging and end of life, luminous maintenance, contrast, and dimming.
- e. The format and layout affects visibility by font, type, size, luminance, color, and shape.
- f. Color appearance is a function of spectral characteristic, gloss, texture, and reflectance.
- g. Glare and reflection
- h. Regulation and certification

Section 4 provides component level requirements and guidance for flight deck lighting design. Each component and system visual factor sub-section provides: a definition, certification regulations, visual performance guidance, and compliance verification methods. The Section 3 general system level requirements and guidance shall be considered for each component level or subsystem. The components discussed are:

- a. Lightplate, integrally lighted information panels
- b. Switches, knobs
- c. Annunciators, indicators
- d. Control panel, keypads, and keyboards
- e. Touchscreen
- f. Electronic displays
- g. Alphanumeric electronics displays
- h. Head-up displays
- i. Integrally lighted instruments. Conventional instruments, painted white on black.
- j. Circuit breaker panel lighting
- k. Markers, placards
- l. General area and localized task and flood lighting
- m. Windows, visors, shades, transparencies

Section 5 is about lighting control; Section 6 discusses light source considerations; Section 7 is on optical requirement compliance verification; and Section 8 provides the non-optical qualification and environmental requirements for flight deck lighting.

2. REFERENCES

2.1 Applicable Documents

This ARP should be used in conjunction with the ARP4101 and ARP4102 series of documents about flight deck design. In addition, the following publications form a part of this ARP to the extent specified herein.

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.

AS264	Instrument and Cockpit Lighting for Commercial Transport Aircraft
ARP378	Passenger Reading Lights
ARP493	Knobs, Control Aircraft, Recommended Design
ARP503	Emergency Evacuation Illumination
ARP798	Design Criteria for White Incandescent Lighted Aerospace Instruments
ARP924	Specification and Inspection of Glass for Integrally Lighted Aerospace Instruments
ARP1048	Instrument and Cockpit Illumination for General Aviation Aircraft
ARP1088	Aircraft Indicating Systems
AIR1093	Numeral, Letter and Symbol Dimensions for Aircraft Instrument Displays
ARP1161	Crew Station Lighting - Commercial Aircraft
ARP1782	Photometric and Colorimetric Measurement Procedures for Airborne Direct View CRT Displays
ARP1798	Portable Emergency Lighting Systems for Flight Crew Members
AMS2521	Coating, Reflection-Reducing for Instrument Glasses
ARP4032	Human Engineering Considerations in the Application of Color to Electronic Aircraft Displays
ARP4101	Flight Deck Layout and Facilities
ARP4101/5	Aircraft Circuit Breaker and Fuse Arrangement
ARP4102	Flight Deck Panels, Controls, and Displays
ARP4102/4	Flight Deck Alerting System (FAS)
ARP4105	Abbreviations, Acronyms, and Terms for Use on the Flight Deck
ARP4155	Human Interface Design Methodology for Integrated Display Symbology
ARP4256	Design Objectives for Liquid Crystal Displays for Part 25 (Transport) Aircraft
ARP4260	Photometric and Colorimetric Measurement Procedures for Airborne Electronic Flat Panel Displays
ARP5287	Optical Measurement Procedures for Airborne Head Up Display (HUD)
ARP5288	Transport Category Airplane Head Up Display (HUD) Systems
ARP5297	Recommended Qualification Tests for Halogen Miniature Lamps Less Than 35 Watts for Aircraft Applications
ARP5873	Passenger Reading Light Assembly

ARP6161	Flight Compartment Glare
ARP6253	LEDs and Aircraft Applications
ARP6402	LED Landing, Taxiing, Runway Turnoff, and Recognition Lights
AS8055	Minimum Performance Standard for Airborne Head Up Display (HUD)
AS18012	Markings for Aircrew Station Displays, Design and Configuration of
AS25050	Colors, Aeronautical Lights and Lighting Equipment, General Requirements For

2.1.2 U.S. Government Publications

Available from DLA Document Services, Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6396, <http://quicksearch.dla.mil/>.

FED-STD-595 Federal Standard No. 595 Colors

Available from the FAA at: http://www.faa.gov/regulations_policies/faa_regulations/

PART 25 - AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES

AC 20-175	Controls for Flight Deck Systems
AC 25-7A	Flight Test Guide for Certification of Transport Category Airplanes
AC 25-11A	Electronic Flight Deck Displays
AC 25.1322-1	Flightcrew Alerting
AC 27-1B	Certification of Normal Category Rotorcraft
AC 29-2C	Certification of Transport Category Rotorcraft

Pilot Safety Brochures <http://www.faa.gov/pilots/safety/pilotsafetybrochures/>

Policy Memo ANM-99-2, Guidance for Reviewing Certification Plans to Address Human Factors for Certification of Transport Airplane Flight Decks

Policy Memo ANM-0103, Factors to Consider When Reviewing an Applicant's Proposed Human Factors Methods of Compliance for Flight Deck Certification

Notice 8110.98, Addressing human factors/pilot interface issues of complex, integrated avionics as part of the Technical Standard Order (TSO) process

TSO C113	Airborne Multipurpose Electronic Displays
TSO-C164	Night Vision Goggles

2.1.3 Military Publications

MIL-DTL-7788	Panels, Information, Integrally Illuminated
MIL-HDBK-217	Reliability Prediction of Electronic Equipment
MIL-PRF-22885	Performance Specification Sheet; Switches, Pushbutton, Illuminated

2.1.4 Industry Standards

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

ISO 11664-1:2007(E)/CIE S 014-1/E: 2006: Joint ISO/CIE Standard: Colorimetry - Part 1: CIE Standard Colorimetric Observers

ISO 11664-4:2008(E)/CIE S 014-4/E: 2007: Joint ISO/CIE Standard: Colorimetry - Part 4: CIE 1976 L*a*b* Color Space

ISO 11664-5:2009(E)/CIE S 014-5/E: 2009: Joint ISO/CIE Standard: Colorimetry - Part 5: CIE 1976 L*u*v* Colour Space and u', v' Uniform Chromaticity Scale Diagram

Available from Illuminating Engineering Society (IES), 120 Wall Street, Floor 17, New York, NY 10005-4001, Phone: (212) 248-5000, www.ies.org.

IESNA The IESNA Lighting Handbook: Reference & application

2.1.5 RTCA Publications

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

RTCA DO-160 Environmental Conditions and Test Procedures for Airborne Equipment

RTCA DO-178 Software Considerations in Airborne Systems and Equipment Certification

RTCA DO-254 Design Assurance Guidance for Airborne Electronic Hardware

RTCA DO-268 Concept of Operations – Night Vision Imaging System for Civil Operators

RTCA DO-275 Minimum Operational Performance Standards for Integrated Night Vision Imaging System Equipment

2.1.6 Other Publications

Davis, Wendy and Ohno, Yoshi, "Color quality scale," Optical Engineering 49(3) 033602 (March 2010)

Murdock, Joseph B., "Step by Step" LD+A, June 1998, page 70

Boeing document D950-10620-1, "Common Displays Performance Requirements," Contact: The Boeing Company, 9725 E. Marginal Way S., Tukwila, WA. 98108-4040, Mail Code: 4C-69, Phone: 425-965-3875, DocumentReleasePugetSound@pss.boeing.com.

2.2 Definitions

Also see ARP4256, Section 5.

2.2.1 CHROMATICITY

The CIE defines chromaticity per International Lighting Vocabulary (ILV) term 17-144 chromaticity - property of a color stimulus defined by its chromaticity coordinates, or by its dominant or complementary wavelength and purity taken together. In this document, u',v' (CIE 1976) coordinates will be used for emissive color per CIE S 014-5. It is recommended CIE L*a*b* be used for reflective color per CIE S 014-4.

2.2.2 COLOR

Measure of the chromaticity and luminance of an object.

2.2.3 CONTRAST: Contrast is defined as follows:

$$C = \frac{L2 - L1}{L1} \quad (\text{Eq. 1})$$

where:

C = luminance contrast

L1 = average luminance of the background (or unlighted area) at specified ambient

L2 = average luminance of the information display (activated or lighted portion of the information display) at specified ambient

2.2.4 CONTRAST RATIO

$$L2/L1 \quad (\text{Eq. 2})$$

2.2.5 DESIGN EYE REFERENCE POINT (DERP)

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

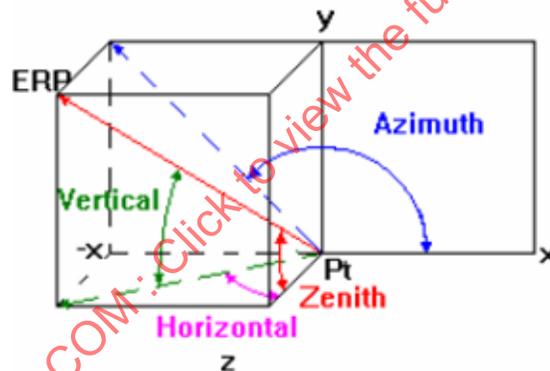


FIGURE 1 - ERP VIEWING ANGLE

2.2.6 FINAL EYE POSITION (FEP)

The eye position obtained when the observer looks at the display by body movement from the design eye reference position.

2.2.7 LUMINANCE

Photometric brightness, from IES, a measure of luminous intensity per unit area; units are candela per square meter (cd/m^2) or fL (footLamberts). $1.000 \text{ fL} = 3.426 \text{ cd}/\text{m}^2$. This document uses the photopic response and the 2 degree CIE 1976 standard observer per CIE S 014-1.

2.2.8 ILLUMINANCE

A measure of power per unit area or flux density on a surface, lumens per unit area; units are lux or fc (footcandle). $1.00000 \text{ fc} = 10.7639 \text{ lx}$.

2.2.9 VIEWING ANGLE

Viewing angle is defined as the angle between the line of sight from the pilot (observer) to the information displayed in its installed location and the normal to the display and is depicted in Figure 2. Within the required viewing angle range, all display elements shall be clearly readable under all expected lighting and operating conditions.

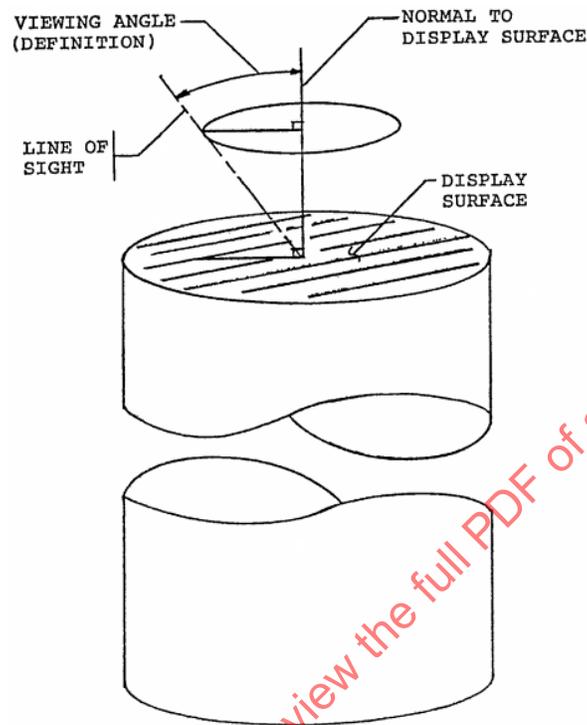


FIGURE 2 - VIEWING ANGLE DEFINITION

3. FLIGHT DECK LIGHTING SYSTEM & DISPLAY OPTICS REQUIREMENTS

Section 3 provides system level requirements and guidance for flight deck lighting design and certification. These general requirements and guidance shall be applied to all subsystems and components in Section 4.

One of the first steps with the flight deck lighting design is to define the pilot's visual tasks with emphasis on what lighting or display is required for the tasks and the task surface. Flight deck lighting must be designed to function in all expected ambient lighting environments ranging from night to bright day. A failure hazard assessment (FHA) needs to be conducted to consider the effects of lighting failures on the design. Failure affects need to be considered for the flight deck lighting Master Minimum Equipment List (MMEL) and Dispatch Deviation Guide (DDGs). A flight deck lighting system description should be created to include flight crew procedures for operating the system.

There are several basic considerations and determining factors that must be taken in account when selecting an optical design, including:

- The individual specifications of the instrument to be designed.
- Environmental conditions (ambient light, high temperature, low temperature, humidity, etc.).
- Power available (AC, DC, 5 V, 28 V, etc.).
- The amount of space and weight allowed for the lighting device.
- Cost.

3.1 Flight Deck Lighting Certification Regulations, Guidelines, Criteria

There are regulatory, customer, and company requirements to consider in the optical design of flight decks. The primary FAA Part 25 "AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES" list is:

- 25.773(a)(2) Pilot compartment view
- 25.1301(a)(d) Function and installation
- 25.1302 Installed systems and equipment for use by the flightcrew
- 25.1303(a) Flight and navigation Instruments
- 25.1309(a) Equipment, systems, and installations
- 25.1321(a)(c)(2)(e) Arrangement and visibility
- 25.1322 Flightcrew alerting
- 25.1381 Instrument lights
- 25.1543(b) Instrument markings: General

The FAA Part 121 "OPERATING REQUIREMENTS: DOMESTIC, FLAG, AND SUPPLEMENTAL OPERATIONS" rules include:

- 121.305(j)(6) Flight and navigational equipment
- 121.323(d) Instruments and equipment for operations at night
- 121.325(c) 121.325 Instruments and equipment for operations under IFR or over-the-top

See Appendix A for the CFR text and typical method of compliance. See Appendix B for the secondary list of CFRs to consider for flight deck lighting design. The amendment level of the CFRs must be noted to know what level is applicable at the time of the design.

Certifiable performance to the CFRs of flight deck lighting is demonstrated on the airplane to FAA pilots in a conformed installation. The main visual performance items to demonstrate are adequate readability, visibility, color identification, and color discrimination of needed controls and displayed information in all expected ambient lighting environments (see 3.3) and in all expected electrical power conditions. In addition, check that glare, stray light, and reflections do not interfere with crew duties during night and day flight. It is common to hold a simulated-night ground demonstration for high-risk electrical failure conditions. For night demonstrations, it is recommended the pilots dark adapt for at least fifteen minutes. It is also recommended pilots wear white shirts that can be a source of reflection, because many airline pilots wear white shirts. AC 25-7A shall be used and "provides guidance for the flight test evaluation of transport category airplanes. These guidelines provide an acceptable means of demonstrating compliance with the pertinent regulations of 14 CFR part 25."

3.2 Visual Performance

The visual interface is the most important pilot and airplane interface. Execution of flight crew visual performance tasks and procedures are measured in terms of accuracy, speed, and comfort. Visual performance factors include:

Task (who, what, when, where, task surface); visibility, readability, legibility; font (visual size, viewing angle, distance, amount of lighted area); luminance, illuminance, polarization, contrast; color, spectral; temporal; glare, stray light, reflections; uniformity, balance, and dimming.

Lighting system level requirements for these factors are applied to the flight deck lighting components to ensure the system level requirements are met. It can be a difficult task to integrate various lighting component media and light source technologies.

A dimming curve, font, and color should be defined for all devices. Where possible, the same lighting and display technology should be used to help with color, appearance, luminance matching and balance so all needed information is visible. For example, if LED and incandescent technology must be mixed, the LED appearance should be selected to match the incandescent or vice-versa.

There are inevitably trade-offs to make between these visual performance factors, however beware that these factors are inter-related. Further complicating the design challenge is that current metrics for these human performance factors do not perfectly represent the human eye-brain visual system at this time. Therefore, subjective evaluations are almost always warranted to supplement the objective requirements and evaluations of the flight deck lighting system.

For more information on visual performance, see the FAA Pilot Safety Brochure "Pilot Vision" at <http://www.faa.gov/pilots/safety/pilotsafetybrochures/>. The FAA pilot eye standards for medical certification are found in CFR 67.103, 67.203, and 67.303.

3.2.1 Tasks

All instruments, display and control information, and controls intended for use by the flight crew shall be readable and visible under all expected ambient lighting conditions in all expected electrical power states. Lighting can help ensure accurate, timely, and comfortable accomplishment of the task.

Some examples of pilot and user tasks that require flight deck lighting include:

- Read and verify checklists
- Write frequencies, passenger count
- Read aircraft situational awareness, flight regime, navigation, altitude, speed, attitude
- Read approach plates, en-route charts
- Ground service
- Set and adjust brightness controls

3.2.2 Viewing Angle

The needed information shall be visible with minimum head movement from the pilot's design eye reference position (DERP) per CFR 25.1321. The airplane's design eye reference point (DERP) shall be defined as the recommended eye position to ensure proper external and internal viewing of forward instruments and displays. The viewing angles are determined from the DERP and from the eye position determined by the pilot's final eye position (FEP) based on head and body movement to view the displays and manipulate the controls. The final eye position (FEP) with head motion shall be used to determine viewing angles to equipment which due to its location requires significant head deviations from DERP. Examples of FEPs that are significantly different from the ERPs are found in pedestal and overhead zones. It is important to know that the visibility of displayed information may change as a function of viewing angle. This is especially critical for some lighting media such as LCDs but is also fundamental for all media because the projected size of the font is reduced off-normal reducing the perceived brightness.

3.2.3 Finish Appearance

Flight deck finish appearance is an important factor in the flight deck lighting system because it immediately surrounds the flight deck lighted information and affects the visibility and comfort of the pilot. Finish appearance is described as the color, gloss, and texture of the lining, window frames, top of glare shield, and instrument bezels. It generally deals with the reflective appearance but the emissive media must also be considered.

The flight deck finish appearance should be low gloss and low reflectance to enhance visibility of information and to prevent distracting glare and reflections per CFR 25.773(a)(2). See ARP6161 for more guidance.

The finish color should be conducive to a good working environment and it shall not interfere with the CFR alerting color selection criteria in 25.1322.

3.2.4 Font Characteristics

Font and marking should meet the guidelines given in:

- AS18012
- AIR1093 covers aircraft instrument dials and panel displays
- ARP4102/7 "Electronic Displays" (6.1.4)
- AS18012 annunciator, indicators

There are a variety of fonts that are typical for aerospace applications. Futura, Gorton, Helvetica, DIN 1451, and variants of these are among the most common. All these fonts have their own design rules for stroke to height ratio and character spacing. Many fonts are copyrighted.

An example of a common font for instruments, controls, and displays is Futura Medium as shown in Figure 3. The font characteristics below should be considered for inclusion in the lighting specification because it has a significant impact on readability. The numbers below are examples for Futura Medium.

- a. Height to width ratio (8:5)
- b. Height to stroke width ratio (8:1)
- c. Spacing between characters (one stroke width)
- d. Spacing between words (one character width)
- e. Spacing between lines (one-half the character height)
- f. Character height and width tolerance $\{\pm 0.013 \text{ cm (0.005 inch)}\}$
- g. Character stroke width tolerance $\{\pm 0.005 \text{ cm (0.002 inch)}\}$
- h. Kerning

In addition, refer to Chapter 5 of AC 25-11A.

Figures, letters, and numbers shall subtend not less than the Table 1 vertical angles from the design eye position of the pilot (or crew) who normally utilizes the displayed information. The font stroke width, font height-to-stroke width ratio, and letter spacing shall be designed for readability at the maximum compound viewing angles for the equipment.

Futura Medium
 ABCDEFGHIJKLMNOPQRSTUVWXYZ
 1234567890 ., - %/

*** Futura Demibold**
 ABCDEFGHIJKLMNOPQRSTUVWXYZ
 1234567890 ., - %/

*** Futura Medium Condensed**
 ABCDEFGHIJKLMNOPQRSTUVWXYZ
 1234567890 ., - %/

* (ALTERNATE FONT)

FIGURE 3 - FONT EXAMPLE - FUTURA FOR CONTROLS/DISPLAYS

TABLE 1 - CHARACTER SYMBOLOGY HEIGHT

Displayed Information	Subtended Angle (minutes of arc)	Subtended Angle (milliradians of arc)
Primary - Dynamic nomenclature	20	6
Alerting (dynamic) nomenclature	15	4.4
Fixed essential nomenclature	12	3.5
Fixed continuously available nomenclature	10	3

3.2.5 Luminance

The displayed information shall be clearly readable throughout the viewing envelope under all ambient illumination levels ranging from dark 1.1 lx (0.1 fc) to sun-shafting illumination of 86 111 lx (8000 fc) incidence on the face of the display or panel. The luminance shall be sufficient to provide the needed information is plainly visible under all conditions of flight deck ambient illumination and provide rapid eye adaptation for transitions from forward field-of-view (FOV) luminance levels of up to 34 260 cd/m² (10 000 fL). Pertinent FAA CFRs include 25.1321(a), 25.1321(c)(2), 25.1381(a)(1), and 25.1543(b).

3.2.6 Luminance Adjustment

Brightness adjustment of information is needed to accommodate pilot vision capability differences and preferences. The designer should consider the legibility of information in both high ambient and dark ambient conditions. All needed information shall be visible at the brightness setting needed for the ambient lighting condition. There should be sufficient steps and resolution to cover a wide range of ambient conditions. Luminance adjustment should follow the CIE L^* metric to ensure a perceptually continuous brightness change. The associated FAA CFR is 25.1381(b).

3.2.7 Contrast, Contrast Ratio

The luminance contrast ratio (total foreground luminance/total background luminance) shall be sufficient to provide plainly visible information under all conditions of cockpit illumination and under all conditions of eye adaptation to the external visual scene. Image brightness, the subjective perception of luminance, is heavily dependent on image size or line width. Smaller line widths than those referenced in the following paragraphs will require higher luminance for comparable readability. Pertinent FAA CFRs include 25.1321(a), 25.1321(c)(2), 25.1381(a)(1), and 25.1543(b).

3.2.8 Color and Spectral Considerations

Flight deck design should have a color philosophy to harmonize information for controls and displays, human factors, and aesthetics. Color selection should be based on a flight deck color philosophy. Colors can be emissive or reflective, or a combination. Colors are determined by the spectral emission of light sources (manmade or natural) and the spectral reflectivity of the reflecting surface.

Color selection for alerts and annunciations are defined in AC 25-11A, 25.1322, and ARP4032. Colors shall be identifiable and distinct under all expected ambient lighting conditions.

Color selection for non-alerts and normal annunciations is important to provide contrasts and comfort. The normal nomenclature display information should be a neutral color or muted, usually white. The white nomenclature is viewed against a neutral darker reflective background typically black, grey, or brown. Color selection for instrument bezels, control/display panels, alphanumeric keyboards, lightplates, knobs, keyboard keys and flight deck side panels, overhead panels (and other flight deck material finishes and linings), etc., shall be consistent throughout the flight deck.

Requirements for reflective control and display colors are specified in terms of FED-STD-595 reflective color standards or in 1976 CIELAB color system. All reflective colors shall match the specified color standard when viewed under CIE Standard Source "A" and "D65" or when measured using a colorimeter or spectrophotometer.

The color of light for displays, unless otherwise specified, shall be per AS25050 and ARP4032. If color compensation is required, materials used for compensation shall be color stable and not subject to damage or loss during lamp replacement or normal maintenance. Lamps should not be painted or dipped to avoid nonstandard processes. The use of filter boots is not recommended because the boots might be damaged or not be re-installed when the lamps are replaced. The preferred method for filtering a light source is via a dedicated filter installed in the lightplate or LCD.

3.2.9 Temporal Characteristics

Flicker, visible temporal luminance variation, should not be readily discernible and shall not be distracting under day, twilight, or night conditions, considering both foveal and full peripheral vision, and using an operational format most susceptible to producing flicker. This is intended to include stroboscopic flicker induced by vibration and or pilot motion.

The response time of dynamic-displayed information shall not produce undesirable artifacts which could lead to the erroneous interpretation or loss of displayed information.

3.2.10 Glare, Unwanted Reflection, Stray Light

Glare, unwanted reflections, and stray light need to be prevented as part of an acceptable and certifiable flight deck lighting design. See ARP6161 for an in depth discussion on perception of glare, glare sources, and strategies to mitigate glare.

All information displays shall have surfaces that mitigate reflections. Optical elements shall be coated per the requirements of AMS2521 for elements with a clear protective window and ARP4256, section 4.2.6, for graphical displays. All clear windows should have coatings to resist fingerprints, oil, and dirt, and facilitate cleaning. The gloss of opaque surfaces should be less than five gloss units per ASTM D523.

All lighting systems shall be designed such that the lamps, light sources, and all reflective areas (with intensity similar to the light source) shall be shielded from direct view of the crew members in accordance with CFR Title 14, Part 25.1381(a) for instrument lights. Care should be given to create designs that provide acceptable performance with respect to flight compartment view as described in CFR Title 14 Part 25.773(a)(2).

3.2.11 Brightness and Color Uniformity

Brightness and colors are used to distinguish critical information. Each flight deck will have its own brightness and color design and context. Brightness is a function of luminance, color, size of the information viewed. For some displays and control panels, the luminance is dependent on the electrical power received at the equipment.

The luminance level of the lighted area of the instrument or display shall be uniform. Back lighting through etched or marked panels shall have such distribution that any marking located in any position on the panel will appear to be of the same intensity. The high to low luminance ratio across the display, for the same color, shall not be greater than 3 to 1 across the specified luminance range. This luminance balance helps ensure all needed information is visible at the brightness setting. Uniformity also promotes a more comfortable viewing environment.

3.2.12 NVIS (Night Vision Imaging System)

This section will be updated in a future revision.

For reference see Technical Standard Order (TSO)-C164, AC 27-1B, AC 29-2C, RTCA DO-275, and RTCA DO-268.

3.3 Flight Deck Ambient Lighting Environment

The flight deck ambient environment is a challenging flight deck design factor because it is dynamic and ranges from extreme low to bright sunshine. The following are general descriptions of the ambient lighting conditions to consider for flight deck lighting design, requirements, requirement verification, evaluations, demonstrations, and certification. The values indicated are approximate.

3.3.1 Night, Dark

Night time with flight deck area lights OFF or very dim. Flying over the ocean at night with no moon is very dark, below 1.1 lx (0.1 fc). A typical night, dark ambient is less than 5.4 lx (0.5 fc) on aisle stand.

3.3.2 Night, Dim, Twilight

Night time with flight deck area lights at medium to bright level. Twilight needs to be considered. 5.4 to 32 lx (0.5 to 3 fc) on aisle stand.

3.3.3 Typical Day

Typical day is considered to be no direct sun in flight deck and clear sky. Typical day: lighting ranges from 685 to 13 704 cd/m² (200 to 4000 fL) in forward field.

3.3.4 Day, Bright Forward Field of View

Day, bright forward field is such that the pilot is adapted to 34 260 cd/m² (10 000 fL) in the forward field. The case is also seen with mid-day sunlight shining on bright clouds in the forward field. This situation creates an adaptation mismatch when the pilots look at the bright outside field and then to the darker flight deck controls and displays.

3.3.5 Day, Transitional Dynamic

Day, transitional, dynamic: lighting ranges from 686 to 34 260 cd/m² (200 to 10 000 fL) in forward field. This case is rapid changes in flight deck ambient and forward field lighting levels from bright to dim or dim to bright due to flying in and out of broken clouds, with clear skies above.

3.3.6 Day, Direct Sun on Instruments

Day, direct sun on instruments: Above 86 111 lx (8000 fc), direct sun is illuminating displays and control panels under evaluation. This case is mid-day bright sunlight shafting through side windows directly onto the instrument panel and glare shield. A subset of this case is where the sun is shining into the opposite window at the specular angle to the pilot's viewing angle. Military cockpits use 107 639 lx (10 000 fc) for display illuminance due to their geometry and open canopy. The illuminance on a flight deck display, annunciator, or instrument is dependent on its installation location, sun position, and window transmission.

These 'direct sun' ambient specifications above can be excessive for performance rating of transport overhead and some rear pedestal equipment. In practice this can drive excessive design luminance, power and touch temperatures. The installed equipment may meet adaptation and readability requirements at lower luminance and power. The ambient levels will be different based upon the equipment installation locations for different airplanes (glare shield, main, pedestal and overhead), see the equipment location recommendations in ARP4102. For example, the display luminance requirements will depend on their installation location per AS8034 and 0. However, for commonality, it is sometimes appropriate to design to the highest illuminance levels for part numbers in multiple locations in the flight deck. For example, depending on the aircraft, the overhead illuminance may be 32 292 lux (3000 fc), forward and glare shield zones 86 111 lux (8000 fc); and 43 045 lux (4000 fc) for pedestal or aisle stand zones.

3.3.7 Day Direct Sun on Pilot's White Shirt

Day, direct sun on pilots' white shirt: Above 86 111 lx (8000 fc) on white Captain's and First Officer's shirt; mid-day direct sunlight shining on the pilots' shirts. Sun can be coming in front or side window. A subset of this case is where the pilot can see the sun. This is called the "white-shirt" effect, where the pilots' white shirt is seen or reflected into displays. Some airline pilots wear highly reflective white shirts. Therefore, during development testing test personnel should also wear white shirts to accurately simulate the work environment.

3.3.8 Ambient Light Spectrum

For laboratory measurements and visual observations, the sun lamps should be CIE Illuminant C or D65 to represent daylight and sunlight. In addition, the flight deck surfaces and displays need to be evaluated and measured to consider the man-made light sources that may include incandescent (CIE Illuminant A), fluorescent (CIE Illuminant F), and LED.

See references about readability in Chapter 5 of AC 25-11A. They apply mainly to LCDs but may contain useful general information. See also ARP4256 and consider DIN1451.

3.3.9 Laser Threats

Lasers can be considered a part of the flight deck ambient lighting environment and are included for information only. The flight deck lighting system does not need to be certified for laser threats. AS4970 introduction states, "In the early 1990s, outdoor laser light shows began to proliferate throughout the USA. While these shows were spectacular and entertaining, some were located near commercial airports and were involved with aircrew laser illuminations. Commercial off the shelf (COTS) and commercial outdoor shows demonstrated a potential hazard to aircraft operations. The threat to aircraft was no longer limited to military-developed laser systems." See also ARP5572 and FAA Safety Brochure <http://www.faa.gov/pilots/safety/pilotsafetybrochures/> "Laser Hazards in Navigable Airspace."

3.4 Brightness Control

Adjustment of luminance and illuminance is needed to achieve the needed intensity in dark and day ambient lighting environments. Brightness control can be automatically or manually achieved. In addition, CFR 25.1381 requires brightness control, "Unless undimmed instrument lights are satisfactory under each expected flight condition, there must be a means to control the intensity of illumination."

3.5 Non-Normal and Special Operation Lighting

Flight deck lighting design needs to consider for the following conditions: backup, standby electrical power, emergency evacuation, cleaning, maintenance, and towing.

3.6 Passenger Cabin Lighting Considerations

Passenger cabin lighting design can affect the flight deck lighting design in the following areas:

- a. Emergency lighting controls and design must be considered as an airplane system design.
- b. The effects of the passenger cabin lighting outside the flight deck door on the flight deck pilots' dark adaptation and glare may need to be considered for night ambient environments.

3.7 Exterior Lighting Considerations

While aerodynamics, observability, and CFR's drive most exterior lighting requirements, it is still crucial to consider the effects of the exterior lighting on the flight deck. The angular relationships between the pilot's and co-pilot's eye positions and the windshield, instruments, panels, etc., and the exterior lights should be considered during the aircraft and flight deck design to minimize direct and reflected glare. The best design method to mitigate glare is to block the direct view of the glare source to the flight crew eye position and windows. Glare and reflections can be mitigated by careful selection of low-reflection finishes and darker colors.

Applicable exterior light FAA regulations include CFRs 25.773(a)(2) Pilot Compartment View, 25.1383(a)(1)(2) Landing Lights, Position Lights (25.1385, 25.1387, 25.1389, 25.1391, 25.1393, 25.1395, 25.1397), 25.1401(a)(1) Anti-Collision Lights, and 25.1403 Wing Icing Detection Lights.

ARP6161 provides additional guidance for minimizing the effects of glare.

4. FLIGHT DECK LIGHTING SYSTEM COMPONENTS

Section 4 provides component level requirements and guidance for flight deck lighting design and certification. All Section 3 general system level requirements and guidance apply to the components in Section 4.

4.1 Lightplate

4.1.1 Definition

Lightplates and integrated switch panels are integrally illuminated information panels used during aircraft operation. They contain static text, numbers, markings, or symbols used to identify the functions of switches, knobs, and control panels.

Refer to ARP498 for design considerations.

4.1.2 Requirement

Lightplates should meet the requirements and guidance of MIL-DTL-7788 with the following considerations:

- Section 3.3.2 - Panel thickness may need to diverge from these requirements to accommodate integrated switches or similar devices and shall be approved by the purchasing authority.
- Section 3.6 - Customers may specify finish colors other than those listed.
- Section 3.6.2.1 - In addition to CIE illuminant F2 (fluorescent), the reflected color appearance should be judged under CIE source illuminants A (incandescent) and D65 (daylight).
- Section 3.7.3 - In addition to luminance, the dimming characteristics need to be defined. The lightplate luminance shall balance with other display luminances in the flight deck so that all needed information is visible.

4.2 Switches, Knobs

4.2.1 Definition

This section refers to integrally lighted switches, knobs, and pushbuttons to include rocker switches, control legends, line select key, MIL-PRF-22885 type N switch, integrated switch panel.

See ARP493 for additional guidance on the basic recommended shapes and dimensions of knobs for aircraft.

4.2.2 Certification

Refer to CFR 25.777 Cockpit Controls for certification guidance.

4.2.3 Requirements

Switches and knobs should be integrally lighted so that they can be located at night unless area lights can be used. The knob should be constructed, marked, or illuminated such that its position can be readily ascertained for night and day operations.

The knob illuminated brightness and color, and markings should match the lightplate lighting requirements.

4.3 Annunciators (Indicators)

4.3.1 Definition

The purpose of flight crew alerts on airplanes is to attract the attention of the flight crew, to inform them of specific non-normal airplane system conditions or certain non-normal operational events that require their awareness, and, in modern alerting systems, to advise them of possible actions to address these conditions.

The flight crew alerting system consists of warning, cautionary, and advisory annunciators and indicators. An annunciator is a visual indication that presents the flight crew with data on the exact nature of the alerting situation. For advisory level alerts it also provides awareness.

Flight crew alerting can be on displays or stand-alone devices like switches, annunciators, and lighted pushbuttons. For display alerting optical requirements see 0. This section provides the optical requirements for the stand alone devices.

4.3.2 Certification

The pertinent certification requirements and government regulations for flight deck alerting systems are found in CFR 25.1322 and AC25.1322-1 "Flight Crew Alerting." Additional guidance can be found in MIL-STD-411.

4.3.3 Requirements

4.3.3.1 System Design Considerations

For system design guidelines refer to:

- ARP4102/4
- ARP1088

4.3.3.2 Failure Considerations

The light source circuit shall be designed according to the failure hazard assessment of the annunciator. The following are considerations for fail safe and fail redundant. Each annunciator should contain a minimum of two light sources connected in parallel. The annunciator legends shall be evenly illuminated such that any lamp or string failure shall not render the annunciator legend unreadable, and a lamp or string failure should be noticeable so it can be replaced. There should be a lamp test to verify indications are working properly.

4.3.3.3 Color

General color requirements and guidance are found in AS25050. See MIL-STD-411 and MIL-PRF-22885 for additional information. Airframe manufacturers often define specific color requirements for annunciation.

4.3.3.4 Font

The alerting legend, when energized, shall be translucent on an opaque background. Consideration may be given to an opaque legend on a translucent background where additional visual stimulus is considered essential, such as MASTER WARNING and MASTER CAUTION legends. The character height of the legend shall subtend a viewing angle of not less than 20 minutes of arc when measured from the aft most point of the design eye line. The character proportions should be in accordance with AS18012. The minimum horizontal separation between two legends should be two times the width of the widest character. The minimum vertical separation between two legends should be two character heights. The minimum vertical separation between two rows of text in the same legend should be one-half the height of a character. The separation between letters should be one stroke width.

There are a variety of fonts that are typical for aerospace applications, Futura, Gorton, Helvetica, DIN 1451, and variants of these are among the most common. All these fonts will have their own design rules for stroke to height ratio and character spacing.

Legends should be as brief as possible and one line presentations are preferred. If abbreviations are used, their meaning should be clear to avoid misinterpretation. Refer to ARP4105. Some legends may contain words of varying character height, such as MASTER CAUTION PRESS TO RESET; these legends should be evaluated by the design activity for legibility. Legends are often limited by available text space, the above requirement should be treated as a guideline, and each legend should be evaluated by the design activity for legibility.

4.3.3.5 Luminance

The purpose of these indicators is to get the attention of the crew members under all operating conditions. The indicators shall have brightness sufficient for legibility under all conditions of flight operation. Thus the designer must consider placement of the indicator, ambient lighting, shading from direct sunlight, size of lit area, steady state versus flashing and brightness. Minimum brightness shall be greater than 514 cd/m² (150 fL) at the pilot's viewing angle to ensure readability in bright sunlight ambient conditions. The Master Warning and Master Caution indicators shall be dimmable between 17 and 69 cd/m² (5 and 20 fL) for nighttime and dark operation. To ensure the annunciators are attention getting, the designer shall consider dimming to values approximately twice the nominal values of the integrally lighted surrounding information. General advisory legends can go as low as 7 cd/m² (2 fL).

In addition consider the luminance as a function of ambient lighting with respect to the minimum dimming level. The designer must consider inadvertent suppression of indications (MIL-STD-411) and state selections in transitions from day to dim and dim to 'dark' modes. Consider recommendations of JSSG-2010-5 (3.5.2.1.8.3) re indicator absolute minimum dimming ranges.

In general, where indicators have legends, the legend should be translucent on an opaque background and not visible when there is no annunciation. Consideration may be given to an opaque legend on a translucent background where additional visual stimulus is considered essential, such as MASTER WARNING AND MASTER CAUTION legends.

Measurements should be in accordance with MIL-PRF-22885 rev H section 4.7.35.

4.3.3.5.1 Luminance Uniformity

At the FEP, within the character, the luminance uniformity ratio (L_{max}/L_{min}) shall not be greater than 2:1, and within the whole artwork, it shall not be greater than 3:1. The average character to character uniformity should be no less than 2:1.

The angular uniformity should be less than 3:1 over the viewing angle.

4.3.3.6 Contrast

Two separate contrast requirements, diffuse and specular, are defined depending on the installation location of the annunciator and observer as defined below. All annunciators need a diffuse contrast requirement.

In addition to luminance contrast (C_L), chromaticity contrast (C_C) and chromaticity uniformity CIE (ΔE^*) might be important and should be considered.

$$\Delta E^*_{uv} = [(\Delta L^*)^2 + (\Delta u^*)^2 + (\Delta v^*)^2]^{\frac{1}{2}}$$

4.3.3.6.1 Diffuse Contrast

The contrast shall be sufficient to ensure visibility in all expected ambient lighting conditions. In bright direct sunlight illuminance, the ON contrast (C_{on}) shall be greater than 0.8 at the pilot's viewing angle and the OFF contrast (C_{off}) shall be less than 0.1. This measurement and visual observation is an engineering approximation of diffuse bright sun illuminance where the sun lamp is set at 45 degrees from the annunciator surface to provide 86 111 lux (8000 fc) to 107 639 lux (10 000 fc) with a CIE Illuminant D65 or equivalent spectrum. See Figure 4 for illustration of a test set-up.

Illuminated pushbutton switches and indicators installed in locations that do not receive direct sunlight may use a lower level of illuminance than 86 111 lux (8000 fc). The level of incident light is typically determined by the flight deck's geometrical design.

ON luminance contrast can be defined as:

$$C_{on} = \frac{L2-L1}{L1} \quad (\text{Eq. 3})$$

OFF luminance contrast is the absolute value defined as:

$$C_{off} = \left| \frac{L3-L1}{L1} \right| \quad (\text{Eq. 4})$$

where:

For legends with translucent characters on an opaque background:

L1 = luminance of background; the background is defined to be adjacent to the artwork

L2 = luminance of artwork when the lighting circuit is energized

L3 = luminance of artwork when the lighting circuit is not energized

For legends with opaque characters on a translucent background (i.e. master warning and master caution legends):

L1 = luminance of the opaque characters

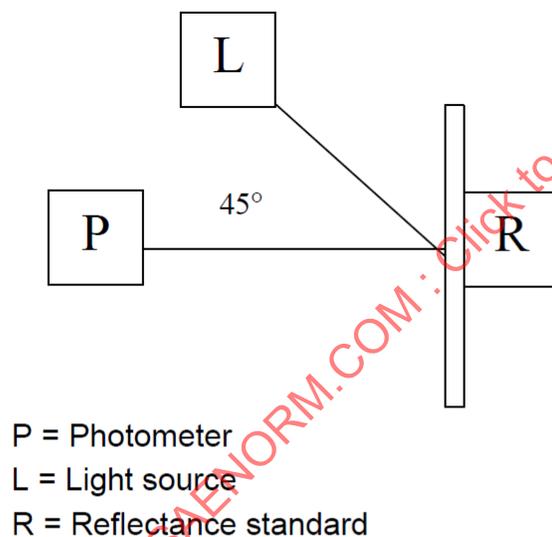
L2 = luminance of background when the lighting circuit is energized

L3 = luminance of background when the lighting circuit is not energized

|| = Absolute value

4.3.3.6.1.1 Requirement Verification

The test arrangement is given in the figures below.



Note: All angles $\pm 2^\circ$

Note: The light source field-of-view to Reflectance Standard, max 20°

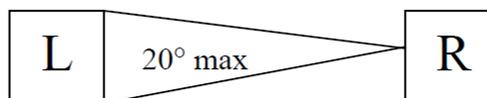


FIGURE 4 - ANNUNCIATOR DIFFUSE CONTRAST TEST SET UP

The average character and background luminance measurements should include three readings per character.

4.3.3.6.2 Specular Contrast

The sunlight readability test requiring readability in direct reflected specular sunlight is the most severe test for readability. It represents the worst case situation where the display is exposed to direct sunshine and positioned such that the pilot sees a specular reflection of the sun. In this case it is recommended that the display have hidden legends and a low reflective, diffuse front surface to avoid ghosting (appearing illuminated when unenergized) and to eliminate surface specular reflections. The intensity and geometry can be tailored for the installation location.

Illuminated switches and indicators requiring readability in direct reflected specular sunlight shall have a lighted contrast C_{on} not less than 0.6 and an unlighted contrast C_{off} with an absolute value less than or equal to 0.1 under 86 111 lux (8000 fc) to 107 639 lux (10 000 fc) glare-source (see MIL-L-85762A and MIL-PRF-22885H) when set at full rated voltages.

ON luminance contrast can be defined as:

$$C_{on} = \frac{L2 - L1}{L1} \quad (\text{Eq. 5})$$

OFF luminance contrast can be defined as:

$$C_{off} = \left| \frac{L3 - L1}{L1} \right| \quad (\text{Eq. 6})$$

where:

For legends with translucent characters on an opaque background:

L1 = luminance of background; the background is defined to be adjacent to the artwork

L2 = luminance of artwork when the lighting circuit is energized

L3 = luminance of artwork when the lighting circuit is not energized

For legends with opaque characters on a translucent background (i.e., master warning and master caution legends):

L1 = luminance of the opaque character

L2 = luminance of translucent background when the lighting circuit is energized

L3 = luminance of translucent background when the lighting circuit is not energized

|| = Absolute value

The test arrangement must be as shown in Figure 5 where the 86 111 lux (8000 fc) to 107 639 lux (10 000 fc) glare source is set to an angle of 15 degrees off the normal to the display and is the angle of incidence (see MIL-L-85762A). The photometer is set at the angle of reflectance of 15 degrees. The photometer and eye should also be moved about the specular angle to measure and visually observe the specular contrast.

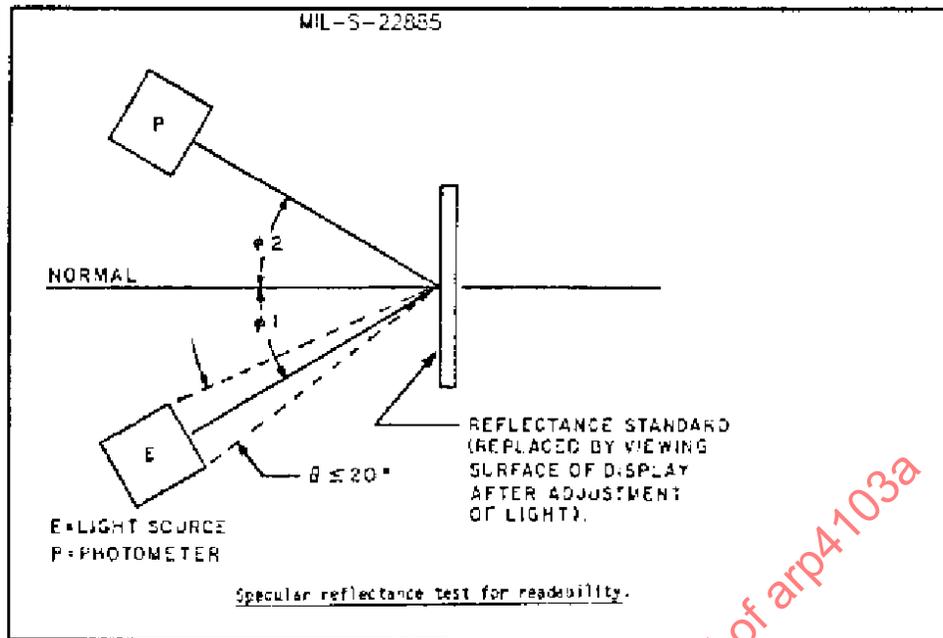


FIGURE 5 - SPECULAR CONTRAST TEST ARRANGEMENT

The average character and background luminance measurements should include three readings per character in accordance with the sunlight readability test procedure defined in MIL-S-22885.

4.3.3.7 Glare and Stray Light

There shall be no objectionable glare and stray light per ARP6161.

4.4 Control Panel

Control panels can consist of lightplates, knobs, switches, annunciators, and displays. See other sections for component guidelines.

4.5 Touchscreen

A touchscreen is normally an overlay on a display. The touchscreen shall not significantly degrade the readability of the displayed information. All optical requirements of the LRU (line replaceable unit) display's luminance, contrast, and chromaticity should be met with the touchscreen in place.

The touchscreen surface should not be easily scratched, smudged, or damaged through normal use with a finger or stylus.

The Federal Aviation Administration Advisory Circular AC No: 20-175 contains general guidance on the use of touch screens in the cockpit.

The SAE G-10 / A-4 committees have begun an effort to create both Aerospace Recommended Practice and Aerospace Standards documents for interactive touch display systems that will cover the human factors, hardware performance and system design considerations of these systems.

4.6 Electronic Displays

4.6.1 Definition

Electronic displays are high-resolution, graphical and video aircraft flight deck displays. The display electronic media allows different functions to be presented and are typically multi-purpose. In modern flight decks they are primary flight, navigation, electronic flight bag displays. These electronic displays may be AMLCD (active matrix liquid crystal display), CRT (cathode ray tube), or other technology. Historically, conventional instruments were used as the display media for the primary flight gauges. Requirements for electronic head-up displays are found in 0.

4.6.2 Visual Performance Certification Requirements

Table 2 lists the primary electronic display CFRs relating to visual performance. Other CFRs may be pertinent.

FAA Advisory circular (AC) 25-11 "ELECTRONIC FLIGHT DECK DISPLAYS" provides guidance for showing compliance with certain requirements of Title 14, Code of Federal Regulations (CFR), part 25, for the design, installation, integration, and approval of electronic flight deck displays, components, and systems installed in transport category airplanes. AC 25-11 Section 16 provides general guidance and a means of compliance for electronic display hardware with respect to its basic visual characteristics. A more detailed set of display hardware characteristics can be found in the following SAE International (formerly the Society of Automotive Engineers) documents:

- For electronic displays - AS8034
- For head up displays - AS8055
- For liquid crystal displays (LCDs) - ARP4256
- For Electronic Flight Bags (EFBs) - Order 8900,1, CHG 331, Electronic Flight Bag Operational Authorization Process

4.6.3 Design and Performance Criteria

Electronic displays should meet the design and performance guidance criteria in:

- For electronic displays - AS8034
- For liquid crystal displays (LCDs) - ARP4256

Technical standard order (TSO) C113 prescribes the minimum performance standard that airborne multipurpose electronic displays must meet in order to be identified with the applicable TSO marking. TSO-C113 calls for the electronic display to meet the minimum performance standard set forth in AS8034.

Boeing document D950-10620-1, "Common Displays Performance Requirements," is also a good resource.

ARP4155 provides a recommended approach for the design of integrated display symbology in support of flight tasks.

In addition to these requirements, there are electronic display manufacturer, airframe and flight deck manufacturer and customer requirements to consider such as the format of the graphical electronic display and brightness control. See ARP4102 and ARP4032.

TABLE 2 - ELECTRONIC DISPLAY OPTICAL CFRS

CFR	Title	Requirement
25.773a(2)	Pilot compartment view. Nonprecipitation conditions.	For nonprecipitation conditions, the following apply: Each pilot compartment must be free of glare and reflection that could interfere with the normal duties of the minimum flight crew (established under Sec. 25.1523). This must be shown in day and night flight tests under nonprecipitation conditions.
25.1301(d)	Function and installation.	Each item of installed equipment must function properly when installed.
25.1321(a)	Instruments: Installation. Arrangement and visibility.	Each flight, navigation, and powerplant instrument for use by any pilot must be plainly visible to him from his station with the minimum practicable deviation from his normal position and line of vision when he is looking forward along the flight path.
25.1321(c)(2)	Instruments: Installation. Arrangement and visibility.	Required powerplant instruments must be closely grouped on the instrument panel. In addition, Powerplant instruments vital to the safe operation of the airplane must be plainly visible to the appropriate crewmembers.
25.1321(e)	Instruments: Installation. Arrangement and visibility.	If a visual indicator is provided to indicate malfunction of an instrument, it must be effective under all probable cockpit lighting conditions.
25.1381(a)(1)	Instrument lights	The instrument lights must Provide sufficient illumination to make each instrument, switch and other device necessary for safe operation easily readable unless sufficient illumination is available from another source
25.1381(a)(2)	Instrument lights	Be installed so that: (i) Their direct rays are shielded from the pilot's eyes; and (ii) No objectionable reflections are visible to the pilot.
25.1381(b)	Instrument lights	Unless undimmed instrument lights are satisfactory under each expected flight condition, there must be a means to control the intensity of illumination.
25.1543(b)	Instrument markings: general.	Each instrument marking must be clearly visible to the appropriate crewmember.

4.6.4 Requirement Verification

Electronic display optical requirement verification can be found in the above documents (specifically AC 25-11, TSO-C113, AS8034, and ARP4256). For LCDs, ARP4256 calls out ARP4260 and VESA Video Electronics Standards Association (VESA) Flat Panel Measurement Standard document version 2. The VESA document has been revised by the SID (Society for Information Display) ICDM (International Committee on Display Measurement) and is called the Information Display Measurement Standard and can be downloaded for free at the SID ICDM website <http://www.sid.org/ICDM.aspx>.

ARP1782 describes methods to be used in measuring optical performance characteristics important for color and luminance of direct-view airborne electronic cathode ray tube (CRT) display systems.

4.7 Alpha-Numeric Electronic Displays

Alpha-numeric displays are a subset of electronic displays. They are known as segmented displays, and can be monochrome or color and they are transmissive, transreflective, or reflective.

The same requirements for electronic displays above apply.

The luminance should match and balance with the surrounding lightplates and control panels. Performance guidance should follow ARP4256 as tailored for the installation's viewing angle and ambient conditions.

4.8 Head Up Display

4.8.1 Definition

Head up displays present flight information such as navigation and aircraft attitude as an overlay in the pilots direct view of the forward exterior.

4.8.2 Certification Requirements

See 4.6.2.

4.8.3 Requirement

Industry accepted guidelines for HUD optical design and performance requirements are found in the following SAE documents:

- AS8055
- ARP5288

The HUD formats and dimming needs to be defined to integrate into the flight deck. The electronic display manufacturer, airframe and flight deck manufacturer and customer have requirements to consider such as the format of the graphical electronic display and brightness control.

4.8.4 Verification

HUD optical performance requirement verification procedures are found in ARP5287.

4.9 Conventional Instruments

Conventional instruments are electromechanical (not solid-state) and painted media that are integrally lighted from behind or from the side or front.

ARP798 covers the general requirements and test procedures recommended for use with white incandescent integrally lighted instruments. Its use should provide uniformity of illumination from instrument to instrument and legibility under daylight operation.

4.9.1 Visibility

At the viewing angles defined by the installation location of the specific piece of equipment, all letters, numerals and indicia shall be visible. The lighting system shall not interfere with the visibility of any portion of the information display or the operation of the display.

4.9.1.1 Letter/Numerical Sizes

Instrument dial letter, numeral sizes and font shall be in accordance with the requirements of Table 3 and 3.2.4 for different Air Transport Indicator (ATI) sizes.

TABLE 3 - INSTRUMENTS LETTER AND NUMERAL HEIGHTS

	TITLES cm (in)	SUBTITLES cm (in)	SCALE NUMERALS cm (in)	COUNTERS cm (in)
1.5 ATI or smaller	0.318 (0.125)	0.203 (0.080)	0.318 (0.125)	0.478 (0.188)
2 ATI-C	0.318 (0.125)	0.203 (0.080)	0.396 (0.156)	0.478 (0.188)
2 ATI	0.318 (0.125)	0.203 (0.080)	0.396 (0.156)	0.635 (0.250)
3 ATI	0.318 (0.125)	0.203 (0.080)	0.478 (0.188)	0.635 (0.250)
4 ATI or larger	0.318 (0.125)	0.203 (0.080)	0.478 (0.188)	0.635 (0.250)

NOTE: Tolerance is 0.002 cm (0.005 inch).

4.9.2 Dial Configuration

The dial configuration, range marks and graduations shall be in accordance with the requirements of Figure 6.

Markers, pointers, and bugs shall be in accordance with the requirements of Figure 7.

4.9.2.1 Scale

Circular scale layout shall be a "sunburst" type per Figure 6, with the graduation marks originating from a common inner radius. Values shall increase in the clockwise direction. Scales shall be linear unless otherwise specified. For straight scale displays, the values shall increase (normally) from bottom to top or left to right.

4.9.2.2 Pointers

Dial pointers shall not overlap the graduation marks, nor terminate at more than 0.076 cm (0.030 inch) from the common inner radius of the graduations. The maximum tip width shall be the same width as the minor graduations. Pointer color shall extend as close to the center of rotation as possible. Where a pointer is used with another type of display, the pointer shall not degrade the readability of the display.

4.9.2.3 Mode Flag

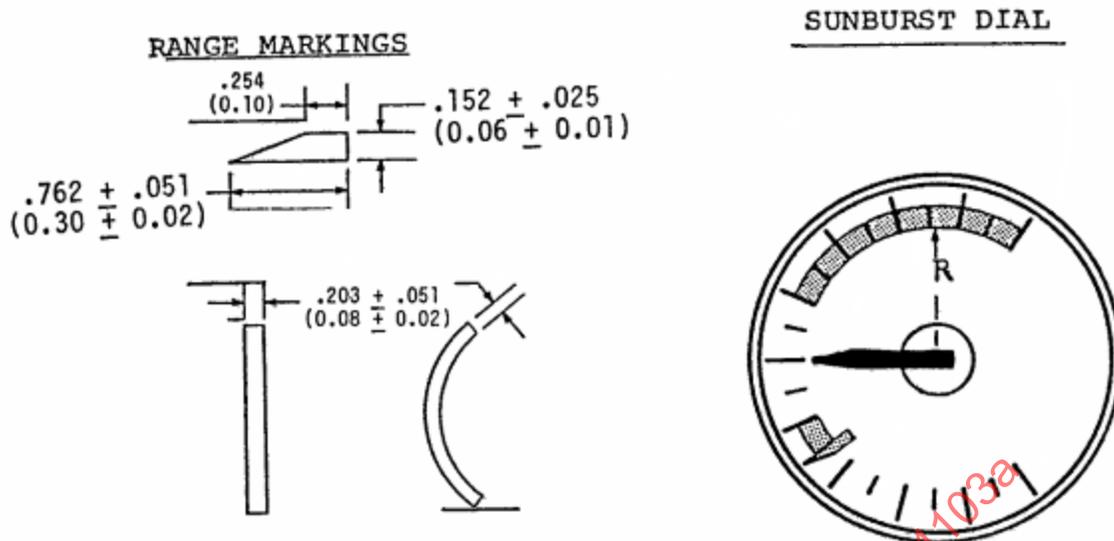
Mode flag nomenclature, if required, shall be black FED-STD-595 #37038.

4.9.2.4 Internal Markers (Bugs)

The internal markers shall rotate about the periphery of the dial such that the tip of the marker is 0.127 cm (0.050 inch) outboard of the inner radius of the scale graduations.

4.9.2.5 Counters

When a counter display is used in conjunction with a pointer display, the counter shall be located outside the pointer's normal operational range.



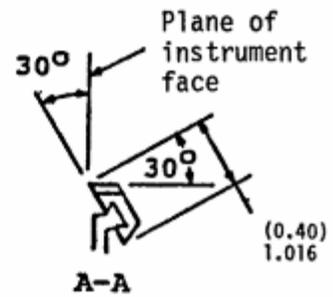
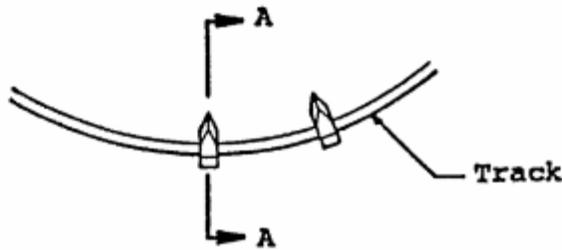
INSTRUMENT CASE SIZE (ARINC 408A)	GRADUATION DIMENSIONS		
	MINOR	GRADUATION INTERMEDIATE	MAJOR
1.5 ATI-C or smaller	.254 X .038 (.10 X .015)	.381 X .051 (.15 X .02)	.508 X .064 (.20 X .025)
2ATI	.254 X .038 (.10 X .015)	.381 X .051 (.15 X .02)	.508 X .064 (.20 X .025)
3ATI	.254 X .051 (.10 X .02)	.381 X .064 (.15 X .025)	.508 X .076 (.20 X .03)
4ATI or larger	.305 X .051 (.12 X .02)	.457 X .064 (.18 X .025)	.635 X .076 (.25 X .03)

NOTES:

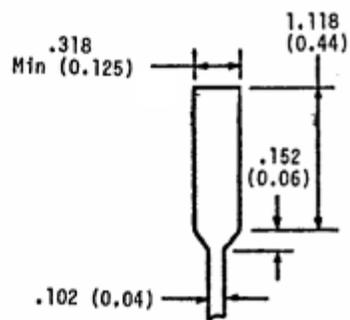
1. Tolerance on graduation marks shall be $\pm .254$ cm (0.10 in) on length and $\pm .013$ cm (.005 in) on width.
2. Instruments that require only two types of graduations shall use major and minor sizes.
3. R = specified by SCD.
4. All dimensions in cm, with inches in parentheses.

FIGURE 6 - DIAL MARKING AND ARRANGEMENT

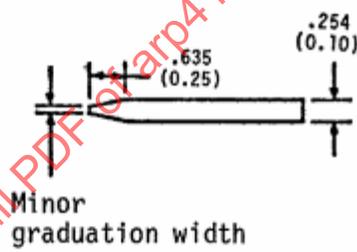
External Markers



Pointers



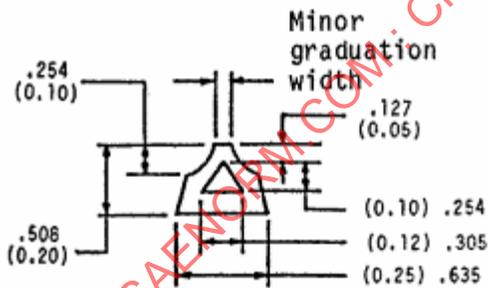
Vertical/Horizontal Tape



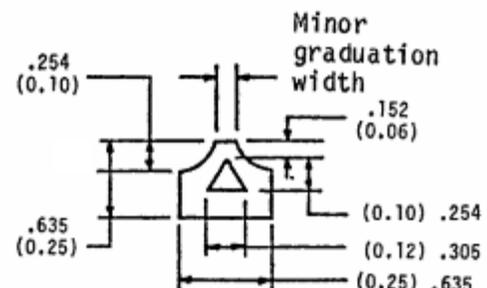
Minor graduation width

Dial

Internal Marker (Settable Bug)



2 ATI AND SMALLER



3 ATI AND LARGER

NOTE:

All dimensions in cm, with inches in parentheses.

FIGURE 7 - POINTER AND MARKER DIMENSIONS

4.9.3 Luminance

The instrument luminance shall match the surrounding lightplates so that the instrument and lightplate information is readable at the brightness control level setting needed for that ambient environment. The average brightness of the pointer shall be 20% greater than the average brightness of the dial markings.

4.9.4 Light Source (Lamps)

Incandescent lamps should be replaceable without removing the instrument case or disconnecting any connectors.

For long-lasting solid-state light sources (for example, LEDs) in order to determine a maintainability plan, the intensity change over time and temperature shall be considered.

4.9.5 Glass for Integrally Lighted Aerospace Instruments

ARP924 covers the requirements for the types of glass to be utilized in the fabrication of cover glasses and lighting wedges used in aerospace instruments. It defines the maximum extent of physical defects and recommends standard methods of inspection and evaluation.

4.10 Circuit Breakers

Per ARP4101/5, a circuit breaker is a resettable circuit-protection device. This device may be a physical or virtual (electronic).

ARP4101/5 provides recommended criteria for the location, arrangement and other requirements of aircraft circuit breakers and fuses on the flight deck.

4.10.1 Integral Panels

Integrally lighted circuit breaker panels shall utilize integrally lighted lightplates meeting the requirements of 4.1.

4.10.2 Light Source

When circuit breaker lighting panels supply light either to flood a portion of a tripped breaker or to supply light to transilluminate a breaker, to prevent glare the light source shall not be in view of a crew member operating the breakers in their normal working position.

4.10.3 Flood Lighted Panels

Flood lighting of circuit breaker panels should not be used as the primary means of lighting the panels. Flood lighting may be provided as a method of emergency, standby, secondary, or backup lighting.

4.11 Marker

"Marker" is a generic term used to describe such indirect marking methods as decals, nameplates, and placards. Markers are fabricated from a secondary material (aluminum, corrosion-resistant stainless steel, vinyl, polyester, or polycarbonate) and are attached to the hardware, either mechanically or with adhesive. The scope of this section is limited to markers that are installed in the flight deck and are on surfaces that are readily viewable by flight deck crew. Markers are not internally lighted and rely on ambient light for readability.

The marker shall be installed adjacent to the control or adjacent to the area where the action of the marker's message is to be performed. Whenever possible, the line of sight to the marker should be in the same view as the action to be performed.

See 3.2.4 for further guidance on fonts.

All markers in the flight deck should have a flat finish.

See ARP577 for more information.

4.12 Flight Deck Area Lighting

Area lighting refers to lights that provide illuminance on surfaces and controls to aid visibility in dark or low ambient lighting conditions. This illuminance is reflected off of surfaces, called luminance, and is perceived as brightness by the user. This includes task lighting, general area lighting, flood lighting, utility lighting, secondary lighting, emergency evacuation lighting, and flashlights.

Area lighting shall be provided:

- to light unlighted controls (e.g., flight controls, brightness controls)
- to light non-backlit nomenclature
- on instrument panels to avoid visual illusions to anchor the text in dark ambient conditions
- to assist in safe movement about the flight deck

4.12.1 Glare, Reflections, and Interference

Flight deck area lighting systems shall not interfere with a clear view of or the legibility of instruments, displays, switches, placards, controls, etc.

Light distribution and shielding shall be accomplished to eliminate, or at least attenuate, direct or indirect glare and reflections per the section on glare (0). The flight deck may be provided with light traps and/or curtains to isolate the flight crew members from light, glare, reflections and interference.

Reflections from cockpit interior surfaces and instrument faces into the eyes of seated crew members should be minimized within the range of normal head and body movements. To minimize glare and reflections from illuminated surfaces, paint or finishes on panels, ceilings, equipment, etc., shall be low gloss and have a reflectance no greater than 10% except for indicia or panel nomenclature.

Lighting systems shall be designed such that lamps, all light sources, or any reflective areas of a similar intensity are shielded from the crew members when seated.

Flood lighting and/or task lighting systems shall be designed to minimize the light in areas other than those intended to be illuminated.

4.12.2 Color

Task lights for map or chart reading shall have a good color rendering index (CRI) and NIST color quality scale (CQS) commensurate with the pilot's visual task. To ensure visibility and readability of all colors on charts and instruments, the CIE general color-rendering index, R_a , which is the average of the nine special color-rendering indexes, should be equal to or greater than 85. In addition, no single CIE special color-rendering index, R_i , for each of the nine test samples shall be below 80. The NIST CQS value should also be above 85. See "Color quality scale" by Davis and Ohno published in Optical Engineering for definitions and usage of CQS.

Color rendering quality is a key attribute of area lighting, yet no metric has been developed that consistently, reliably fully described the color quality of all types of light sources. CIE TC 1.91 is currently working on New Methods for Evaluating the Color Quality of White-Light Sources.

4.12.3 Task Surface Illuminance

This section describes the typical area lights required for aircraft crew stations and provides recommendations on task illuminance.

It is recommended to use the IESNA Lighting Handbook Illuminance Selection procedure, for identifying the illuminance needed for a particular task [9th edition, page 10-13] [Murdock].

4.12.3.1 Instrument Panel Flood Lights

Flood lighting of instrument panels shall be provided. Panel background lighting shall have separate intensity controls. Location of the light source(s) shall be in close proximity to the panel so that shadowing of the panels by equipment or personnel cannot occur. Instrument panels may be glare shield, overhead, forward main front, pedestal (aisle stand), and side consoles.

The instrument panel floodlights are sometimes called secondary lighting.

The flight deck crew panels should be illuminated with at least 100 lx (9 fc) at full brightness and shall be continuously dimmable to a minimum of 1 lx (0.1 fc) or lower and completely off. There are exceptions that are quite a bit lower for specialty applications, like the oxygen mask flood lights.

A consideration for the illuminance amount needed is the visibility of white nomenclature in a dark ambient. White nomenclature reflectance is typically 60%. To be visible in dark ambient the luminance (the illuminance x reflectance = luminance) should be at least 3.4 cd/m² (1 fL).

4.12.3.2 Controls

Lighting for controls, such as the throttle quadrant, flight controls, etc., shall be provided so they can be located and used properly per CFR 25.777 "Cockpit controls." The unlighted controls should be illuminated with at least 100 lx (9 fc) at full brightness and shall be continuously dimmable to a minimum of 1 lx (0.1 fc) or lower and completely off.

Refer to CFR Sec. 25.777 Cockpit controls.

"(a) Each cockpit control must be located to provide convenient operation and to prevent confusion and inadvertent operation."

4.12.3.3 Task (Chart, Map, Work Table) Lights

Task lighting shall be provided for night or dark ambient environmental operations to assist with reading maps, charts, aircraft manuals, etc. Every task surface area should have a dedicated light. Every crew member including the observer station shall be provided with a dedicated, directable task light source with an adjustable pattern size, circular or square, to illuminate hand held and mounted maps and charts. An illuminance pattern on the task surface of at least 45 cm (18 inches) diameter is typically needed. However, there are places on the flight deck where that pattern is too big, for example illuminating the chart holder on wheel and columns, and places where this is not big enough. The size of the illumination pattern shall be commensurate with the task area being illuminated. It should illuminate the intended task area without spilling over into other areas not intended to be illuminated. This light shall provide diffused illumination adequate for map/chart reading without interfering with other flight deck activities. The light shall be mounted such that a fixed writing pad, map or chart held on the lap is not shadowed by the crew member's hands or body. Where provided, chart lights should have independent and adjustable illumination from a directable light source with an adjustable pattern size. A chart light with a fixed pattern has been found to be acceptable.

The task light should be able to be turned off and on without changing the previously set brightness level. This allows immediate visibility without having to adjust the brightness and to turn off a source of glare.

With the lighting control in the full bright position, the illuminance on the task surface shall be 300 lx ± 100 lx (28 fc ± 10 fc). The light should meet the guidance recommendation of ARP5873, section 3.1.1.

ARP378 provides recommended minimum design criteria which will lead to adequate performance standards for passenger reading lights in aircraft and may be appropriate for flight deck.

4.12.3.4 Floor and Threshold Lights

Irregularities in flight deck floors shall be illuminated by step lights of fixed low intensity. Other floor areas and low level cabinets may be illuminated at prescribed levels so as to aid overall visibility without compromising external visibility.

Irregularities in the floor such as steps or door frames that pose tripping hazards in the flight deck floor shall be illuminated by low level, fixed intensity lighting with a maximum intensity of 30 lx (2.8 fc).

4.12.3.5 Flight Kit, Portable Lights, Utility Light

Small, dimmable, adjustable aperture, white lights should be provided at each pilot's station near the briefcase position for briefcase interior lighting. The dimming range should be from 'off' to 100%. The light may be a mounted, detachable and movable light assembly. If portable, the light shall provide both spot and flood distribution and be directable when mounted in the holder.

With the lighting control in the full bright position, at 1 m (39.37 inches) the lights should provide an illuminance of 161 to 323 lx (15 to 30 fc).

4.12.3.6 Flashlight

A flashlight is a portable, battery operated light source. Flashlights are required by government regulations. The flight deck lighting designer should consider including a flashlight in the basic flight deck design although it could also be carried on board as part of an airline's or crew's standard equipment.

The FAA requirements for flashlights are:

"CFR 91.503, Flying equipment and operating information.

a. The pilot in command of an airplane shall ensure that the following flying equipment and aeronautical charts and data, in current and appropriate form, are accessible for each flight at the pilot station of the airplane:

1. A flashlight having at least two size "D" cells, or the equivalent, that is in good working order."

CFR 121.549, Flying equipment.

a. Each crewmember shall, on each flight, have readily available for his use a flashlight that is in good working order.

1. Night walk-around, exterior preflight.
2. Internal compartment inspection.
3. Any miscellaneous task that requires illumination. For example, when a wallet is dropped in the footwell of the flight deck.
4. Emergency use.
5. Is an MEL requirement.
6. Maintenance check is required for installed flashlights.
7. At least one installed flashlight in the flight deck in addition to the flashlights pilots carry.
8. Flashlight must be water-proof.

The flashlight shall meet the guidance in ARP1798. The ARP calls out an intensity of 1500 MBCP (mean beam candle power) in 4.8.2. This equates to an illuminance of 1500 lx (139 fc) at 1 m (3.28 feet) distance.

4.12.3.7 Dome/Ceiling Luminaires

Dome/ceiling lights shall provide high brightness variable intensity, general purpose flood lighting of the side walls, seats, tables and the floor area of the flight deck. Dome/ceiling lights shall be recessed or flush mounted to preclude possible damage or risk to personnel and provide light coverage of the entire flight deck. Recessing the fixture also can help to reduce glare.

With the lighting control in the full bright position, the dome/ceiling lights shall provide a minimum of 50 lx (4.6 fc) at the floor level.

4.12.3.8 Backup Standby Lighting

The needed controls, displays, instruments, and control panels shall be viewable under all conditions including loss of main or primary electrical power. Adequate standby lighting shall be automatically provided on backup electrical busses and battery electrical power to ensure continued safe flight and landing.

Backup standby illuminance of the pilots' and crew members' instrument panels shall be provided. The standby lighting system shall be powered from a backup standby battery supply to illuminate essential instruments, displays and controls for aircraft operations when normal instrument, display and flight deck lighting is inoperative. The standby lighting system shall come on automatically with the loss of main or primary electrical power.

With the lighting control in the bright position, panel surfaces shall be provided with a nominal 55 lx \pm 33% (5 fc) of illuminance. With the lighting control in the dim position, the panel surface shall be provided with a nominal 11 lx \pm 33% (1 fc) of illuminance.

A consideration for the floodlighting illuminance amount needed, see the floodlighting section above, is the visibility of white nomenclature in a dark ambient. White nomenclature reflectance is typically 60%. To be visible in dark ambient the luminance should be at least 3.4 cd/m² (1 fL):

$$L = E * R \quad (\text{Eq. 7})$$

where:

E = illuminance

R = reflectance

L = luminance

This is an engineering approximation for diffuse surfaces using English units.

Another design consideration is to have the lights come on variable or fixed. Instruments must be readable with the standby system control in the dim position in a dark flight deck environment. As an alternate, instruments may be controlled to a fixed brightness (readable in a dark environment) when on the standby power system.

4.12.3.9 Emergency Evacuation Lighting

Emergency lighting shall be provided for use during crew evacuation. The system shall consist of one or more dome, ceiling, or other lights to illuminate the evacuation path and controls needed.

The emergency lighting system shall provide a minimum of 0.54 lx (0.05 fc) of illuminance over the emergency evacuation path per CFR 25.812. MIL-STD-1472 and the IESNA Handbook recommend illuminances as high as 35 lx (3 fc) for evacuation.

ARP503 provides criteria for design and location of power supplies, controls, light fixtures, and associated equipment which are used to provide emergency illumination in transport aircraft, designed to comply with FAR 25 for operation under FAR 91 and FAR 121, and also in compliance with FAA Advisory Circulars AC25.812-1A and AC25.812-2.

4.12.3.10 Light Override (Storm) Lighting

A Light override function should be provided to support the activities listed below. Typically, this light override switch causes panel flood light and area dome lights to come on to a sufficiently bright level. The visibility of the displays and annunciators need to be considered in the brighter override function. The light override control switch should be a single action manual control reachable by both pilots.

- Storm Lighting: Flight during electrical storms to help reduce the adaptation mismatch between bright lightning flashes and the dark flight deck
- Pre-flight and post-flight operations
- Maintenance operations
- Other times at the discretion of the flight crew

A sufficient brightness level is usually the maximum level achievable by the area lighting system. Care must be exercised to avoid unwanted window and display reflections and glare.

4.13 Windows, Visors, Shades, Transparencies, Sunglasses

To be updated at a future revision.

Sunglasses are worn by many pilots and the flight deck optical performance must be acceptable when wearing appropriate (non-polarizing) sunglasses. See the FAA Safety Brochure "Sunglasses for Pilots: Beyond the Image" at <http://www.faa.gov/pilots/safety/pilotsafetybrochures/> for more information, "Sunglasses help safeguard a pilot's most important sensory asset - vision. A quality pair of sunglasses is essential in the cockpit environment to optimize visual performance. Sunglasses reduce the effects of harsh sunlight, decrease eye fatigue, and protect ocular tissues from exposure to harmful solar radiation. Additionally, they protect the pilot's eyes from impact with objects (i.e., flying debris from a bird strike, sudden decompression, or aerobatic maneuvers). Sunglasses can also aid the dark adaptation process, which is delayed by prolonged exposure to bright sunlight."

5. LIGHTING CONTROLS

To minimize pilot workload, brightness of each group of instruments, light plates, and displays on the same panel should have a common lighting control which provides a smooth, continuous change in apparent brightness from the point of minimum brightness to the point of maximum brightness. Brightness controls for utility, annunciator, and integral instrument and panel lighting should be independent of each other. Certain displays might require individual brightness controls because of the unique nature of their presentation.

See Section 5 in ARP4102 for top level guidance on the design, installation, and operation of lighting controls.

CFR 25.777 Cockpit Controls shall be used to ensure the design is certifiable. The full bright position for a typical rotary type lighting control shall be the extreme clockwise position, with the power OFF position at the extreme counterclockwise position. The first power ON position should provide a selected minimum brightness.

Brightness adjustment is needed to comply with CFR 25.1381 (a)(1) and (b).

The primary flight display brightness should not be dimmable to the off position so that primary flight information is always available at nighttime.

5.1 Lighting Controls Type

In addition to the requirements of ARP4102, section 5.3, the controls for map, approach chart and working area lighting shall control brightness across the entire range of available intensity levels. Intensity controls for utility, annunciator and integral instrument and panel lighting shall be independent of each other. Certain displays (emissive displays) may require individual brightness controls due to the unique nature of the presentation.

5.2 Lighting Controls Location

Intensity controls shall be conveniently located for the crew member whose duty it is to control that particular function. General lighting and master control switches, controllable by both pilots, shall be placed on one panel convenient to the reach of both the pilot and copilot while seated with seat belts fastened.

5.3 Panel Lighting-Integral

Integrally-lighted instrument panels shall be lighted in sections corresponding to the intended usage. The main panel shall be lighted in at least two sections, with separate intensity controls. Additional sections shall have their own intensity controls.

5.4 Lighting Controls Knobs

The brightness control knob shall be able to be located in dark ambient and the brightness setting should be visible in all ambient lighting conditions. For example, the knobs (other than instrument bezel knobs) used for control of lighting intensity should be transilluminated, with a mark indicating the setting location.

5.5 Ceiling (Dome) Light Controls

A master switch, controllable by both pilots, shall adjust the brightness of the ceiling (dome) lights and turn the ceiling (dome) lights "on" or "off."

5.6 Standby Lighting Controls

Standby lights shall be automatically energized at dim intensity from an emergency battery supply on loss of normal aircraft power. A dimming control for all standby lighting should be provided, convenient to both pilots so that standby lighting intensity can be increased if needed. The control, in the most counter-clockwise position, shall not reduce the standby lighting intensity below a level suitable to read instrumentation under flight deck dark ambient conditions.

The recommended system design should have the minimum standby lighting intensity set as a function of the integral instrument lighting level such that the instruments would be equally illuminated when the standby lighting is activated.

5.7 Light Override Controls

Light override controls can be three positions (off-dim-bright) or two position (off-bright).

A three-position switch controllable by both pilots should be provided, for control of the storm lighting. In the "off" position, all panel lights, integral instrument lights and lightplate lighting should be operated from their individual lighting controls. In the "dim" position, the control should override individual dimming controls and all integral instrument and panel background lighting will be on at full intensity. In the "bright" position, the control should turn on all crew station lighting at full intensity in addition to the instrument and panel background lighting, so as to completely floodlight the flight deck.

5.8 Emergency Lighting

A switch shall be provided to allow emergency lights to be energized at maximum intensity from an emergency battery power supply. See CFR 25.812 "Emergency Lighting" section (f) for certification requirements.

- (1) The lights must be operable manually from the flight crew station and from a point in the passenger compartment that is readily accessible to a normal flight attendant seat.
- (2) There must be a flight crew warning light which illuminates when power is on in the airplane and the emergency lighting control device is not armed.
- (3) The cockpit control device must have an "on," "off," and "armed" position so that when armed in the cockpit or turned on at either the cockpit or flight attendant station the lights will either light or remain lighted upon interruption (except an interruption caused by a transverse vertical separation of the fuselage during crash landing) of the airplane's normal electric power. There must be a means to safeguard against inadvertent operation of the control device from the "armed" or "on" positions.

5.9 Special Circuitry Requirements

The standby and emergency lighting circuits shall be independent circuits protected by individual circuit breakers and routed in different wire bundles to minimize the potential for loss of all emergency lighting systems.

6. LIGHT SOURCE CONSIDERATIONS

The recommendations in this document are intended to be based on optical performance and independent of the light source technology. The light source technology choice is fundamental because it drives the overall product design, including key factors such as the electrical, mechanical, and thermal design, along with optical performance, reliability, maintainability, cost, and efficiency. Light source technologies have unique characteristics that need to be addressed. These characteristics include: intensity, thermal, voltage and drive current, color, and dimming control. In addition, the lighting designer may need to integrate different light source technologies in a flight deck.

Current flight deck light source technologies include: LED (light emitting diode), incandescent, EL (electroluminescent), fluorescent, and halogen. LEDs are becoming more prevalent due to their low power, durability, life and reliability, and ability to meet the optical performance needs of the user. For guidance on LED light source usage, see ARP5873, section 3.1.2.1.1, ARP6253, and ARP6402A.

ARP5297 provides the qualification test procedure requirements for low wattage halogen lamps (less than 35 watts) intended for use primarily in aircraft applications. The purpose of these tests is to provide a laboratory means of determining the performance characteristics of lamps in airplane power and environmental conditions and to verify the integrity of the lamp design and production process.

6.1 Life

Light sources should have a life rating of at least 25 000 hours.

Use of incandescent lamps is discouraged for new design due to their higher power consumption and lower reliability compared to solid state devices such as LEDs.

LEDs typically do not fail catastrophically during use. However, over time their light output will gradually depreciate. LED light source life is typically defined as the time to decay to 70% of initial intensity at the rated electrical power used in the application. Incandescent lamp life in specification sheets is typically defined to be when half the lamps have failed in laboratory test conditions. Refer to MIL-HDBK-217 for guidance on reliability predictions of electronic assemblies.

Historically, incandescent lamps have not been included in the end item reliability predictions since the lamp generally is expected to have a much lower reliability than the rest of the fixture and the aircraft designer would like to ensure that the fixture meets a minimum mean time between failure (MTBF). If the incandescent lamp were included in the total prediction, the lamp life has a predominant influence on the result that could mask other potential life limited components in the fixture. The low reliability of the lamp shall be mitigated by the circuit design, redundancy, press-to-test checking, and other checks to make sure the lights are operational for MMEL and aircraft dispatch.

6.2 Incandescent and Fluorescent Types

The number of different types of lamps that are used throughout the flight deck lighting systems should be held to a minimum to: limit the number of different spares on the flight deck, minimize the risk of installing an incorrect part number, and to ensure compatibility with the flight deck electrical lighting control system.

6.3 Replaceability

Light sources with low reliability, should be replaceable without major disassembly of the device containing the lighting system. Replacement of lamps shall not require light rebalancing to address lighting uniformity.