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# AEROSPACE RECOMMENDED PRACTICE

ARP 1161

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Revised

## CREW STATION LIGHTING - COMMERCIAL AIRCRAFT





### 1. PURPOSE

The purpose of this ARP is to present a practical set of requirements for the lighting systems which provide illumination for crew station areas and displays and for the characteristics of displays which affect their readability. It is intended that it be used as a guide by those involved with the design, use, or procurement of lighting systems for commercial and non-military aircraft or aerospace vehicles.

### 2. SCOPE

This ARP covers the recommended requirements for the lighting and characteristics of instruments; information plates and displays; emergency, cautionary, advisory and status displays; circuit breaker and toggle switch positions; and the recommended requirements for the utility lighting system.

2.1 Specification Documents: As a general practice, it is recommended that a separate specification be prepared to define crew station lighting and separate specifications be prepared to define each type of lighting.

2.2 Referenced Documents:

AMS 2521 - Reflection-Reducing Coatings for Instrument Glasses
Fed Std 595 - Colors
MIL-C-26482 - Connectors, Electric, Circular, Miniature, Quick Disconnect, Environment Resisting
MIL-P-7788 - Panels, Information, Integral Illumination

### 3. DEFINITIONS

3.1 EMI: Electromagnetic Interference

3.2 ANSI: American National Standards Institute

Used herein to apply to that agency's system of numbering lamps (e.g., #715 is ANSI designation for a T-1 size unbased lamp equivalent to MS24367-715).

3.3 Photometric Terms:

3.3.1 Photometric Brightness: The intensity of illumination reflected or emitted by a surface as measured by a photoelectric device.

3.3.2 Footcandle: A measure of the intensity of illumination. One footcandle (FC) is the intensity of illumination at a point on a surface one foot from a uniform point source of one standard candle or the illumination of a surface one square foot in area on which there is a uniformly distributed flux of one lumen.

3.3.3 Footlambert: A measure of the brightness of an emitting or reflecting surface. A 100% reflective surface illuminated by one footcandle has a brightness of one footlambert.

3.4 Illuminant C: A source of illumination having an energy distribution similar to that adopted by the International Commission on Illumination as "average daylight." Normally produced by a tungsten lamp and an appropriate filter. Also similar to "North skylight" illumination.

3.5 Light Leaks: Light emitted by a surface intended to be opaque; normally associated with integral transilluminated systems.

3.6 Glare Source: Any light emitting source or reflective surface of similar brightness; normally associated with integral flood lit systems.

3.7 Stray Light: Light emitted by components of the lighting assembly directly into the crew station area. Stray light is not visible to crew station members but contributes to the ambient light level; normally associated with flood lit integrally-lighted displays.

3.8 Critical Viewing Sector: Those geometric sectors of an instrument which include the normal viewing angles of the various crew members for the particular instrument.

3.9 Noncritical Viewing Sector: Those geometric sectors of an instrument excluding the critical sectors.

3.10 Transilluminated Systems: Integrally lit displays in which the light source is behind the display and the light passes through the lit portions of the display.

3.11 Flood Lit Systems: Integrally lit displays in which the light source or a light distributing material directs light to the front of the display where it is reflected to the observer. Examples of flood lit systems are wedge lighting, ring lighting, and parallel plate lighting.

3.12 Flood Lighting: Lighting similar to normal home lighting where a light source floods a general area or is directed by reflectors to light a particular area.

3.13 Supplier: The manufacturer, vendor, or agency who supplies the lighted assembly to the "user."

3.14 User: The aircraft company, airline or other agency who uses or installs the lighted assembly in a crew station.

3.15 Low Intensity Readability: The visual clarity of a lighted display when compared with other lighted displays, both energized at a selected low level of excitation.

4. GENERAL REQUIREMENTS

4.1 Color:

4.1.1 Illuminant: The color of illumination, unless otherwise specified in subsequent sections, shall be white, (unfiltered) incandescent lighting or its equivalent. The use of the term "unfiltered" shall not preclude the use of materials to compensate for color changes caused by nomenclature films or by light sources appreciably different in color than incandescent sources. When compensation is required, the manufacturer is cautioned to avoid overcompensation and the appearance of a "cool white" color. Materials used for color compensation should be color stable and not subject to damage or loss with normal lamp replacement.

4.1.2 Nomenclature: Unless otherwise specified, the color of white nomenclature when illuminated by its own lighting system at rated voltage, shall meet one of the following requirements:

Color Temperature - The color temperature shall be within 1880°K and 2460°K. Note: Color temperature is generally an inappropriate measure for any light source except unfiltered incandescent light.

Spectro-Radiometric Or Colorimetric Measurements - The value of x shall be .510 ± .030 and the value of y shall be .415 ± .030 on the CIE Chromaticity Diagram. When a colorimetric measurement is used, the calibration source shall be a tungsten lamp whose color is 2360°K.

Visual Comparison (Preferred method) - The nomenclature shall not appear more yellow than a matte white surface (Fed Std 595, Color 37875) illuminated to approximately the same brightness as the nomenclature by unfiltered light from an MS24367-683 lamp energized at 4.50 ± .03 volts, or more blue than the above surface illuminated to approximately the same brightness as the nomenclature by unfiltered light from an MS24367-715 lamp energized at 5.00 ± .03 volts.

4.1.3 Color Specification: When not integrally lighted or when in the nonlit condition, all colors shall match the specified color when viewed under Illuminant C (e.g. MacBeth North Skylight or equivalent). Colors including their finish shall be per Fed Std 595 unless otherwise specified. When possible, it is recommended that colors be selected and used for specific purposes as shown in Table I.

4.2 Glare Sources:

4.2.1 All lighting systems shall be so housed that the lamp, light source, or any reflective areas of similar intensity are not visible to any crew member as he performs his duties. In addition, the housing of flood lit systems shall minimize the light in all areas except the area desired to be lit.

4.2.2 Anti-Reflective Coating: Each face of a transparency which is in view of a crew member and which interfaces with a medium, such as air, liquid or other material, which has refractive or reflective properties different from the transparency, shall be coated or otherwise designed to reduce reflections and increase the light transmission through the transparency or its system. Unless otherwise specified, the transparency surfaces or system shall meet the requirements of AMS 2521.

4.3 Contrast: Unless otherwise specified, the contrast between white and black areas of a display shall be 12 or greater; between white and grey areas of a display 5 or greater. Contrast shall be defined and measured per MIL-P-7788.

4.4 Lamps:

4.4.1 Replaceability: It shall be a design objective for the lighting system including its lamps that its operating life, expressed as Mean Time Between Unscheduled Removals (MTBUR), shall exceed the MTBUR of any other portion of the instrument. Where practical, the lamps of a lighting system shall be replaceable without major disassembly of the device containing the lighting system. Replacement of lamps shall not require light rebalancing.

4.4.2 Lamp Types: The number of different types of lamps that are used throughout the cockpit lighting systems should be held to a minimum. The lamps in any one display shall be of one type.

The lamps used in a lighting system shall be one of the types specified in the appropriate section of this ARP.

4.4.3 Lamp Placement: The lamps in an integrally lit system shall be so arranged that no portion of a display depends upon one lamp for its illumination. The loss of one lamp in such a display shall not diminish the brightness of any indicia below 40% of the minimum value specified for the display.

4.4.4 Lamp Circuits: The lamp circuits shall be designed to operate from a DC or a 400 Hertz AC system. Voltages of the systems shall be 5.0, 28.0, or 110.0 as appropriate for the vehicle and system. All lamps in a single display shall be connected in parallel with the lamp(s) removed, the insulation resistance of the lighting circuits shall be at least 100 megohms when measured between the power terminal and the case or ground.

4.4.5 Interchangeable Lamps of Different Voltages: Lamps which operate at different nominal voltages and are dimensionally interchangeable shall not be used in the flight crew station, unless it can be demonstrated that the consequences of their inadvertent mix-up would not have an adverse cost effect on the overall operation of the aircraft including crew function, flight safety, dispatchability or maintainability.

4.4.6 Lamp Identification: Identifying information shall be clearly and permanently marked on each lighted display or near the lamp receptacles or lamp installation points of all cockpit light fixtures in a manner that is readily visible to the person replacing the lamps. It is recommended that the identifying information include the nominal voltage in addition to the lamp type number, e.g. (#387(28V).

The corresponding lamp "identifying information" also should be marked by the holder for the respective lamps in the cockpit "spare lamps" stowage compartment.

4.4.7 Legibility: Markings of displays should be such that they may be easily read under a wide range of lighting conditions. Some recommended fonts are New Gothic and Futura Medium.

4.5 Light Control Requirements:

4.5.1 Intensity Controls: Unless otherwise specified, each group of instruments, light plates, and displays on the same panel shall have a common lighting control which provides a smooth, continuous change in apparent intensity from the point of minimum brightness to the point of maximum brightness. Intensity controls for utility, annunciator, and integral instrument and panel lighting shall be independent of each other. Certain displays (e.g. electronic projection displays) may require individual brightness controls because of the unique nature of their presentation.

4.5.2 Control:

4.5.2.1 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 excitation.

4.5.2.2 A variation in light emitted from a lighting system is considered optimum when the output between each succeeding linear position of its controller is a constant ratio, which in mathematical terms, is in geometrical progression. (See Appendix I, and Reference 10.1.)

4.5.2.3 A method of defining the requirements for an incandescent lighting control system to provide for a change in intensity as a geometrical progression is illustrated in Fig. 1 and is described as follows:

a. Prepare a graph with the abscissa as a linear scale and the ordinate as a log scale.

b. Divide the abscissa into equally spaced divisions corresponding to the desired number of equally spaced positions of the control selector. The first position should be that where power is applied initially to the lighting system to produce its minimum required intensity or threshold brightness.

c. Label the ordinate either in percent (up to 100%) or in absolute values of the electrical parameter being considered, e.g. percent voltage, or 1, 2, 3, etc. volts.

d. Plot the following points:
Point A: This is the value of the electrical parameter (i.e. volts) for minimum required brightness plotted against the lowest intensity position of the selector.

Point B: This is the value of the electrical parameter for the maximum brightness plotted against the brightest intensity position.

e. Draw a straight line between points A and B. The resulting straightline curve defines the required variation of the electrical parameter vs. a linear control travel to provide a change in intensity as a geometrical progression.

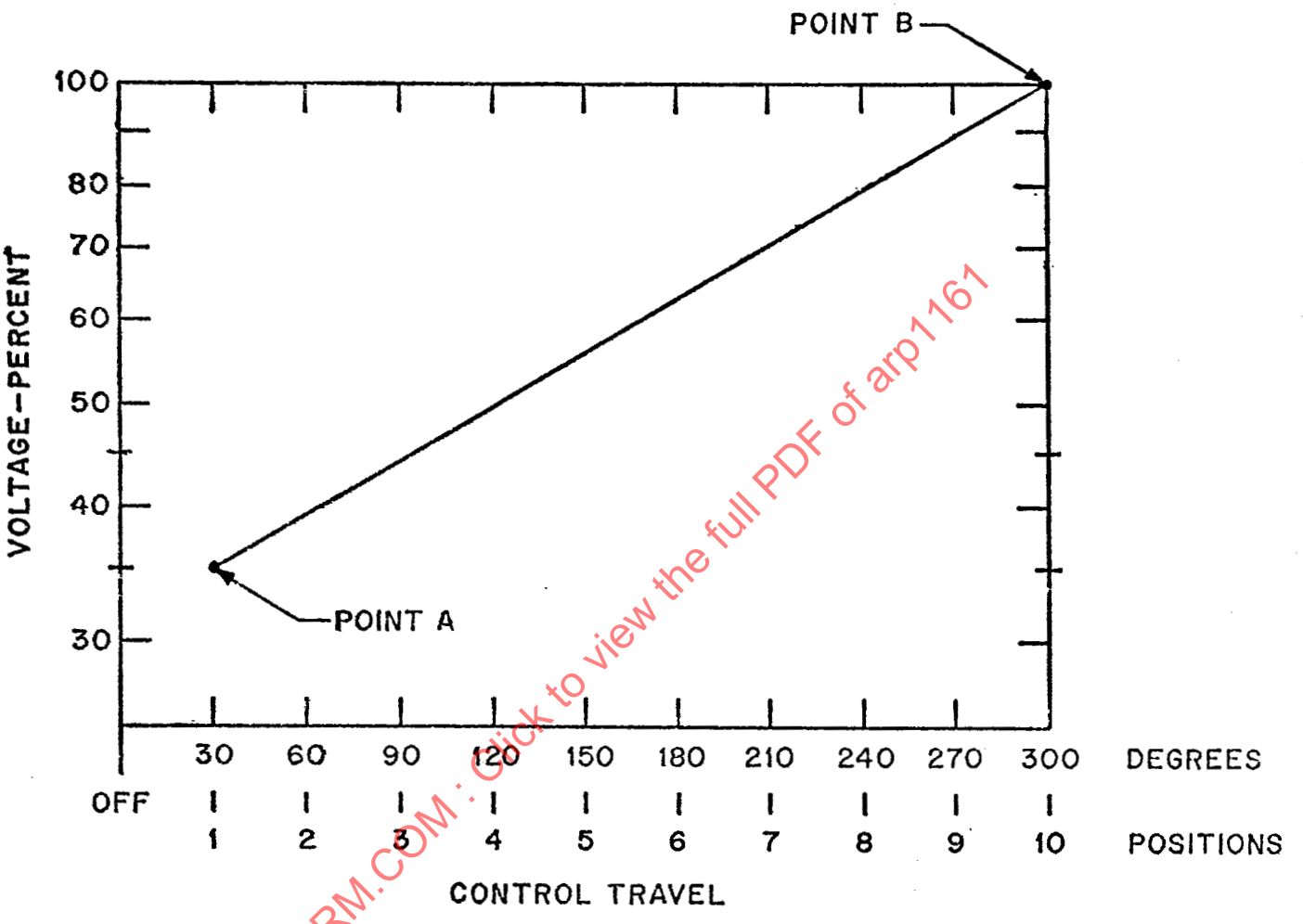




Figure 1. VOLTAGE VS CONTROL TRAVEL FOR INTENSITY CHANGE IN GEOMETRICAL PROGRESSION

4.6 Materials: Materials chosen for lighting systems shall be compatible with the functional and environmental conditions in which the system is operated. Material selection should consider equipment operating temperatures in the specified ambients.

5. INSTRUMENT LIGHTING SYSTEM

5.1 Purpose: This section presents the recommended requirements for the lighting systems of displays located in the crew station areas (i.e. analog, digital, graphic displays).

5.2 Scope: This section is concerned primarily with the flight, engine, and other subsystem instruments. Dynamic displays mounted in or behind a lightplate and illuminated by the lightplate shall meet the requirements of this section. Displays which are integral parts of an instrument but function as warnings or cautions for systems other than the instrument in which they are placed shall meet the appropriate requirements of section 8 unless otherwise specified.

5.3 General Requirements:

5.3.1 The instrument lighting system shall meet all of the applicable requirements of section 4.

5.3.2 Visibility: The lighting system shall not interfere with the visibility of any portion of the information display. The lighting system shall not interfere with the specified operation of the instrument.

5.3.3 Electromagnetic Interference: The instrument lighting system shall comply with the Electromagnetic Interference Control requirement and the Electrical Bonding requirements applicable to the aircraft in which the instrument will be installed.

5.3.4 Helium Environment: Incandescent lamps used in the lighting system shall not be placed in a helium environment unless helium is required in the instrument and helium resistant lamps are used.

5.3.5 Approved Lamps: The following lamps or "approved equivalents" shall be used. It is recommended that an "approved equivalent" lamp shall have a lamp life MTBF of at least 25,000 hours. The MS part number or the ANSI number of the lamp (or the type and manufacturer) and the quantity of lamps installed in each instrument shall be marked on the instrument placard.

MS24367-715 AS15 (T-1, unbased)
MS24515-718 AS15 (T-1, based)
MS90451-715 AS15 (T-1, unbased short)
ANSI 7715 (T-1, type 715, Bi-pin base)

5.3.6 Circuitry: The wiring of the lighting circuit shall be AWG 26 or larger. The power and ground leads of the lighting circuit shall terminate at pin A and pin B, respectively, (or pin 1 and 2) of the instrument receptacle whenever possible. It is recommended that the ground side of the integral lighting circuit not be grounded to the instrument case. If it is necessary to ground part of the lighting circuit to the case, an internal ground having a greater current carrying capacity than any other internal wire shall be used. In the event that the instrument does not require an electrical connector except for the integral lighting circuit, a 6 pin electrical receptacle shall be used in accordance with MIL-C-26482.

5.4 Instrument Colors: The colors of instrument bezels, knobs, and displays shall be per this section and Table I unless otherwise specified.

5.4.1 Bezel: The bezel of instruments shall be dark grey unless black is specified. Letters, numerals and markings on the bezel shall be white except as noted in 5.4.4.

5.4.2 Cases: Painting of unexposed portions of the instrument case is optional and shall be governed by the individual instrument specification.

5.4.3 Knob Colors: Knobs generally shall be light grey. If the knob has an index skirt with a marking, the skirt shall be black. Indicia on the knob skirt or on the dark grey bezel of the instrument on which the knob is mounted shall be white. Nonintegrally lit indicia on a light grey knob may be black. If concentric knobs are used, the knob adjacent to the display shall be light grey and the top or inner knob shall be black. Integrally lit knob indicia shall meet the requirements of the display on which the knob is mounted.

5.4.4 Display Colors:

5.4.4.1 The primary nomenclature of displays, including pointers and lubber lines, which are referred to during flight operations shall be white. The nonlit area of the pointer and the background of the display shall be black, and are not required to be illuminated by the lighting system of the display.

5.4.4.2 Secondary markings which are required only for crew training, for maintenance information or which are not essential during flight operations shall be blue. If such markings are placed on the dark grey bezel, they shall be black.

5.4.4.3 The colors of special markings such as range and limit markings, warning flags, bugs specified in the individual display document shall match the requirement of Table I as applicable.

5.4.4.4 Extraneous markings such as manufacturer's name, part identification or other information not essential for flight or ground operation should not be on the display face. Where there is a deviation to this requirement, the markings shall be black of a contrasting finish to the black background.

5.5 Illumination Requirements: The Low Intensity Readability recommendation as noted herein for instruments and light plates is considered a prime illumination requirement of this ARP. The reason for this is the increased emphasis by aerospace operators on the importance of "uniform readability" of all of the displays at each crew station in contributing to flight crew efficiency and flight safety. (Also see Appendix II.)

The instrument lighting system shall meet the Photometric Brightness requirements and the Low Intensity Readability requirements as noted herein.

When a lighting system cannot meet both Photometric Brightness and Low Intensity Readability requirements, the Low Intensity Readability requirements of 5.5.3 shall take precedence.

5.5.1 Daylight Readability: Before a lighting system for a new display is designed, it is essential that the readability of the display first must be acceptable under daylight viewing conditions. In this regard, the following factors are emphasized as contributing in general to good display design:

a. Elimination of unnecessary markings or clutter.

b. Maximum spacing between graduations and markings.

c. Careful selection of the size of graduations, numerals, and markings, and the discrete shape and size of the pointer, with consideration given to the viewing distance, the time required to comprehend the information displayed, and the relative importance of the display.

d. Recognition that displays which are similar in respect to points a. through c. will be more likely to have equal Low Intensity Readability.

It also follows that various techniques can be employed in the design of a lighting system to "tailor" the quantity, intensity and/or color of the light emitted from the illuminated areas of the display to achieve uniform readability at low intensities. However, good low intensity readability is not necessarily assured by providing uniform brightness and uniform color temperature of the light emitted from markings, pointers, etc.

5.5.2 Photometric Brightness:

5.5.2.1 White Markings: The brightness of all white markings shall be .20 ± .10 foot-lamberts at 2.7 ± .03 volts DC.

5.5.2.2 Black Backgrounds:

5.5.2.2.1 Nontransilluminated Systems: The brightness of the black background shall have a maximum value of 7% of the brightness of nearby white markings (within an approximate 0.25 in. (6.35 mm) radius), and wherever practical no light shall be emitted from the black background.

TABLE I - DISPLAY COLORS

| Use - Typical | Color | Color Description* |
|---|---|---|
| **Display Markings:** | | |
| Primary | White | 37875 |
| Secondary | Blue | 35177 |
| Extraneous | Black | 27038 |
| Flag | Black | 37038 |
| **Backgrounds:** | | |
| Display | Black | 37038 |
| | Dk. Gray | 36118 |
| Flag | Red | DAY-GLO Fire Orange |
| | Yellow | DAY-GLO Saturn Yellow |
| **Pointers, Lubber Lines & Bugs:** | | |
| Primary | White | 37875 |
| Secondary | Orange | DAY-GLO Arc Yellow |
| | Red | DAY-GLO Fire Orange |
| Non-lit areas | Yellow | DAY-GLO Saturn Yellow |
| | Black | 37038 |
| **Limit Marks:** | | |
| Warning | Red | DAY-GLO Fire Orange |
| Caution | Yellow | DAY-GLO Saturn Yellow |
| **Range Bands:** | | |
| | White | 37878 |
| | Yellow | DAY-GLO Saturn Yellow |
| | Green | DAY-GLO Signal Green |
| | Red | DAY-GLO Fire Orange |
| **Knobs:** | | |
| Handle | Lt. Gray | 36440 |
| Skirt | Black | 37038 |
| Markings | White | 37875 |

* 1. Color numbers noted in this Table, including their finish, are per FED-STD-595.

2. Although the colors identified as DAY-GLO shall match in color the respective colors of the DAY-GLO Daylight Fluorescent Paints made by the DAY-GLO Color Division of Switzer Bros., Inc., Cleveland, Ohio, they are not necessarily required to have the fluorescent characteristics of those paints.

5.5.2.2.2 Transilluminated Systems: The black background shall appear opaque when the instrument is energized at noted voltage.

5.5.2.3 Colored Markings: The reader is cautioned that the brightness of colored markings will vary appreciably from one photometer to another and that the apparent color of a marking will change as the level of the lighting voltage is varied.

5.5.2.3.1 Nontransilluminated: The brightness of colored markings is controlled by the comparative reflectance of the white marking and the colored marking for the color of light provided by the lighting system. Specification of color of the marking, lamp type and white marking brightness will govern the colored marking brightness.

5.5.2.3.2 Transilluminated Systems: In transilluminated systems, the brightness of colored markings may be specified separately. The most economical system is one in which the colored brightness is in the same approximate ratio to the white brightness as their respective reflectances for the color of illuminating light. When colored brightness is required to equal white brightness, a separate system of lighting or illumination control for the two colors may be required.

5.5.3 Low Intensity Readability: The lighting system of the instrument or display shall provide uniform readability of all portions of the display (that are required to be read during flight operation) when it is compared with another display or a group of displays whose lighting system(s) have been approved by the user for installation at the flight crew station in the aircraft for which the instrument is being procured. Where lighting systems are of different types or displays are unique, it may be necessary to raise or lower the brightness values of a particular instrument in order to achieve equal Low Intensity Readability.

This readability requirement shall be met at a low level of illumination as follows:

a. The lighting systems of the displays being compared shall be energized from a common voltage source, which shall be 2.0 ± .02 volts DC.

b. The comparison shall be made in a darkened room with the viewing distance to the display being approximately 28 in. (0.71 m). It is recommended that a minimum of 15 minutes be allowed for dark adaptation prior to making the visual comparison.

c. Uniform readability of the display and the requirements for extraneous light shall be met throughout the range of the viewing angles and their orientation that are designated in the procurement specification for the display.

5.5.3.1 Design and Evaluation For Readability: The criterion for evaluating the lighting of a single instrument by visually comparing its readability with the readability of a panel full of previously approved instruments and displays at a low intensity is relatively straightforward and can be generalized as follows:

If when the subject instrument is placed among an array of approved displays its entire dial can be read as well as can the other displays under the foregoing conditions, and its apparent brightness is not of an intensity which makes adjacent instruments more difficult to read, then the subject display meets the requirements of 5.5.3; otherwise, it does not.

On the other hand, when an array of approved displays is not available, it becomes necessary to use other method(s) or standards which are available to both the supplier and the user for the development and evaluation of new displays.

Following are practices or guidelines recommended for use in designing and evaluating the lighting system of a display to meet the requirements of low intensity readability, extraneous light emission and other applicable readability requirements defined herein. These practices are intended to apply to both the qualification and production procurement phases of a new or revised display.

5.5.3.2 Design Using Lighting Standards: This method utilizes a single display (or a group of displays) whose low intensity readability has been approved by the user and it is available to the supplier for use as a visual "standard". During the design of a new display its low intensity readability is compared directly with that of the "standard" for conformity with the requirements of 5.5.3. (In addition to this visual comparison, it also is recommended that photometric measurements of the new design be recorded during its development as an aid in reproducing or modifying the lighting system as required in the fabrication of follow-on hardware.)

When it is believed that a design has been achieved that will comply with the low intensity readability requirements of 5.5.3, Lighting Evaluation Articles are to be fabricated for evaluation by the user and for ultimate use as production article standards as described in 5.5.3.4.

5.5.3.3 Design Using Lighting Values: When an acceptable lighting "standard" is not available, the following procedure may be used during the initial development of the lighting system for a "new" display. It is emphasized that this method should be considered only as a design guide, and the ultimate objective and the final and superseding requirements are as defined in 5.5.3.

The lighting system of the new display is designed so the intensities of the light emitted from its indicia, pointer, etc., is within the limits listed below when the lighting system is energized at 2.70 ± .03 volts DC.

a. Markings:

The brightness of the lighted markings shall be .20 ± .10 foot-lambert. This applies to all the white and all the colored markings.

b. Pointers:

The average brightness of the pointer(s) or lubber line(s) of the instrument shall be .240 ± .01 foot-lambert.

c. Background:

As a design objective, it is recommended that the integral lighting system of displays be designed so no light is emitted (either by reflection or by transillumination) from the background area of the display when its integral lighting system is energized. This will provide a maximum contrast between the markings or pointers and their background for all controlled brightness levels of the integral lighting system.

It also is recognized that many "dark cockpit" conditions make it essential that additional lighting be provided to illuminate the instruments and control panels and their backgrounds so that the crew can see control knobs, switches, etc., and to preclude vertigo or other visual illusions. For these reasons it is recommended that a dimmable floodlighting system be used to illuminate the background of the instruments or lightplates rather than attempt to design the integral lighting system to illuminate those areas.

(1) On non-transilluminated displays the brightness of the black background shall not exceed 7% of the brightness of any white lighted markings or pointer (pointer in any position) within a 0.25 in. (6.3 mm) radius of that portion. In addition, the maximum brightness of the background shall not exceed 0.010 fl. at any point on the displays.

(2) On transilluminated displays the brightness of the black background shall not exceed 0.0025 fl.

d. The quantity of lamps and their location in the display shall be such that the photometric brightness of any lighted portion of the display shall not be reduced more than 60% by the loss of any one lamp at 2.70 ± .03 volts.

When the supplier is satisfied that the intensities of the emitted light from the new display are within the foregoing limits and/or the display appears uniformily readable at the low input voltage noted in 5.5.3, two Lighting Evaluation Articles should then be fabricated, as noted below, and submitted to the user for his evaluation.

5.5.3.4 Low Intensity Readability Evaluation: Two instruments or lighting assemblies (Evaluation Article) shall be submitted by the supplier to the user for the evaluation of Low Level Readability. Lighting assemblies shall be identical in design to the proposed production units. Unless the user supplied a standard for Low Intensity Readability, the Evaluation Articles shall meet the preceding photometric brightness requirements.

5.5.3.4.1 Evaluation Conditions: The displays being compared and the Evaluation Articles shall be energized by a common source at such a voltage that the brightness will be similar to night operating conditions. The comparison shall be made under the conditions and voltage noted in 5.5.3.a and 5.5.3.b.

5.5.3.4.2 Evaluation Criteria: If the entire display of the Evaluation Articles can be read as well as other previously accepted displays and the apparent brightness of the Evaluation Articles does not make adjacent instruments difficult to read, the display meets the requirements of Low Intensity Readability.

5.5.4 Low Intensity Readability Compensation: If the Evaluation Articles have unsatisfactory Low Intensity Readability, the following steps are recommended:

a. The two Evaluation Articles shall be returned to the supplier along with an instrument whose Low Intensity Readability is considered satisfactory.

b. The supplier shall determine the percent change in brightness required to achieve equal Low Intensity Readability and shall modify the Evaluation Articles as required. The Evaluation Articles shall be resubmitted to the user.

5.5.5 Use of Evaluation Articles: When the user has approved the Evaluation Articles for Low Intensity Readability, one article shall be retained by the user and one by the supplier as reference standards. It is recommended that the supplier measure and record the photometric values of his reference standard and that visual limit standards or photometric tolerances be established as go-no-go guides for production units.

5.6 Extraneous Light:

5.6.1 Light Leaks and Glare Sources: There shall be no light leaks or glare sources visible in the critical viewing sectors as defined by the device specification.

5.6.2 Stray Light Limitations: The purpose of this section is to limit the light emitted by the lighting components directly into the crew station area without being used to illuminate the display.

5.6.2.1 Method of Measurement: Stray light shall be measured by placing a white matte surface (85% ± 5% reflective) such as a clean white blotter or Kodak Publication No. R-27 perpendicular to the cover glass and to a line from the center of the instrument to the midpoint of the outer diameter of the critical or noncritical sector. The lighting terminals shall be energized at the voltage specified for brightness readings and the photometer shall observe an area approximately 0.25 in. (6.3 mm) in diameter. No part of the measuring instrument shall be in front of the display and brightness readings shall be taken with the measuring instrument focused on the white matte surface.

5.6.2.2 Brightness Limits: The following limits shall apply to instruments whose display is flat and approximately 3 in. (76 mm) or less in diameter. Ball type displays or displays larger than 3 in. (76 mm) may require larger limits.

With the white surface tangent to the instrument at the midpoint of the outer diameter of the critical sector and looking across the instrument cover glass at the white surface, the maximum brightness reading shall be equal to 40% of the specified low limit of a white indicia. In a similar manner with the

white surface at the midpoint of the noncritical sector, the maximum brightness reading shall be equal to the high limit of a white indicia.

6. LIGHTPLATES

6.1 Purpose: The purpose of this section is to present the recommended requirements for the integral illumination of lightplates located in the crew station area.

6.2 Scope: This section is concerned with the static information presented to the flight crew and illuminated integrally during night flying conditions. Unless otherwise specified, dynamic presentations mounted in or behind a lightplate and illuminated by the lightplate shall meet the requirements of section 5 as applicable. Lighted displays which are an integral part of a lightplate but which function as warning, cautionary, etc. displays shall meet the requirements of section 8 as applicable.

6.3 General Requirements:

6.3.1 Lightplates may be of the types V and VII as defined in MIL-P-7788D.

6.3.2 Except when specifically excepted, lightplates shall meet the applicable requirements of section 4.

6.3.3 Ease of Relamping Lightplates: Lightplates shall be designed so that failed lamps may be replaced in the cockpit by simple disassembly from the lightplate, from the instrument panel, or by substitution of a new circuit board/lamp assembly without the need for tools other than a screwdriver.

6.3.4 There shall be a minimum of 0.03 in. (7.6 mm) of material between the lamps and the front face of the lightplate.

6.3.5 Approved Lamps: The following lamps or approved equivalents shall be used. The MS part number or the ANSI number of the lamp (or type and manufacturer) installed in the lightplate shall be marked on the back of the lightplate.

MS24367-683 AS15 (T-1, unbased)
MS90451-6832 (T-1, unbased, short)
MS24367-715 AS15 (T-1, unbased)
MS24515-718 AS15 (T-1, based)
MS25237-327 AS15 (T-1-3/4, based)
MS25237-328 AS15 (T-1-3/4, based)

6.3.6 Electrical Connector: Electrical terminations of lighting circuitry which is integral to the lightplate shall be by means of a two-contact coaxial male plug firmly attached to the back of the lightplate. In cases where a separate circuit board is used, terminations may be as above, may be in an electrical connector which is used for another electrical system of which the mounting plate is a part or may be a 6-pin electrical connector per MIL-C-26482.

6.3.7 Markings of lightplates should be such that they may be easily read under a wide range of lighting conditions. Some fonts which are recommended are News Gothic and Futura Medium.

6.4 Specific Requirements:

6.4.1 When integrally illuminated, the photometric brightness of a lightplate shall be per section 5.5 as applicable.

6.4.2 Stray Light: The lightplate shall not emit light from any surface except the markings or specified light emitting areas. Design of lightplates shall be such that light leaks from edges and corners during normal operation and maintenance is minimized.

## 7. CIRCUIT BREAKER LIGHTING

7.1 Purpose: The purpose of this section is to present the requirements for illuminating circuit breakers and circuit breaker nomenclature panels so that a tripped circuit breaker and the circuit breaker nomenclature can be located and read.

7.2 Scope: This section covers the lighting systems for integral illumination of push-pull type circuit breakers and their lightplates and the flood lit illumination of circuit breakers and their panels.

7.3 General Requirements:

7.3.1 Unless specifically excepted, circuit breakers and their lightplates or panels shall meet the requirements of section 4 as applicable.

7.3.2 Unless specifically excepted, integrally lit circuit breaker lightplates shall meet the requirements of section 6 as applicable.

7.3.3 Mounting: Circuit breaker lightplates or panels shall be mounted so the exposed face is at the same level as the untripped circuit breakers. The tripped circuit breaker shall protrude above the exposed face of the panel.

7.3.4 Accessibility: Sufficient clearance for two fingers shall be provided between circuit breakers and the lightplate or panel permitting the circuit breaker to be gripped and pulled out to the detent position. This clearance shall be provided on at least two opposing sides of the handle. If used, high visibility attachments shall not hinder the grasping of a circuit breaker handle or the recognition of a tripped circuit breaker under night flying conditions.

7.4 Integrally Lit Circuit Breaker Panels:

7.4.1 Integrally lit circuit breaker panels shall be considered to be integrally lit lightplates and shall meet the same requirements as applicable.

7.4.2 Light Leakage: When circuit breaker panels supply light either to flood a portion of a tripped breaker or supply light to transilluminate a breaker, the light emitting areas of the panel shall not be visible to a crew member operating the breakers or to any crew member in his normal working position.

7.4.3 Illumination of Circuit Breaker Handles: The circuit breaker panels shall provide for individual circuit breaker lighting by emitting light from openings in the panel. The emitted light shall be approximately perpendicular to the panel openings. The illumination falling on the circuit breaker panels shall be 1.50 $\pm$ .75 footcandles at 5.0 $\pm$ .05 volts or .75 $\pm$ .04 footcandles at 2.7 volts as specified in the device specification. Measurements shall be made with an illumination meter or a brightness meter and opal glass of known transmittance. The illumination midway between any two handles shall not be greater than 20% of the specified nominal value.

7.5 Flood Lit Circuit Breaker Panels: It is recommended that flood lighting of an entire circuit breaker panel be avoided whenever possible.

7.5.1 Light Position: Light sources to flood light a circuit breaker panel shall be so positioned and shielded that they are not visible to any crew member in his normal working position or to a crew member operating the breakers. As far as practical, they shall be positioned so that a crew member operating the breakers does not obstruct the light falling on the panel.

7.5.2 Brightness: With the lighting system energized at specified voltage, the nomenclature of the panel and the area of the breaker signifying a tripped condition shall meet the brightness and color requirements of an integrally lit lightplate.

7.5.3 Excess Illumination: Every effort shall be made to limit the illumination in areas beyond the panel. The maximum illumination 3 in. (76 mm) from the edge of the panel shall not be greater than 15% of the nominal value.

7.5.4 Measurement: Where direct measurements of a panel are impractical, a white matte surface may be substituted for the panel, or a cosine corrected photometer may be used to measure the illumination at the surface of the panel. In the case of the cosine corrected photometer, the brightness limits shall be multiplied by 1.18. (Multiplication by 1.18 is to compensate for the assumed white matte reflection of 85%.)

8. WARNING, CAUTION, AND ADVISORY SYSTEM LIGHTING

Refer to the latest issue of SAE ARP 450 for recommendations on warning, caution, and advisory lighting. As an option, sections 8.1 through 8.10 can be omitted.

8.1 Purpose: The purpose of this section is to present the lighting requirements for warning, caution, and advisory systems.

8.2 Scope: This section sets forth the lighting requirements for warning, caution, and advisory systems.

8.3 Definitions:

8.3.1 Master Warning: A signal indicating a condition requiring immediate action. The specific condition is shown by a separate indication.

8.3.2 Independent Warning: A signal indicating a condition requiring immediate action. The specific condition is defined by the location of the signal or the legend associated with the signal.

8.3.3 Master Caution: A signal indicating a condition which may require action. The specific condition is shown by a separate indication.

8.3.4 Advisory, Safe: A signal indicating a safe condition.

8.3.5 Advisory, Status: A signal indicating a status condition only, not necessarily a safe condition.

8.3.6 Dependent Warning or Caution: A signal indicating the specific cause of activation of the master warning or caution signals, respectively.

8.4 Colors:

a. Warning Signals: Aviation red per MIL-C-25050.
b. Caution Signals: Aviation yellow per MIL-C-25050.
c. Advisory, Safe: Light green per device specification.
d. Advisory, Status: Any color including white except those above or colors easily confused with the above colors. A light (ice) blue is recommended.

8.5 Master Warning Indicator and Master Caution Indicator: The purpose of these indicators is to intrude upon the attention of the crew members under all operating conditions. Thus the designer must consider placement of indicator, ambient lighting, shading from direct sunlight, size of lit area, steady state versus flashing and brightness. Minimum brightness shall be 150 footlamberts at rated voltage provided the indicators can be placed out of direct sunlight. The indicators shall be dimmable to 15 footlamberts. The bright-dim control shall return to full bright position whenever power is removed from the control or the ambient brightness reaches a predetermined level. The indicators shall be resettable so that a second signal shall reactivate the master indicator.

8.6 Independent Warning Indicator: In general, the independent warning indicator shall meet the requirements of 8.5 with the following exceptions: The indicator need not be resettable; either the placement of the indicator or an associated legend shall clearly show the nature of the warning; the designer shall consider additional dimming to 5 footlamberts.

8.7 Dependent Warning and Caution Indicators: These indicators shall be activated simultaneously with their respective master indicator and shall show the specific cause of the master indicator activation. In general, their brightness shall be 150 footlamberts minimum at rated voltage but the required brightness shall be evaluated in term of operating conditions and lower brightness used where practicable. The indicators shall be dimmable to 15 footlamberts and the designer shall consider dimming to values approximately twice the nominal values of the integrally lighted displays.

The bright-dim control shall return to full bright position under the conditions described in 8.5. The indicators shall not be resettable while the activating condition exists.

8.8 Status Indicators: The status indicators shall have a brightness sufficient for legibility under all conditions of flight operation. The designer shall consider location and shading from sunlight to inhance readability at lower brightnesses. The indicators shall be dimmable to values comparable to the integrally lit displays of section 5.

8.9 Legends: In general, where indicators have legends, the legend should 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. 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.

8.10 Lamps and Circuitry:

8.10.1 The following lamps or approved equivalents shall be used in the warning, caution, and advisory systems:

MS24515-715 (T1, flanged 5V)
MS25237-327 (T1-3/4, flanged -28V)
MS25237-328 (T1-3/4, flanged -5V)
ANSI 7327 (T1-3/4, bi-pin 28)
ANSI 7387 (T1-3/4, bi-pin 28)
ANSI 7377 (T1-3/4, bi-pin 5V)
ANSI 7715 (T1, bi-pin 5V)

8.10.2 Each indicator shall contain a minimum of 2 lamps connected in parallel. The lamps shall be replaceable without removal of the indicator and without special tools. Circuitry of the systems shall be such that transitory signals which are normal in the operation of the aircraft are suppressed. Each system shall have a master test switch which enables the testing of at least all of the indicators of the system.

8.10.3 It also is recommended that consideration be given to including the testing of all portions of each flight critical or flight essential system through the master test switch. The decision to include testing of the total circuit of each subsystem should be based on its effect on aircraft safety, aircraft dispatch and/or its cost effectiveness.



9. UTILITY LIGHTING

9.1 Purpose: This section sets forth the basic considerations and criteria which the design engineer should observe in the design of utility lighting for the flight crew station of commercial aerospace vehicles.

9.2 Scope: This specification is intended to cover all crew station utility lighting included in the categories listed below:

A) General Area Lighting - Illumination of large surface areas using one or more lighting devices.

B) Limited Area Lighting - Lighting a specific size area in the crew station to illuminate an individual work task.

C) Auxiliary Lighting - Lighting of instruments and controls essential for aircraft operation during abnormal flight conditions such as loss of the normal instrument lighting system and electrical storms.

9.3 General Requirements:

9.3.1 Utility Lighting System: The utility lighting system shall meet all of the applicable requirements of Section 4.

9.3.2 Type of Light: Utility lighting devices shall provide white lighting. White lighting shall be obtained using the natural white color of the incandescent lamp, the warm white fluorescent lamp, or any light source providing equivalent color. Only clear, stippled, and white diffuse light covers and filters shall be used to avoid color shifting of the white lighting.

9.3.3 Glare and Surface Reflections: To minimize glare and reflection from surfaces illuminated by utility lights, paint finishes on panels, ceilings, equipment, etc., shall be low gloss and have a reflectance no greater than 20 percent.

9.3.4 Light Shielding: The utility lighting devices shall be designed and located so that no light sources are visible in the crew's normal field of vision when the crew members are seated at their respective stations. Each lighting fixture required to illuminate a limited size area shall have a sharp cutoff. The light intensity 2 in. (50.8 mm) from the periphery shall be 1/10 of the periphery value.

9.3.5 Temperature: The surface temperature of all lighting fixture surfaces exposed to crew members shall not exceed 120 F (49 C) at normal room ambient.

9.4 Specific Requirements: Utility lighting shall consist of the following systems:

9.4.1 General Area Lighting:

9.4.1.1 Ceiling Lights (Dome): Provide high brightness flood lighting of the sidewalls, seats, tables, and floor of the crew station area. Ceiling lights shall be recessed or flush mounted and shall provide light coverage to the entire flight deck area.

9.4.1.2 Panel Background: High intensity incandescent and/or fluorescent flood lighting of instrument panels; excluding overhead panels. Panel background lighting for the captain's, center, first officer's, and flight engineer's panels shall have separate intensity controls. Location of light source(s) should be in close proximity to the panel so that shadowing of the panels by equipment or personnel cannot occur.

9.4.1.3 Threshold Lights: Low intensity illumination to reveal irregularities in the crew station floor.

9.4.2 Limited Area Lighting: Design and mounting arrangement of illumination sources for individual work tasks shall be such that the crew member may easily read check lists, manuals, maps, and weather charts without undue interference of the other crew member's vision outside the aircraft. Light distribution of limited area lighting devices shall be uniform so that no dark or bright light striations are visible within the light pattern.

9.4.2.1 Map-Reading Light: An aimable light source with adjustable pattern size, up to 18 in. (0.46 m) square, for each crew member to illuminate hand and lamp-held charts and maps. The map-reading light shall be mounted so that a fixed writing pad or a navigational plotting board held on the lap is not shadowed by the crew member's hands or body.

9.4.2.2 Chart and Table Lights: Light sources for illumination of the captain's and first officer's approach chart and work tables. Chart holder lighting shall be hooded to prevent unwanted spread of light beyond the chart surface.

The navigation table and flight engineer's table shall be lighted over the total work area.

9.4.2.3 Portable Utility Light: A mountable, detachable, and movable light for each crew member and observer's station. The portable light shall have both a spot or flood distribution and be aimable when mounted in its holder. The holder should be located near the flight briefcase position for lighting its interior.

9.4.3 Auxiliary Lighting:

9.4.3.1 Standby Lighting: Low brightness background flood lighting of the captain's, center, first officer's, and flight engineer's instrument panels. The standby lighting system shall be powered from an emergency battery supply to illuminate essential instrumentation and controls for aircraft operation when normal instrument and crew station lighting is inoperative.

9.4.3.2 Storm Lighting: Bright illumination for the crew station area during electrical storms. System shall consist of panel background lights and integral instrument lighting and ceiling lights (optional) at full intensity.

9.4.3.3 Emergency Lighting: Used during crew evacuation of an aircraft or when a high illumination level is required under the standby lighting condition. System shall consist of one or more ceiling lights which the crew has the option of turning on.

9.5 Utility Lighting Controls:

9.5.1 Utility Lighting: Utility lighting shall be dimmable. Dimming controllers shall meet the applicable requirements of section 4.5.2 except as noted below.

9.5.2 Ceiling Lights: Forward and aft ceiling lights in the crew station should be separately controlled by intensity controls located near the captain and flight engineer respectively. The first officer shall be able to reach either the captain's or flight engineer's controls. On/off switches for the ceiling lights shall be located near the doorway(s) into the flight deck.

9.5.3 Panel Background: Panel background lighting of the captain's and center, first officer's, and flight engineer's panels shall be separately controlled by intensity controls located convenient to the crew members.

9.5.4 Threshold Lights: The captain's ceiling dimming controller shall control threshold light intensity.

9.5.5 Limited Area Lighting: Each of the limited area lighting devices shall have its own dimming control located on or near the lighting device and convenient to the crew member expected to use it. The intensity controller shall consist of a switch and dimming control or a "push on/pull off" rotary dimming control so that the light can be switched on or off without disturbing the intensity.

9.5.6 Standby Lighting: Design of the standby lighting system shall be such that dark adaptation of the crew is not impaired when the standby lights turn on.

Standby lights shall be automatically energized at dim intensity from an emergency battery supply with loss of normal airplane power. A dimming control for all standby lighting shall be located between the captain and first officer so that standby intensity can be increased if required at the option of the crew. The dimming controller at full dim shall not extinguish the standby lighting below an intensity level suitable to read instrumentation under a night crew station dark ambient condition.

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

9.5.7 Storm Lighting: A three position switch, off, on, and bright, shall be provided and located near the captain (within reach of the first officer) for storm lighting. "Off" position, all utility lights (and integral instrument lighting) will be operated on their individual intensity control. "On" position shall override individual dimming controls and all integral instrument and panel background lighting will be at full intensity. The "bright" position shall turn on all crew station ceiling lights at full intensity in addition to the instrument and panel background lighting to completely floodlight the crew station.

9.5.8 Emergency Lighting: A guarded on/off switch shall allow one or two ceiling lights to be energized at maximum intensity from emergency battery power to supplement standby lighting or for purpose of crew evacuation.

9.5.9 Special Circuitry Requirement: The standby and emergency lighting circuits shall be independent circuits protected by individual circuit breaker and routed in different wire bundles to minimize loss of all emergency lighting systems.

9.6 Brightness: Utility lighting sources shall be of such a brightness and so positioned as to provide illumination specified over the area described in Table II. Systems shall be energized at the nominal rated voltage of the system ± 5% with the dimmer control positioned to provide full voltage to the system except where other positions are specified. Measurements shall be taken within the face of the sensor parallel to the surface illuminated and as close to the surface as practical. Aimable systems shall be positioned so that a line from the lamp source to the center of the surface illuminated would be the axis of the cone enclosing the luminous flux.

TABLE II

| Type of Lighting | Area Measured | Location of Measurement | Footcandles Max | Nom | Min |
|---|---|---|---|---|---|
| Ceiling | N. A. | Floor | -- | -- | 5 |
| Panel Background | Captain's, Center, and First Officer's | Panel Surface | 150 | 90 | 50 |
| | Flight Engineer's | Panel Surface | 120 | 80 | 40 |
| | Center - Side Console | Panel Surface | 60 | 40 | 20 |
| Threshold - (Bright) | N. A. | Approximately 6 in. (152 mm) from Irregularity (See 9.4.1.3) | 3 | -- | -- |
| - (Dim) | N. A. | | -- | -- | .05 |
| Limited Area | Map-Reading (18 in. x 18 in. (.46 x .46 m)) | Crew's lap | 30 | 20 | 15 |
| | Approach Chart and Small Work Table Lighting | Chart and Table Surface | 15 | 10 | 5 |
| | Navigation and Flight Engineers' Tables | Table Surface | 30 | 20 | 15 |
| | Portable - (Spot) | 6 in. (152 mm) Dia. Circle, 2 ft (.61 m) from Source | -- | -- | 10 |
| | - (Flood) | 4 sq ft (.37 sq m) area, 2 ft (.61 m) from Source | -- | -- | 5 |
| Standby - (Bright) | Captain's, Center, First Officer's, and Flight Engineers' Instrument Panels | Panel Surface | -- | 5 | -- |
| - (Dim) [1] | | | -- | 1 | -- |
| Emergency | Crew Station Emergency Egress Path | Seat Arm Rest Height | -- | -- | .05 |

[1] Instruments must be readable with standby intensity control in full dim position under a dark flight deck ambient.

10. REFERENCES

10.1 Baumunk, Dean B.: "A Concept for Brightness Variation in Design of Aircraft Lighting Control Systems," Douglas Aircraft Company Paper No. 5852, October 1, 1970.

APPENDIX I - SOME FACTORS AFFECTING HUMAN PERCEPTION

APPENDIX II - DESIGN PHILOSOPHY AND RECOMMENDATIONS INDIRECTLY RELATED TO CREW STATION LIGHTING



PREPARED BY

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## APPENDIX I

## SOME FACTORS AFFECTING HUMAN PERCEPTION*

### QUANTITY OF ILLUMINATION

Quantity of illumination generally refers to a specific footcandle level of illumination on a surface or plane. The illumination level may be selected in one or more ways. The user may follow an IES footcandle recommendation; he may get his inspiration from an exemplary lighting installation in a building where the seeing tasks are similar to those performed in his own building; he may base his decision on available lighting research data; or there may be other criteria. In any case, the object should be to select a lighting level that will provide the best seeing possible, consistent with practical and economic limitations.

Basically, seeing is largely dependent upon four fundamental factors: (1) visual size of the object or detail, (2) contrast between the object and its background, (3) brightness of the object, and (4) the time available to see the object. The lighting designer is not usually able to increase the visual size or the contrast, or increase the time allotted in which to see, but more than likely he can provide a level of illumination or a brightness pattern that will affect all of these factors.

Increased illumination influences or apparently influences all four factors. For example, the details of an object appear to be magnified when the light on them is increased, just as though their visual size were increased. Similarly, objects involving low contrasts are ordinarily easier to see when the illumination is increased. Brightness of an object usually increases in proportion to the amount of illumination. Also, in most situations, the time it takes to see a critical detail actually decreases as the illumination increases.

A basic concept closely associated with increased illumination is that the scale of footcandle effectiveness is in approximately geometric (not arithmetic) steps; 10, 20, 50, 100, 200, 500, etc. In other words, as indicated by the progression, the illumination must be approximately doubled to produce equal and significant increases in the visual effect. For example, the addition of 10 footcandles to 10 footcandles is a significant step. Adding 10 footcandles to 100 footcandles is not considered a significant step, although it is not to be presumed that the added 10 footcandles will have no influence on seeing. Most authorities agree that it will have an influence, even though the effect may not be detectable by ordinary methods. Similar relationships between stimulus and sensation are commonly encountered in other sensory responses.

### LIGHT AND COLOR

The perception of color is a complex visual sensation, intimately related to light. The apparent color of an object primarily depends upon four factors: its ability to reflect various colors of light, the nature of the light by which it is seen, the color of its surroundings, and the characteristics and state of adaptation of the eye.

In most discussions of color, a distinction is made between white and colored objects. White is the color name most usually applied to a material that diffusely transmits a high percentage of all the hues of light. Colors that have no hue are termed neutral or achromatic colors. They include white, off-white, all shades of gray, down to black.

All colored objects selectively absorb certain wave-lengths of light and reflect or transmit others in varying degrees. The internal structure of objects also helps to determine their apparent color.

Inorganic materials, chiefly metals such as copper and brass, reflect light from their surfaces. Hence we have the term "surface" or "metallic" colors, as contrasted with "body" or "pigment" colors. In the former, the light, specularly reflected from the surface, is often tinted.

Most paints, on the other hand, have body or pigment colors. In these, light is specularly reflected from the surface without much color change, but the body material absorbs some colors and reflects others; hence, the diffuse reflection from the body of the material is colored, but often appears to be overlaid and diluted with a "white" reflection from the glossy surface of the paint film. In paints and enamels, the pigment particles, which are usually opaque, are suspended in a vehicle, such as oil or plastic. The particles of a dye, on the other hand, are considerably finer, and may be described as coloring matter in solution. The dye particles are more often trans-

* Excerpted from: "Fundamentals of Light and Lighting," General Electric Co., Bulletin LD-2, August 1960.