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An SAE International Group

AEROSPACE RECOMMENDED PRACTICE

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Measurement Procedures for Strobe Anticollision Lights

RATIONALE

This document has been reaffirmed to comply with the SAE 5-Year Review policy.

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1. SCOPE:

This SAE Aerospace Recommended Practice (ARP) provides the user with standardized guidelines for the measurement of effective intensity of strobe anticollision lights for aircraft in the laboratory, in maintenance facilities, and in the field. A common source of traceability for calibration of the measurement systems, compensation for known causes of variation in light output, and recommendations which minimize sources of errors and uncertainties are included in this document. Estimates of uncertainty and error sources for each class of measurement are discussed.

1.1 Purpose:

This document recommends the test methods and equipment necessary to perform photometric measurements used to determine the effective intensity of red and white strobe type anticollision lights for aircraft.

1.2 Limitations:

This document does not include the measurements of long duration flashes, such as those achieved with rotating beacons or flashed incandescent lamps. This procedure does not apply to light sources where the flash duration is longer than 0.2 s. The measurement of long duration flashes and the iterative calculation process required to determine the effective intensity from the intensity-time curve is discussed in FAA Advisory Circular 20-74. Measurement of the effective intensity of bursts of flashes or multiple closely spaced flashes is not included in this document.

1.3 Categories of Test:

The measurements are divided into three categories. The categories in descending order of accuracy and detail are:

a. laboratory measurements
b. maintenance facility measurements
c. field measurements

1.4 Test Considerations:

Photometric calibration traceability for each type of measurement is recommended. The uncertainties of the measurement system, causes for variations in intensity of the lights, and sources of error for each type of measurement are reviewed in Appendix H. Particular attention is given to the effect of temperature on the transmittance of red glass. In the laboratory test section, a procedure is outlined for compensating for this temperature dependent effect when making intensity measurements.

1.5 Safety:

Observe the following safety recommendations when working with strobe based anticollision light systems:

CAUTION: EXPLOSION HAZARD ! Do not operate the strobe light without the fitted lens securely in place. Always wear eye protection when testing strobe lights. The flash tube is under pressure, and possible injury can occur if flash tube explodes.

CAUTION: HIGH VOLTAGE ! Use care when handling cables, power supply and strobe lights during test, as high voltage is present. Allow adequate time for voltage to bleed off or manually discharge the system.

CAUTION: HOT SURFACES ! Do not touch the strobe light during or immediately after operation, as surface temperatures near the lamp may be hot enough to cause injury.

CAUTION: INTENSE LIGHT ! Do not look directly at strobe light during operation as eye injury could result. Use protective eyewear, or assure that the light is properly enclosed within the test compartment.

2. REFERENCES:

2.1 Applicable Documents:

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

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

SAE Aerospace Technical Report Style Manual Dated Jan.,1996

SAE 8017, Minimum Performance Standards for Anticollision Light Systems.

SAE J1330, Photometry Laboratory Guidelines

SAE J575, Test Methods and Equipment for Lighting Devices and Components

2.1.2 U.S. Government Publications: Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

14 Code of Federal Regulations, Part 23, Airworthiness Standards: Normal, Utility, and Acrobatic Category Airplanes

14 Code of Federal Regulations, Part 25, Airworthiness Standards: Transport Category Airplanes

14 Code of Federal Regulations, Part 27, Normal Category Rotorcraft

14 Code of Federal Regulations, Part 29, Transport Category Rotorcraft

2.1.3 FAA Publications: Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591.

FAA Advisory Circular 20-74, Aircraft Position and Anticollision Light Measurements

2.1.4 CIE Publications: Available from TLA - Lighting Consultants Inc., 7 Pond Street, Salem, MA 01970.

CIE Publication 69, Methods of Characterizing Illuminance Meters and Luminance Meters

2.1.5 NIST Publications: Available from National Institute of Standards and Technology, U.S. Department of Commerce, Gaithersburg, MD 20899.

NIST Special Publication 250-37, Photometric Calibrations

2.1.6 Other Publications:

Spectroradiometry, Kostkowski ISBN 0-9657713-O-X, Reliable

Handbook of Applied Photometry, ed Casimer DeCusatis, ISBN 1-56396-416-3

Lighting Handbook. Eighth Edition, ed. Mark S. Rhea (Illuminating Engineering Society of North America, New York, 1993)

Y. Ohno and Y. Zong, Establishment of the NIST Flashing-Light Photometric Unit, Proceedings of SPIE, Vol. 3140, Photometric Engineering of Sources and Systems, 2-11 (1997)

2.2 Definitions:

2.2.1 LABORATORY STANDARD PHOTOMETER: A photometer which maintains the primary standard of flashing light measurements for the laboratory and provides traceability to the NIST standard.

2.2.2 INTEGRATED ILLUMINANCE: Integrated illuminance, E_V, [lux·second (lx·s), footcandle·second (fc·s)], is the integral of the instantaneous illuminance, E(t), [lx, fc], of a flashing light source over the entire flash duration, (t_2 - t_1), as given by:

$$E_v = \int_{t_1}^{t_2} E(t)dt \quad \text{(Eq. 1)}$$

2.2.3 INTEGRATED LUMINOUS INTENSITY: Integrated luminous intensity, I_V, [candela·sec, (cd·s)] is the integral of instantaneous luminous intensity I(t), [cd] of a flashing light source over the entire flash duration, (t_2 - t_1), as given by:

$$I_v = \int_{t_1}^{t_2} I(t)dt \quad \text{(Eq. 2)}$$

To obtain I_V from E_V:

$$I_v = E_v \cdot D^2 \quad \text{(Eq. 3)}$$

where:

D = Distance from the source to the photometer

D is expressed in [meters] when the integrated illuminance, E_V, is in [lx·s], and [ft] when E_V is in [fc·s]. Equation 3 is valid only when D is large enough to enable the source to behave as a point source, where illuminance is inversely proportional to distance squared. For strobe measurements, D must never be less than 2.4 m. A minimum of 9 m is recommended for laboratory tests

2.2.4 EFFECTIVE INTENSITY: The concept of effective intensity [cd] of a flashing signal is intended to represent the luminous intensity [cd] of a steady light source with equivalent visual conspicuity. The Blondel-Rey equation defines effective intensity as:

$$I_c = \frac{\int_{t_1}^{t_2} I(t)dt}{0.2 + (t_2 - t_1)} \quad \text{(Eq. 4)}$$

where:

$(t_2 - t_1)$ = Flash duration [s]

The [0.2] in the denominator was derived experimentally under certain experimental conditions. In this document, the equation for effective intensity is based on a simplified Blondel-Rey Equation. Since the pulse duration $(t_2 - t_1)$ for a xenon flash is very small compared with 0.2 s, it may be omitted from the denominator of the effective intensity equation. This will insure more uniform results by removing the uncertainty introduced by variation in determining the pulse width. For xenon strobe measurements, the effective intensity is, therefore, expressed as:

$$I_e = \frac{I_v}{0.2} = 5 \cdot \int_{t_1}^{t_2} I(t)dt \quad \text{(Eq. 5)}$$

For the purposes of determining the performance of the anticollision light, I_e is expressed in candelas (also referred to as effective candelas in other documents, or ecp in 14 Code of Federal Regulations). The photometer should be capable of measuring a single flash or averaging multiple flashes. Usually, the integral of several flashes is measured and the average result calculated. Reference SAE 8017. This procedure recommends that the measurements be based on the average of a minimum of 8 flashes.

2.2.5 FIELD OF COVERAGE: An aircraft's anticollision light system consists of one or more lights which produce an intensity pattern covering 360° horizontally around the aircraft and vertically over a specified range. The field of coverage of a strobe light refers to that portion of the entire anticollision light pattern which must be produced by that light. See Figure 1 for a pictorial representation of field of coverage.

2.3 Conversion Factors:

1 candela (cd) = 1 lumen/steradian
1 footcandle = 10.76 lux
1 footcandle = 1 lumen/foot^2
1 lux = 1 lumen/meter^2

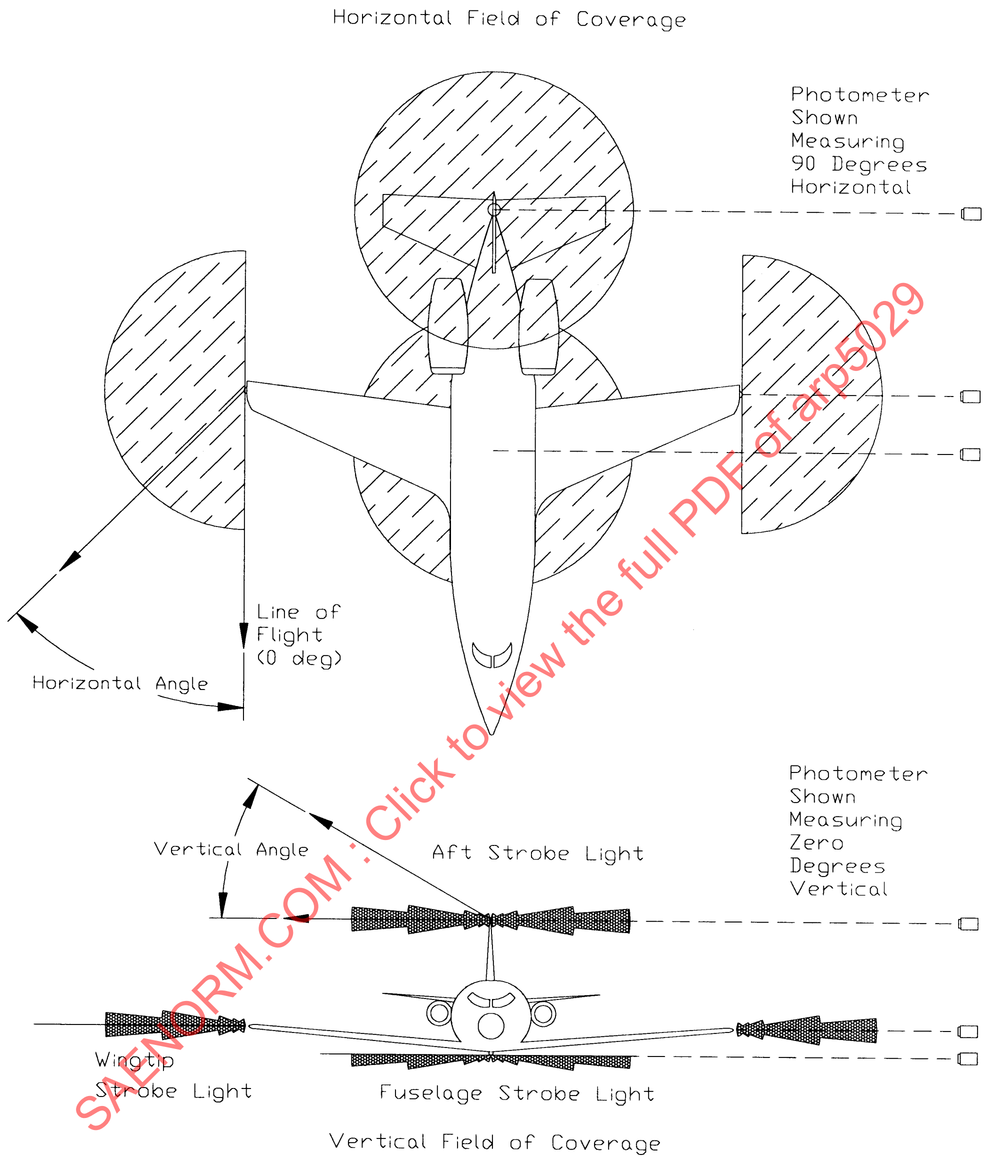

FIGURE 1 - Illustration of the Field of Coverage of Various Strobe Lights
0° Vertical, 90° Horizontal Photometer Location Shown

3. LABORATORY TESTS:

3.1 Scope:

This section describes the required equipment, test procedure, safety precautions and other information necessary to perform white or red strobe anticollision light measurements in a photometric laboratory.

3.2 Minimum Required Equipment:

a. Calibrated photometer for measuring strobe light as described in Appendix A

b. Goniometer for positioning strobe light as described in Appendix B

c. Photometric tunnel in which light measurements are made described in Appendix C

d. Regulated power supply to supply electrical power to strobe light system as described in Appendix D

e. Temperature measurement device to read ambient temperature and temperature of strobe light lens

f. Hand tools, voltmeter and other standard laboratory equipment

3.3 Anticollision Light Intensity and Field of Coverage Requirements:

Determine the intensity and field of coverage requirements for the strobe light being tested. The field of coverage of the light must be determined relative to some reference feature of the light assembly, such as its mounting surface. Note that in some cases, the aircraft surface to which the light assembly mounts changes angular orientation during flight. This is often the case for wingtip strobes where the wing tip deflects upward during flight. It may be necessary to consider this mounting surface deflection when defining the field of coverage relative to the mounting surface of the light.

3.4 Safety Considerations:

Verify that all safety considerations have been met, as discussed in 1.5. The potential hazards of the strobe light system include: high temperatures, high voltage, pressurized components, and intense light.

3.5 Test Preparation:

3.5.1 Apply power to the photometer system and allow it to stabilize for at least 30 min. Confirm that all lenses, filters and optical elements are clean and free from fingerprints as this can adversely affect the measurements.

3.5.2 Install the unit-under-test (UUT) onto the goniometer. Position and align the UUT onto the goniometer such that its total field of coverage can be measured.

3.5.3 Record the laboratory temperature and humidity.

3.5.4 Record the distance from the reference surface of the photometer to the center of the light source of the UUT. The distance should be as long as possible so that the light source will behave as a point source (i.e., the illuminance is inversely proportional to distance squared). For this procedure, a minimum of 9 m is recommended for laboratory tests. Additionally, the peak instantaneous illuminance must lie well within the linear response range of the photometer.

3.5.5 Red Lens Temperature Dependence Correction: Red glass lenses darken significantly (i.e., transmits less of the Xenon spectrum) with increased temperature. See Appendix E. This section of the procedure will allow the intensity data taken under a laboratory condition (hot stabilized lens) to be corrected to be more representative of the conditions encountered in flight (ambient temperature lens). A clear glass lens may be installed in place of a red glass lens prior to making the measurements and a correction factor applied to the data. When testing a UUT with a red glass lens, follow the procedure below; otherwise, proceed directly to 3.6.

3.5.6 Install a temperature sensor on the glass lens (i.e., cover glass, red filter) and record its temperature. This location shall remain fixed for all lens temperature measurements called out in this procedure.

3.5.7 Apply power to the UUT and record the input voltage and current. The applied power must be in accordance with Appendix D.

3.5.8 Record the average integrated illuminance (lens - room temperature) of 8 or more flashes over the horizontal field of coverage in 20° (or smaller) increments, with a vertical angle of 0°. The lens must be at room temperature (25 °C ± 3 °C) during these measurements. Cooling air is permissible during this test. It may be necessary to power off the unit between orientations to allow the lens to cool down. This is the measurement of illuminance at room temperature.

3.5.9 Once again apply power to the UUT and record the input voltage and current. Allow UUT to stabilize for at least 60 min. No cooling air is permissible during this portion of the test.

3.5.10 Record the lens temperature, using the temperature sensor location of 3.5.6.

3.5.11 Record the average integrated illuminance (lens - hot steady state) of 8 or more flashes in the same orientations as in 3.5.8 with the lens temperature stabilized hot. The lens temperature must be within ±3 °C of the temperature recorded in 3.5.10.

3.5.12 Compute the correction factor for each horizontal orientation (vertical angle is zero):

$$\text{temperature correction} = \frac{\text{Illuminance (lens - room temperature)}}{\text{Illuminance (lens - hot steady-state temperature)}} \quad \text{(Eq. 6)}$$

3.6 Intensity Measurements:

3.6.1 Apply power to the UUT and record the input voltage and current. The voltage should be set at the nominal design voltage for the light. The applied power must be in accordance with Appendix D. Allow UUT to stabilize. No cooling air is permissible for strobe lights with red glass lenses.

3.6.2 Record the lens temperature. If measuring a strobe light with a red glass lens, the temperature should be within ±3 °C of the temperature measured in 3.5.10.

3.6.3 Record the average integrated illuminance of 8 or more flashes over the vertical and horizontal fields of coverage. Measure in 10° steps over the horizontal range. Measure in 5° steps over vertical ranges of ±30° and every 15° beyond that, if testing a light with a ±75° vertical field of coverage.

3.6.4 As a double check of UUT stabilization, once again measure the integrated illuminance for the angular position measured at the beginning of the test. The two measurements should agree within the measurement uncertainty of the measurement equipment.

3.6.5 Record the lens temperature. The temperature should be within ±3 °C of the temperature measured in 3.5.10 if testing a strobe light with a red glass lens. The temperature is not critical for a white strobe light.

3.6.6 Calculate the effective intensity using the recorded distance and illuminance for all angular orientations as discussed in 2.2. The intensity data should be reported in candelas (effective intensity) in order to compare the data to 14 Code of Federal Regulations requirements.

3.6.7 If the strobe light was measured with a red glass lens, multiply each set of data collected at a particular horizontal angle by the temperature correction factor associated with that horizontal angle. For example, illumination values recorded at 10 °H, -30 to 30 °V would be multiplied by the correction factor measured at 10 °H, 0 °V.

3.6.8 If a clear glass lens was substituted for a red glass lens prior to testing, multiply all the clear lens measurements by the transmittance of the red lens. To obtain the lens transmittance, divide the illuminance measured using a red lens by the illuminance measured using a clear lens for a particular UUT orientation. The lens temperature during the red measurement must be 25 °C ± 3 °C. The UUT must be in the exact orientation for both measurements, as the intensity of the source will most likely vary with orientation.

$$\text{lens transmittance} = \frac{\text{red illuminance } (25\,° \pm 3\,°\text{C})}{\text{white illuminance (same orientation)}} \qquad \text{(Eq. 7)}$$

This concludes the laboratory test procedure.

4. MAINTENANCE SHOP TESTS:

4.1 Scope:

This section describes the required equipment, test procedure, safety precautions and other information necessary to perform white or red strobe anticollision light measurements in maintenance shops.

4.2 Minimum Required Equipment:

a. Calibrated photometer as described in Appendix I
b. Power supply as described in Appendix D
c. Lab meters, tape measure, hand tools
d. Anticollision light holding fixture

4.3 Anticollision Light Intensity Requirements:

Obtain the intensity that the strobe light is required to meet in the horizontal plane and the total horizontal angle over which the light is required to produce this intensity (the horizontal field of coverage of the light).

4.4 Safety Considerations:

Strobe light testing is potentially dangerous. Ensure that all safety considerations discussed in 1.5 are met when performing the following test. The potential hazards of the strobe light system include: high temperatures, high voltage, pressurized components, and intense light.

4.5 Test Preparation:

4.5.1 Assemble and install the necessary measurement equipment and power supply as defined in 4.2.

4.5.2 Locate the strobe light being tested a minimum of 2.4 m away from the photometer and record the exact distance.

4.5.3 Make sure that the line of sight between the strobe light and detector aperture is free from obstructions.

4.5.4 Locate equipment and other objects in the test area to minimize the amount of reflected light reaching the photometer. Verify that if a plate is used to mount the light, that it does not reflect light in the direction of the photometer.

4.5.5 Clean the lens of the strobe light. Fingerprints or other contaminants on the lens can adversely affect the measurements.

4.5.6 Operate the photometer in accordance with manufacturer specifications. Ensure that all optical elements are clean and free from fingerprints or other contaminants as this can adversely affect the measurements.

4.5.7 Mount the strobe light onto its holding fixture. The holding fixture should be able to hold the UUT in a known angular orientation relative to the photometer such that the intensity in a particular direction from the light can be measured. Orient the UUT to the desired horizontal and vertical angle. It is recommended that a vertical angle of zero be used for maintenance shop measurements.

4.5.8 Apply power to the UUT and record the input voltage and current. The voltage should be set at the nominal design voltage for the light.

4.6 Intensity Measurements:

4.6.1 Darken the room and confirm that any remaining ambient light will not interfere with the photometric measurements.

NOTE: It is not necessary to darken the room if it can be verified that the ambient light does not influence the measurement.

4.6.2 Record the average integrated illuminance of 8 flashes or more. If the strobe light lens is made of red glass, make the measurements with the lens close to room temperature. A lens temperature of 25 °C ± 3 °C is recommended.

4.6.3 Calculate the effective intensity based on illuminance and distance as discussed in 2.2 and record the results. The data should be reported in candelas (effective intensity) in order to compare it to 14 Code of Federal Regulations requirements.

This concludes the shop test procedure.

5. FIELD TESTS:

5.1 Scope:

This section describes the recommended practices for making white and red (xenon) strobe anticollision light measurements on the aircraft. It is recommended that each light which comprises the aircraft's strobe anticollision light system should be tested using this procedure.

5.2 Minimum Required Equipment:

a. Calibrated portable photometer as described in Appendix I
b. Tape measure (if distance measurement is not part of portable photometer)
c. Aircraft power source

5.3 Anticollision Light Intensity Requirements:

Obtain the intensity that the strobe light is required to meet in the horizontal plane and the total horizontal angle over which the light is required to produce this intensity (the horizontal field of coverage of the light).

5.4 Safety Considerations:

Ensure that all safety considerations have been met, as discussed in 1.5. The potential hazards of the strobe light system include: high temperatures, high voltage, pressurized components, and intense light. Follow all warnings and cautions contained in the applicable aircraft maintenance manuals, component maintenance manuals, and test equipment manufacturer manuals.

5.5 Test Preparation:

5.5.1 Inspect the area around the light to be tested to make sure that ambient light and reflections off nearby surfaces will not adversely affect the measurement. Follow recommendations by the test equipment manufacturer regarding environmental considerations.

5.5.2 Confirm that the line of sight between the strobe light to be tested and the photometer is free from obstructions.

5.5.3 Inspect the general conditions of each strobe light to be tested. The exterior of the lens should be clean. Fingerprints or other contamination on the lens can adversely affect the measurement.

5.5.4 Inspect the photometer for proper operation. Verify that all the optical elements of the photometer are clean and free from fingerprints. Fingerprints and other contamination can adversely affect the measurement.

5.5.5 Verify that the calibration of the photometer is current.

5.6 Intensity Measurement Procedure:

5.6.1 Locate the portable photometer at the same elevation as the strobe light, within the horizontal field of coverage of the strobe light, at the distance recommended by the photometer manufacturer. A minimum distance of 2.4 m is recommended. A discussion of measurement distance is given in 2.2.3.

5.6.2 Apply power to the strobe light.

5.6.3 Individual flashes from strobe lights can vary in intensity. Measure the effective intensity for a sample of flashes in a fixed orientation until a representative measurement is made. It is recommended that the average of 8 or more flashes be made. The intensity data should be reported in candelas (effective intensity) in order to compare it to 14 Code of Federal Regulations requirements (see 2.2.4).

5.6.4 If the strobe light has a red glass lens, avoid allowing the lens to get hot during the measurement, as this will adversely affect the data. It is recommended that the intensity be measured with the lens as close to ambient temperature as possible. A lens temperature of 25 °C ± 3 °C is recommended.

This concludes the field measurement procedure.

PREPARED BY SAE COMMITTEE A-20, AIRCRAFT LIGHTING

APPENDIX A
LABORATORY PHOTOMETER REQUIREMENTS

A calibrated photometer, as described below, is the type recommended to measure (xenon) strobe anticollision lights.

A.1 PHOTOMETER HEAD:

A.1.1 Detector:

Silicon photodiodes are generally most suitable due to their linearity over a wide dynamic range (≥7 decades), fast response and long-term stability. Selenium cells shall not be used due to their instability and non-linearity.

A.1.2 Photopic Filter:

The photopic filter is used to shape the spectral response of the photometer to simulate the CIE $V(\lambda)$ photopic function. The spectral response shall be determined with all optical components that will be used for the flash measurements in place.

A.1.3 Spectral Responsivity:

The photometer optical system, including the detector, filter(s) and other optical components, shall closely match the CIE $V(\lambda)$ function between 380 and 780 nm. The spectral mismatch can be evaluated by calculating the f_1' value as defined in the CIE Publication No. 69. For laboratory standard photometers, f_1' shall be less than or equal to 3.0%. Special attention should be paid to match the responsivity curve in the red region which is critical for red anticollision light measurements.

A.1.4 Calibration:

The photometer shall be calibrated at a calibration cycle that assures the long-term drift of the photometer to be within 1% between recalibrations. The photometer shall be calibrated for response in lux·second (lx·s) against the NIST flashing light photometric scale or laboratory standard traceable to the NIST flashing light standards. If the photometer is designed to calculate and display candelas based on a specified test distance, appropriate conversions must be calculated and used. The calibration chain shall not exceed one intermediate step between the photometer being calibrated and the NIST standard. The photometer system shall be calibrated for measurement of both white xenon strobe and red xenon strobe lights.

A.1.5 Measurement Geometry:

The photometer shall be equipped to measure integrated illuminance in lux·s or to process the integrated illuminance to display candelas (based on test distance) as described in I.1.4. This is normally achieved by using a diffuser or a limiting aperture as the input optics of the photometer. The front surface of the diffuser or the aperture will be the reference plane of the photometer. This reference plane is used when measuring the distance from the photometer to the strobe source.

If the detector/filter combination is used without a diffuser or aperture, the reference plane shall be considered to be the detector plane and shall be clearly marked on the photometer.

A.1.6 Angular Response:

It is desirable that the photometer head be equipped with a hood or have a limited angular field of view so that any stray light reflections are shielded from the detector. If a cosine-corrected photometer head (with no hood) is to be used, great care must be taken to avoid ambient reflections.

A.2 AMPLIFIER REQUIREMENTS:

A.2.1 Pulse Response:

The detector/amplifier combination should be able to respond to optical energy pulses with a rise time of more than 1 µs, and a pulse duration less than 10 ms.

A.2.2 Repetition Rate:

The detector/amplifier combination should be ready to respond to the next reading or ignore subsequent flashes occurring more than 600 ms after the previous flash. This could be accomplished automatically or manually by intervention after a given number of flashes.

A.2.3 Range:

The measurement system must be able to handle charges produced by the optical detector over the range for which it is designed. A range of 5 to 10,000 cd is recommended for maximum versatility. Note that different test distances may be required to cover this range. Narrower limits of coverage may be acceptable for some applications.

A.2.4 Thermal:

The system must be able to operate within laboratory temperature specifications outlined in C.2.1. The range of operating temperature must be included in the determination of uncertainty.

A.2.5 Background Rejection:

The laboratory tests should be conducted in a darkened laboratory. Darkening the laboratory is optional if the photometric system is able to subtract the effect of ambient light, and display only the flash component. This subtraction capability should be effective for the entire integrated interval between flashes.

A.2.6 Signal Processing:

Signal processing may be analog or digital with a user readout resolution equal to or better than 0.5% throughout its measurement range.

A.2.7 EMI:

Electromagnetic interference caused by electrical radiation from the flash lamp or flash power supply should produce a negligible result in the final readout. This can be checked by blocking the detector with an opaque, non-metallic material to measure the EMI component separately. The system shall be shielded from broadcast sources of radio frequency energy.

A.2.8 Averaging:

The system must be capable of either computing the average of, or integrating, 8 or more flashes.

A.3 DESIGN CONSIDERATIONS:

Choice of electronics is optional; however, power supply regulation, short circuit protection, and overload protection are to be incorporated in the design. In addition, Electrical Static Discharge (ESD) susceptibility to any of the input or output connector pins should conform to the prevailing standards or requirements.

A.4 LINEARITY OF PHOTOMETER SYSTEMS:

The photometer system, consisting of the photometer head and amplifier, shall be linear to within ±2% throughout its entire measurement range which is recommended to cover 5 to 10,000 cd. Note that more than one test distance may be required to cover this range. Narrower limits may be acceptable for some applications. The linearity can be checked using a calibrated neutral density filter (e.g., 10% transmittance) and a white xenon strobe light. The photometer reading should be reduced by the same percentage as the transmittance of the filter. If the reading does not decrease by the correct amount, saturation is generally the cause. For highest accuracy of this linearity measurement, an additional photometer system can be used to monitor and correct for the variations of intensity between flashes. The photometer response shall also be consistent to within ±2% for strobe light sources having a pulse duration ranging from 0.1 to 10 ms.

APPENDIX B
GONIOMETER EQUIPMENT

B.1 GONIOMETER REQUIREMENTS:

B.1.1 Description:

A goniometer (Figure B1) is a mechanical device which is designed to provide precise angular positioning of the unit-under-test (UUT) about two perpendicular rotational axes. The goniometer will be used to position the UUT such that the vertical and horizontal intensity distributions can be measured.

B.1.2 Angular Requirements:

The goniometer is configured as azimuth rotation over elevation (Type A) as shown in Figure B1. The azimuth axis of the goniometer must be able to rotate one complete 360° revolution. The elevation axis must be able to rotate ±90°. More information can be found in “The Illuminating Engineering Society Handbook”.

B.1.3 Angular Repeatability:

The angular repeatability of each axis of the goniometer must be within ±0.1° at the mounting plate.

B.1.4 Angular Accuracy:

The angular accuracy of each axis of the goniometer must be within ±0.1° at the mounting plate.

B.1.5 Orthogonality:

The two axis of the goniometer must be orthogonal to within ±0.1°.

B.1.6 Structural Rigidity/Holding Torque:

Each axis of the goniometer must be rigid and have sufficient holding torque to maintain the specified angle within ±0.1° in any orientation.

B.2 GONIOMETER MOUNTING FIXTURE:

B.2.1 Description:

The unit-under-test (UUT) shall be mounted on the goniometer using a fixture or mounting plate. The fixture should hold the UUT rigidly in place, and have adequate clearances to allow rotation of the UUT over the specified horizontal and vertical fields of coverage.

B.2.2 UUT Location and Alignment:

The location/angular orientation of the UUT on the mounting plate should be accomplished using alignment pins, fixed edges or other means to insure that the UUT can be removed and reinstalled in the same location/orientation. The alignment uncertainty between the UUT and mounting plate shall be less than ±1.0° in each axis.

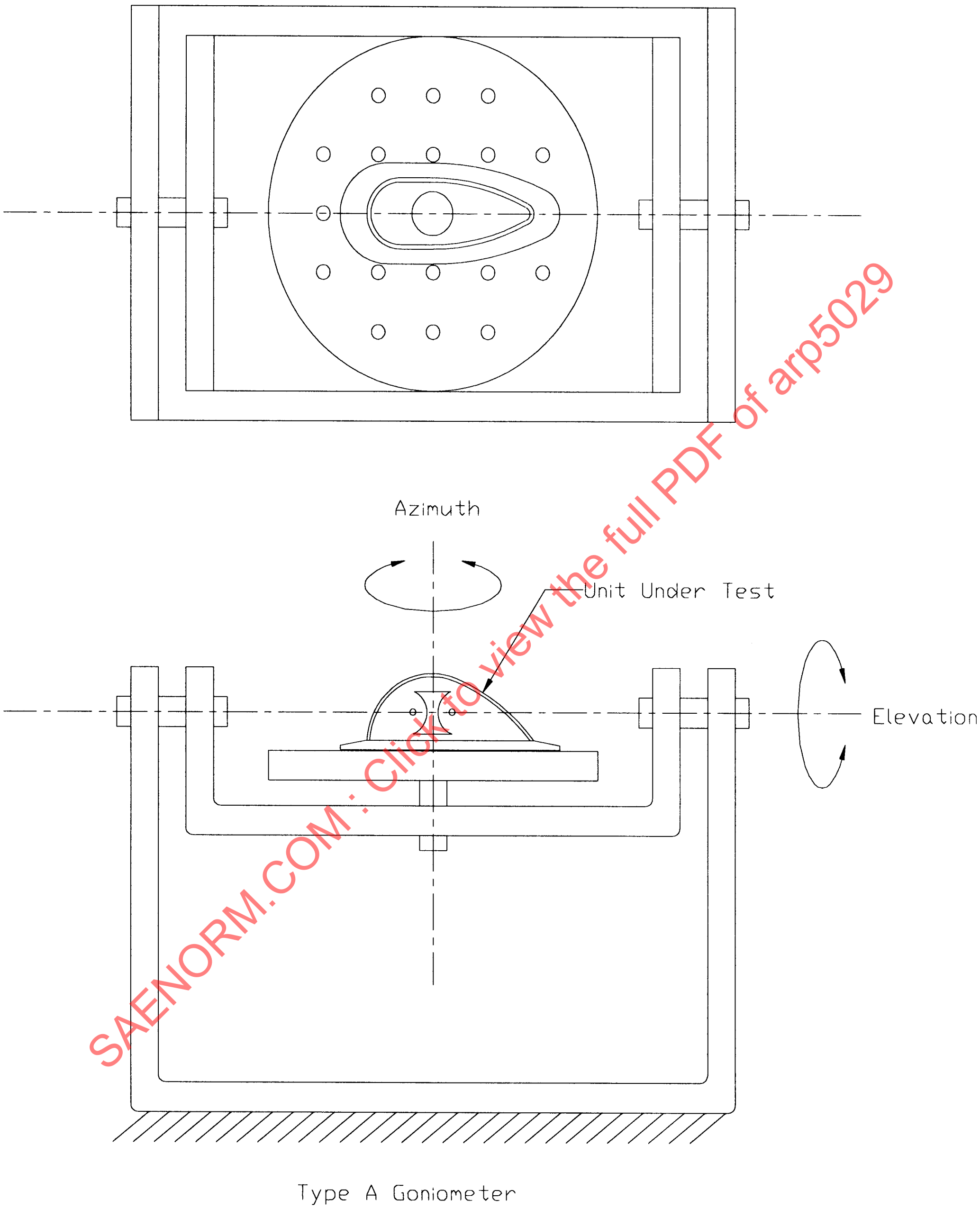

FIGURE B1 - Type A Goniometer

APPENDIX C
PHOTOMETRIC LABORATORY

C.1 LABORATORY LAYOUT:

The photometric laboratory generally consists of a darkened tunnel with a goniometer located at one end, and a photometer at the other end. One example of a photometric tunnel is shown in Figure C1. Baffles are placed at various locations along the line of sight between the goniometer and photometer to prevent stray light from reaching the photometer.

C.1.1 Wall/Floor Coatings:

The walls and floor coatings of the photometric laboratory shall be non-reflective (flat black or equivalent) to reduce light from reflecting off these surfaces and reaching the photometer.

C.1.2 Baffles:

Each baffle includes an aperture to allow direct light from the UUT to pass through to the photometer. The edge of the baffle where the aperture is cut should be reduced to a sharp edge in order to reflect a minimum amount of light. The baffle should not block any portion of the direct light from the UUT to the photometer. An adequate number of baffles should be used to minimize the amount of reflected light reaching the detector head.

C.2 AMBIENT CONDITIONS:

C.2.1 Temperature and Humidity:

The laboratory temperature shall be 25 °C ± 5 °C, with relative humidity of 80% or less.

C.2.2 Temperature Gradients:

Large temperature gradients and turbulent air can cause fluctuations in luminous intensity measurements taken over long distances. For this reason, the air in the photometric lab should be of uniform temperature. Extreme temperature differences in any of the tunnel surfaces should be avoided.

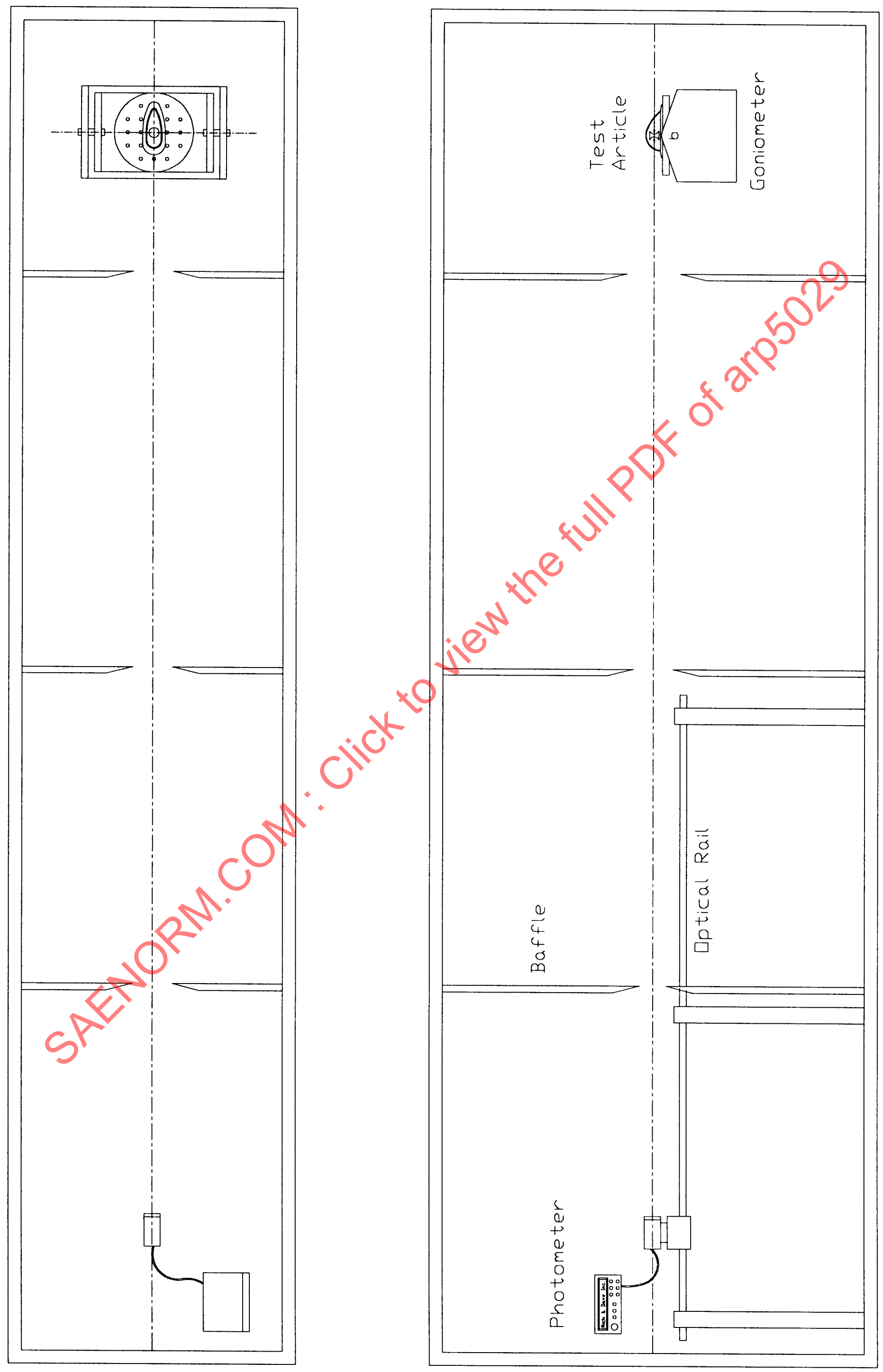

FIGURE C1 - Typical Photometric Tunnel

APPENDIX D
LABORATORY POWER REQUIREMENTS

D.1 LABORATORY POWER REQUIREMENTS:

D.1.1 Scope:

This appendix applies to 115 V AC (rms) 400 Hz and 28 V DC power supplies, for testing anticollision lights in the laboratory.

D.2 115 V AC SYSTEMS:

D.2.1 Voltage and Frequency Characteristics:

The voltage and frequency characteristics of the 115 V AC supply are shown in Table D1.

TABLE D1 - Electronic Power Supply Characteristics

Definition	Voltage V AC (rms)	Frequency, Hz
Maximum	117.3	404
Nominal	115.0	400
Minimum	112.7	396

D.2.2 Grounding:

A three-wire AC power system shall be used. The third wire (ground) shall be attached to the chassis of the power supply, unless otherwise indicated by the manufacturer. This chassis ground shall be a low-impedance path to earth ground.

D.2.3 AC Current Limiting:

The lab power supply shall be connected to the UUT through a current-limiting device such as a circuit breaker or fuse. The power supply and breaker shall be capable of supplying sufficient current to power the UUT, including inrush current.

D.2.4 Transformers:

Isolation or autotransformers may be used in accordance with manufacturer's specifications and the specifications herein.

D.3 DC POWER SUPPLIES:

D.3.1 Electrical Characteristics:

The DC power supply shall have the characteristics specified in Table D2 and Figure D1:

TABLE D2 - DC Power Supply Requirements

Definition	Voltage, DC
Maximum	28.8
Nominal	28.0
Minimum	27.4

D.3.2 Voltage and Frequency Characteristics of DC Ripple Voltage:

Figure D1 shows the maximum allowable ripple voltage over the frequency range of 0.01 to 1000 kHz.

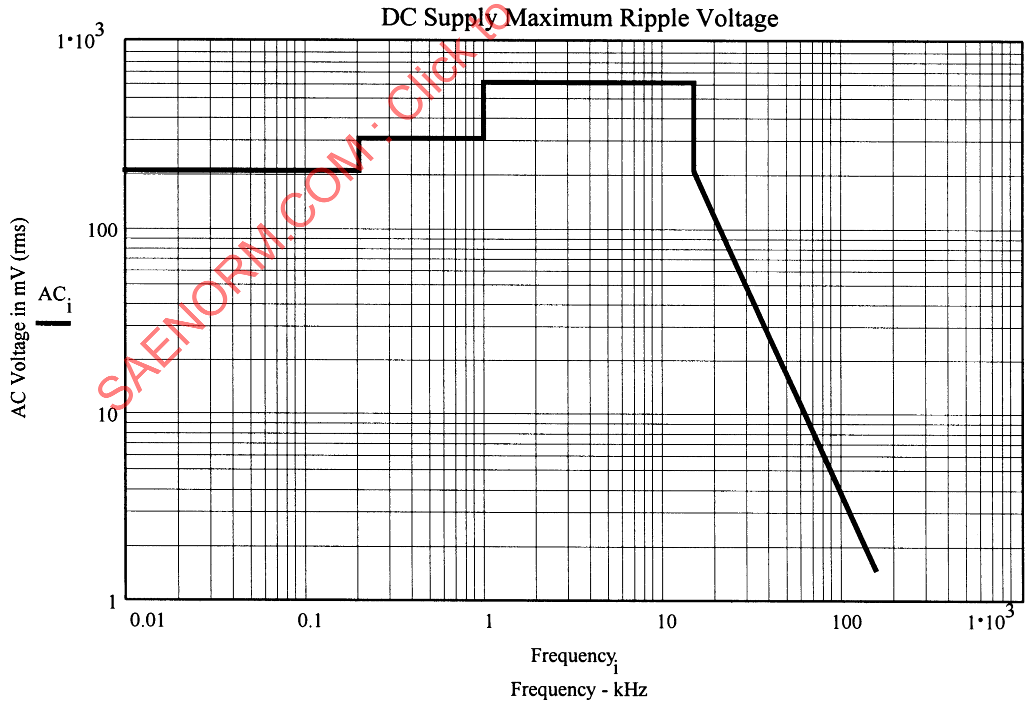

FIGURE D1 - DC Supply Maximum Ripple Voltage

APPENDIX E
CHROMATICITY AND TRANSMISSION PROPERTIES OF SHARP-CUT RED FILTER GLASS AT ELEVATED TEMPERATURES

David A. Dutt and David Fox
Kopp Glass, Inc., 2108 Palmer Street, Pittsburgh, PA 15218

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The use of colored signal glasses in traffic signaling and warning applications is common both domestically and internationally. In many applications the glass temperature is elevated due to external conditions or operation with a high power illuminant. The change in chromaticity of colored signal glass at elevated temperatures is important to understand in order to accurately design a lighting system and to predict the optical performance of the unit. All colored glass filters change color, to some degree, with increasing temperature; however, this monograph will concentrate on the changes evident in sharp-cut red filter glass produced by changes in glass temperature. The scope of this paper is to quantitatively describe the changes in chromaticity and photopic transmission induced by elevated glass temperatures and to relate this information to the considerations of anticollision lights currently undertaken by this task group.

Chromaticity and Transmission Properties

The color and transmission properties of sharp-cut red filter glasses coupled with CIE illuminant A (2856 K incandescent source) were described in 1955 by Leberknight and Stone (see Reference 1). The visible (photopic) transmission and chromaticity coordinates of six sharp-cut red filters were determined as functions of temperature in the range 78 to 500 °F. A sample of the data collected by Leberknight and Stone is shown in Figure E1. The photopic transmission of a red filter glass decreases dramatically as the glass temperature is increased. The transmission profiles plotted in Figure E1 indicate why such a change in photopic transmission is observed at elevated temperatures. As the filter temperature is increased, the entire transmission curve is shifted to longer wavelengths and the maximum transmission is decreased. The shift of the curve to longer wavelengths is visibly noticeable as a change to a deeper red color and a decrease in the amount of light transmitted through the glass. In terms of the 1931 CIE standard observer, the shift in transmission profiles will decrease the photopic transmission and decrease the y chromaticity value. Changes in the transmission profile induced by an increased filter temperature are reversible. As long as the filter temperature remains well below the glass strain temperature, the original room temperature transmission profile is restored simply by cooling the glass to room temperature again.

The photopic transmission versus absolute glass temperature data for the six red filters examined by Leberknight and Stone is summarized in Figure E2. The upper three photopic transmission curves have a nearly linear dependence with temperature; however, the lower three curves show signs of curvature at higher temperatures. All the photopic transmission curves monotonically approach zero at elevated temperatures. Although the changes in photopic transmission are not strictly linear functions of temperature, the family of curves shown in Figure E2 are useful in predicting the behavior of red filter glasses at elevated temperature. One small annoyance with the six discreet curves in Figure E2 is that interpolation may be necessary for filters having photopic transmission values which fall between two curves.

By changing the x-axis of Figure E2 from an absolute temperature to a temperature difference, a single photopic transmission versus temperature difference curve can be constructed to remove the annoyance of interpolation. Beginning with the 56.5% filter curve in Figure E2, the 45.7% filter curve can be shined upwards 214 °F to become appended to the 56.5% filter curve. As such, the two curves become one curve with the x-axis representing a temperature difference rather than an absolute temperature. In a similar fashion the remaining four curves can be shifted in temperature until one united curve is obtained. Using the data from Leberknight and Stone (see Reference 1), a curve of this type is shown in Figure E3. The solid squares represent the data from Reference 1 and the solid line represents a least-squares fit to an arbitrary mathematical function.

The data in Figure E3 can now be used to find the shift in photopic transmission of any sharp-cut filter with temperature. If the initial photopic transmission and temperature of the filter are known, then the photopic transmission of the filter at some elevated temperature can be determined from the graph. As an example, suppose a filter at 70 °F has a photopic transmission of 50% and suppose the filter temperature during operation will be 270 °F. By shifting upward 200 °F on the curve from the 50% transmission point, the photopic transmission at 270 °F can be estimated to be 39.5%. Because of the reversible nature of the filter transmission profiles described earlier, the data in Figure E3 can also be used to calculate photopic transmission increases for filters operating at reduced temperatures.

The data in Figure E3 have proven useful to engineers needing to determine the proper filter transmission properties for particular applications involving incandescent illuminants. However, the natural property of red filter glass with an incandescent source illustrated in Figure E3 also applies to red filter glass coupled with other illuminants, such as xenon flash lamps. By using the measured spectral output of a xenon flash lamp and a representative sharp-cut transmission profile, a photopic transmission versus temperature difference curve can be calculated. The output of a xenon flash lamp was measured using an EG&G model spectroradiometer. The measured spectral intensity data compares well with xenon flash lamp data published in the IES Reference Guide 2. A representative sharp-cut red filter glass transmission profile was obtained from a Kopp code 6150 filter glass of 0.200 in thickness and was measured using a Unicam UV4 spectrophotometer. Chromaticity and photopic transmission values, based on the CIE 1931 standard observer, were calculated for a standard C1E A (2856 K) and the xenon flash illuminant using a commercial spreadsheet program. Changes in filter temperature were simulated by shifting the entire transmission profile by fixed wavelength intervals. In order to plot the resulting data on a temperature difference axis, the data were connected with the data in Figure E3 by matching the photopic transmission values of the calculated and experimentally measured CIE A data and plotting the xenon flash lamp value at the same relative temperature location. The resulting data is shown in Figure E4.

There are two characteristics of the data shown in Figure E4. As is the case for the curves in Figure E3, the photopic transmission of red filter glass coupled with a xenon flash lamp monotonically approaches zero with increasing temperature difference. The shape of the curve is also nonlinear. Secondly, the photopic transmission of the red glass coupled with a xenon flash lamp is lower than that for the same filter coupled with an incandescent source (CIE A 2856 K). The spectral intensity of the CIE A source has a maximum in the red spectral region while the spectral intensity of a xenon flash lamp has a maximum in the blue spectral region. Since the photopic transmission is the ratio of light transmitted with the filter to light transmitted without the filter, and the CIE A source emits most of its light in the red spectral region, the red glass filter coupled with the CIE A source will have the highest photopic transmission.

Although the data in Figure E4 is useful in a general application, the data for the xenon flash lamp can be extended to provide further insight into the nature of chromaticity and photopic transmission changes with the operation of certain anticollision lights. The solid line in Figure E5 shows the y-value versus photopic transmission for sharp-cut red filter glass coupled with a xenon flash lamp. The y-value data was determined using the same theoretical calculation previously described. The individual data points plotted on the curve are from experimental measurements of a red anticollision lens with a xenon flash lamp. The agreement between the experimental data and the theoretical curve is good, but the calculated curve gives a slightly more conservative estimate of the photopic transmission. For an anticollision light using a xenon flash lamp, the maximum photopic transmission which can be predicted for a chromaticity of y = 0.350 is 20.8%. This estimate assumes room temperature (70 °F) operation.

The decrease in photopic transmission due to operation at elevated temperature can now be estimated using data plotted in Figure E6. The solid curve is data from Figure E4 expanded to cover the aviation red chromaticity range. The point labeled RT is room temperature (70 °F) experimental data measured along one axis of a red anticollision lens. The point labeled END is experimental data measured along the same axis for the same anticollision lens after continuous operation for 30 min. At a temperature of 133 °F the photopic transmission has decreased from 23.6% to 20.4%. As the experimental data show, the decrease in photopic transmission was well predicted using Figure E6. Therefore, the experimental data validate the use of the calculated photopic transmission versus temperature difference curve in practical applications.

Anticollision Light Considerations

The temperature of an anticollision light lens is a complicating factor in determining the output of the entire lighting unit. The data shown in Figure E6 indicate that the output of a lens (as deluded by the photopic transmission) is strongly related to the temperature difference between the operating temperature and some reference temperature. Although it is possible to determine a scaling factor for calculating an effective output of a lens operating at an elevated temperature, the scaling factor can be confounded by variations in the transmission within a group of lenses and temperature distributions within a single operating lens.

Glass manufacturers require a working tolerance in order to economically produce lenses. The working tolerances account for variations in surface quality, internal color homogeneity and wall thickness. Generally the tolerance observed is at least 4 to 5%. From the example given above the maximum allowed photopic transmission for an anticollision lens, the working tolerance would generally be 20.8 to 16.8%. Tighter tolerances could be requested, but would result in lower yields and higher final cost.

The second complicating factor, and the most important, is the temperature variation realized in an operating lens of asymmetric geometry. In general, the temperature of a lens will be inversely proportional to its distance from the light source. The closer the glass is to the source, the higher the glass temperature will be. The external temperature profile measured for an elliptically shaped anticollision light with a xenon flash lamp is diagrammed in Figure E7. The lens was operated continuously in a room temperature (72 °F) laboratory for 30 min. Since the lamp was located in the center of the ellipse, the temperatures measured along the minor axis are higher than those measured along the major axis. The maximum temperature difference is 56 °F (31 °C). From the data in Figure E6, a temperature distribution of this magnitude will produce a significant variation in photopic transmission, and therefore output, around a single lens.

Based on a glass manufacturing background, the optimum specification for photometric compliance of red anticollision lights would be developed to be met at operating temperature. The optimum specification would be developed using the glass property data as a background to determine the proper operating photometric levels. In this way any scaling problems associated with manufacturing tolerances and temperature distributions could be avoided. Also, the measurement process would be simplified and more easily transferred to practical measurements for fixtures mounted on the aircraft. Some details of the operating temperature specification will need to be determined or assumed, but our opinion is that it is much easier and less time consuming to rewrite the specification for testing conditions once than to scale the test data from each laboratory measurement to a defined reference temperature. This will be most evident when the testing procedure is transferred to practical airfield or in situ measurements.

References:

1. C.E. Leberknight and G.E. Stone, "Color and transmission properties of sharp cut-off red glass filters at elevated temperatures."

2. Lighting Handbook. Eighth Edition, ed. Mark S. Rhea (Illuminating Engineering Society of North America, New York, 1993), p. 234.

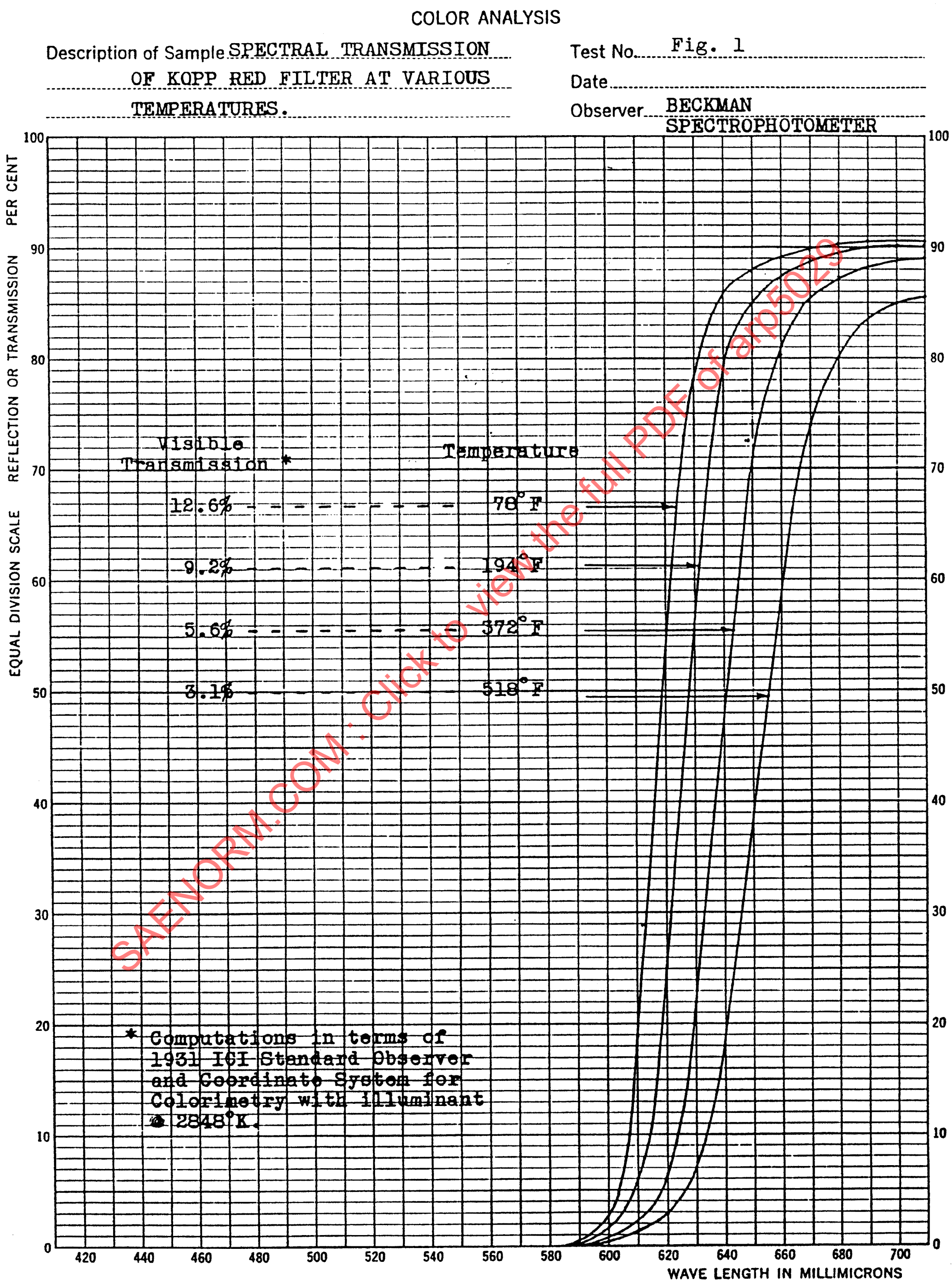

FIGURE E1 - Spectral Transmission of KOPP Red Filter at Various Temperatures

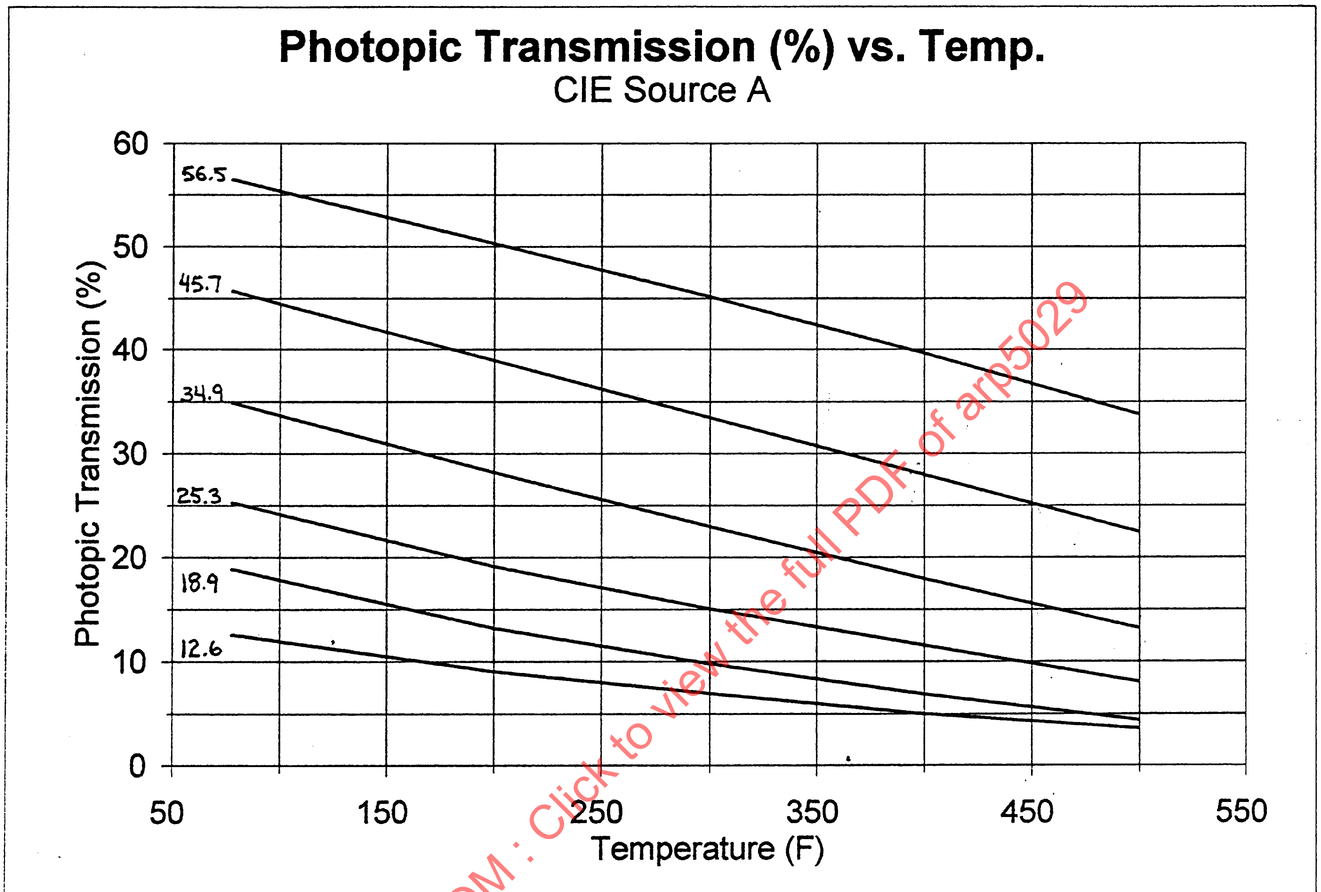

FIGURE E2 - Photopic Transmission (%) versus Temperature, CIE Source A

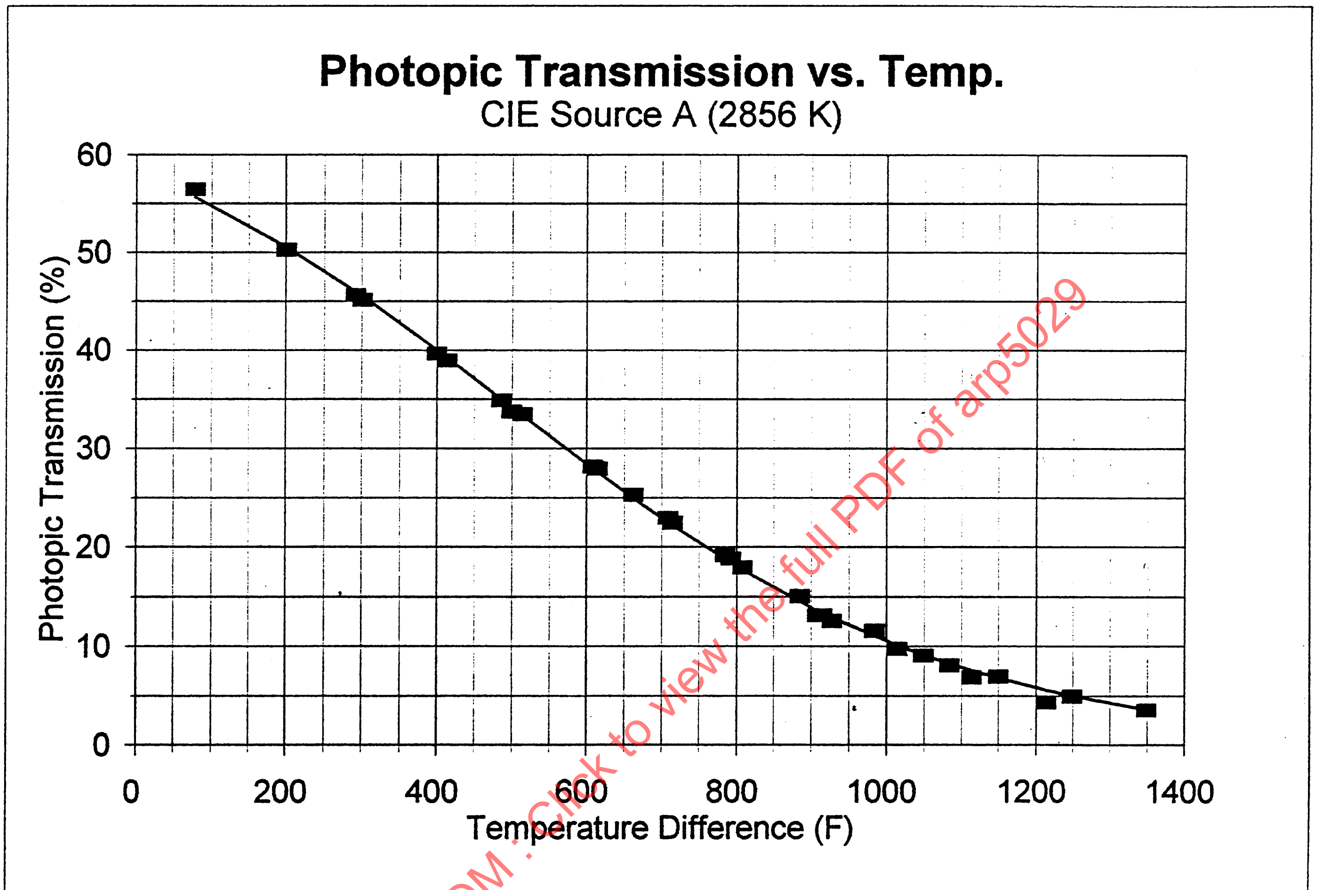

FIGURE E3 - Photopic Transmission (%) versus Temperature Difference, CIE Source A

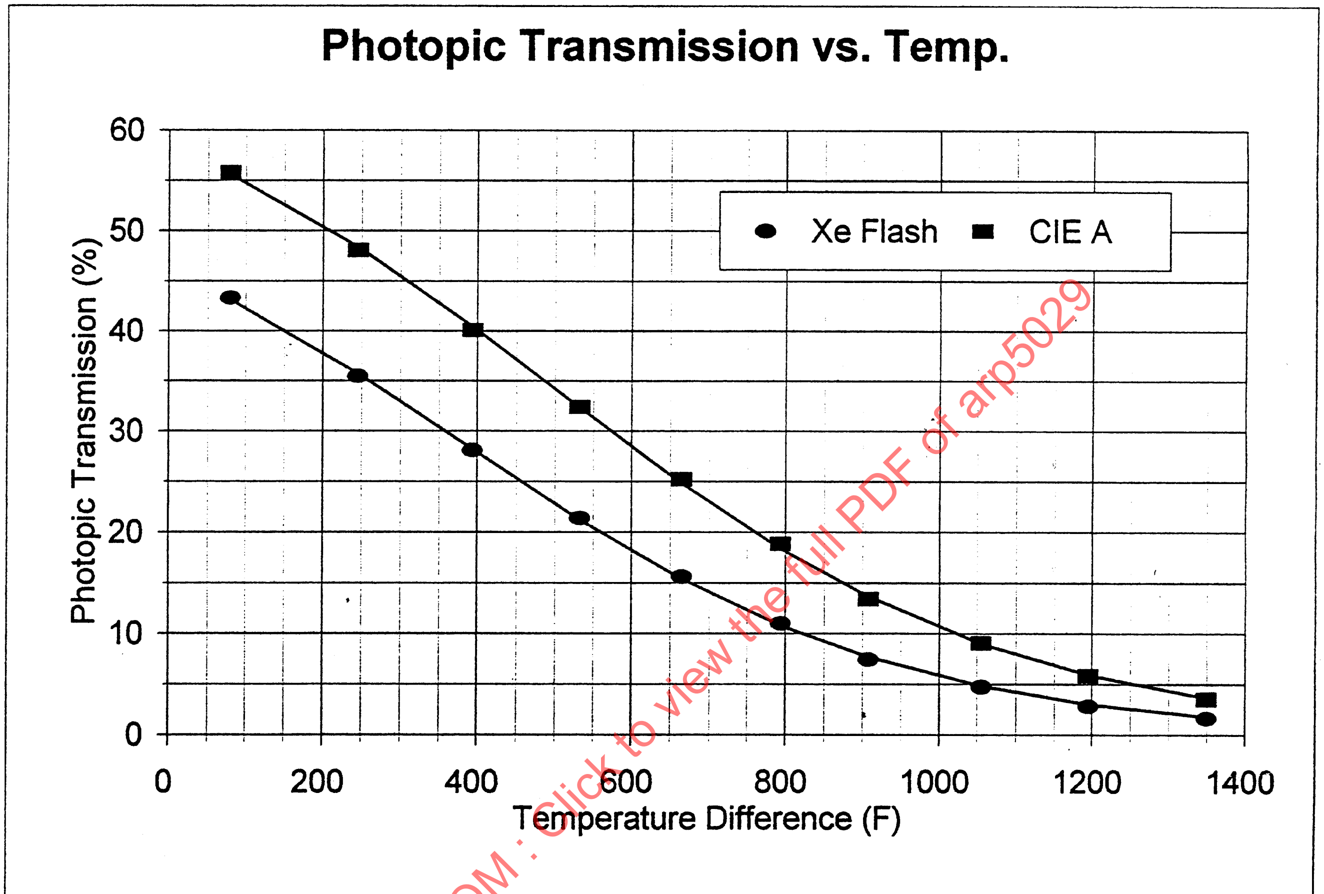

FIGURE E4 - Photopic Transmission (%) versus Temperature Difference, CIE Source A and Xenon Flash

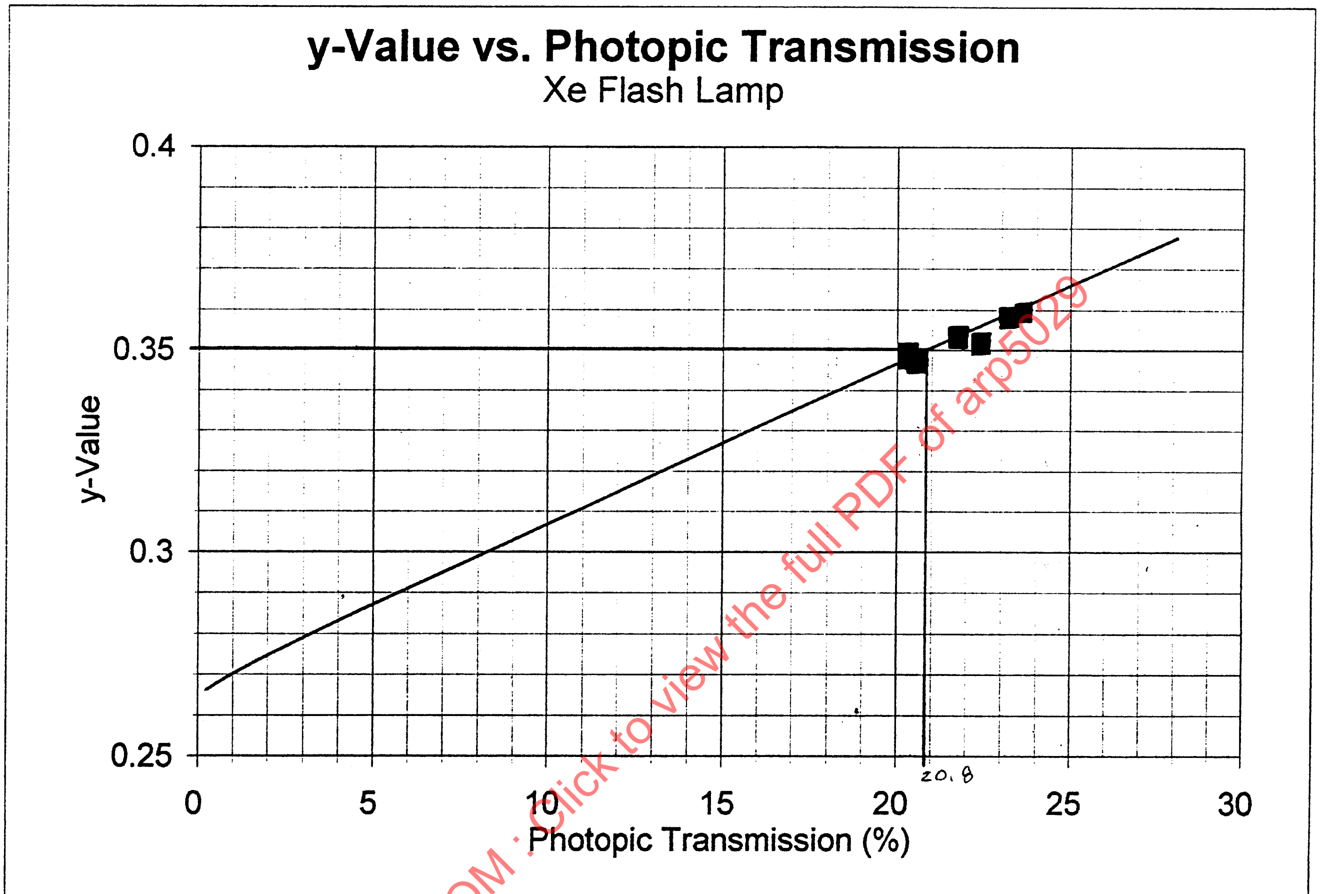

FIGURE E5 - y Value versus Photopic Transmission for Xenon Flash Lamp

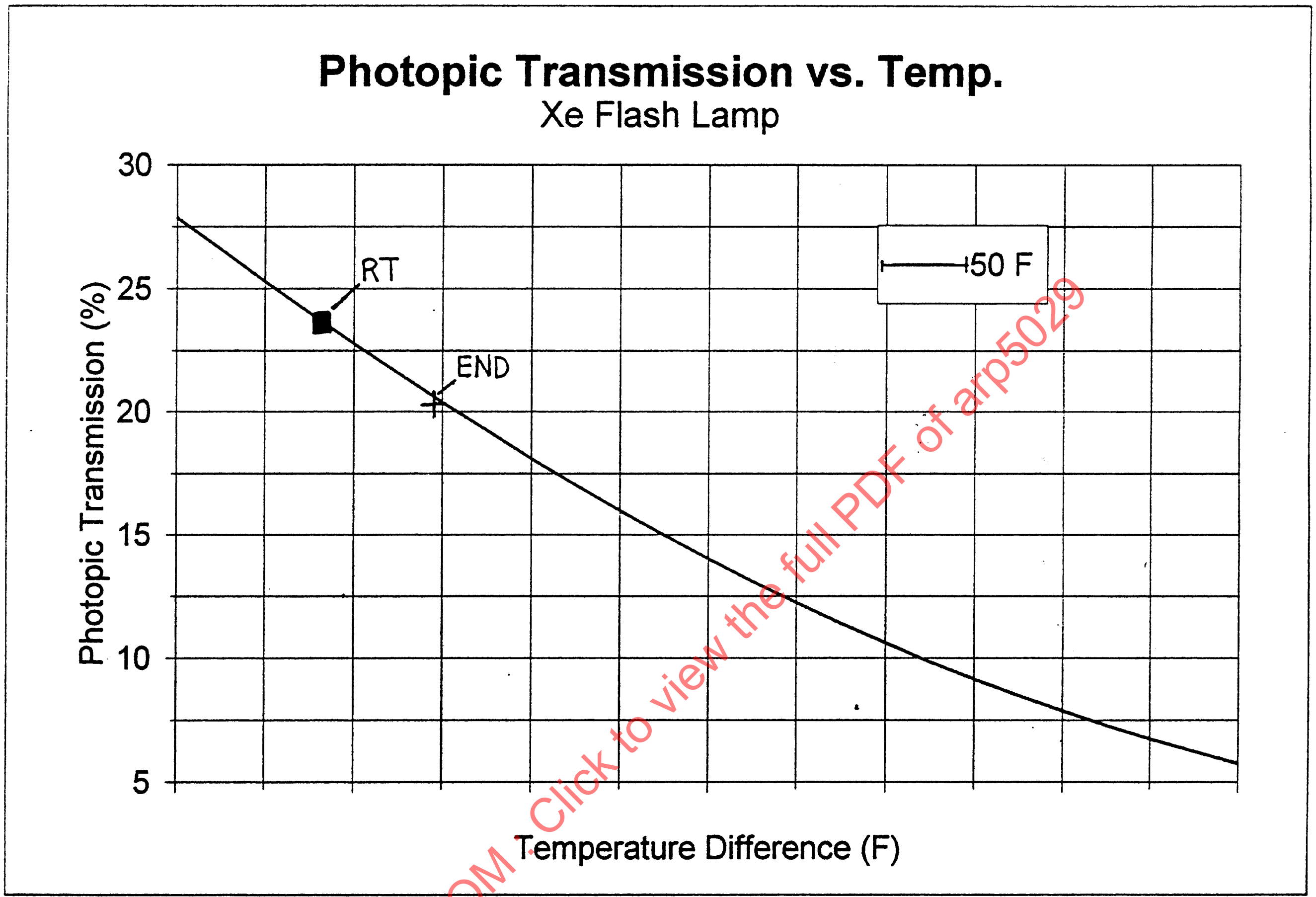

FIGURE E6 - Photopic Transmission versus Temperature for Xenon Flash Lamp

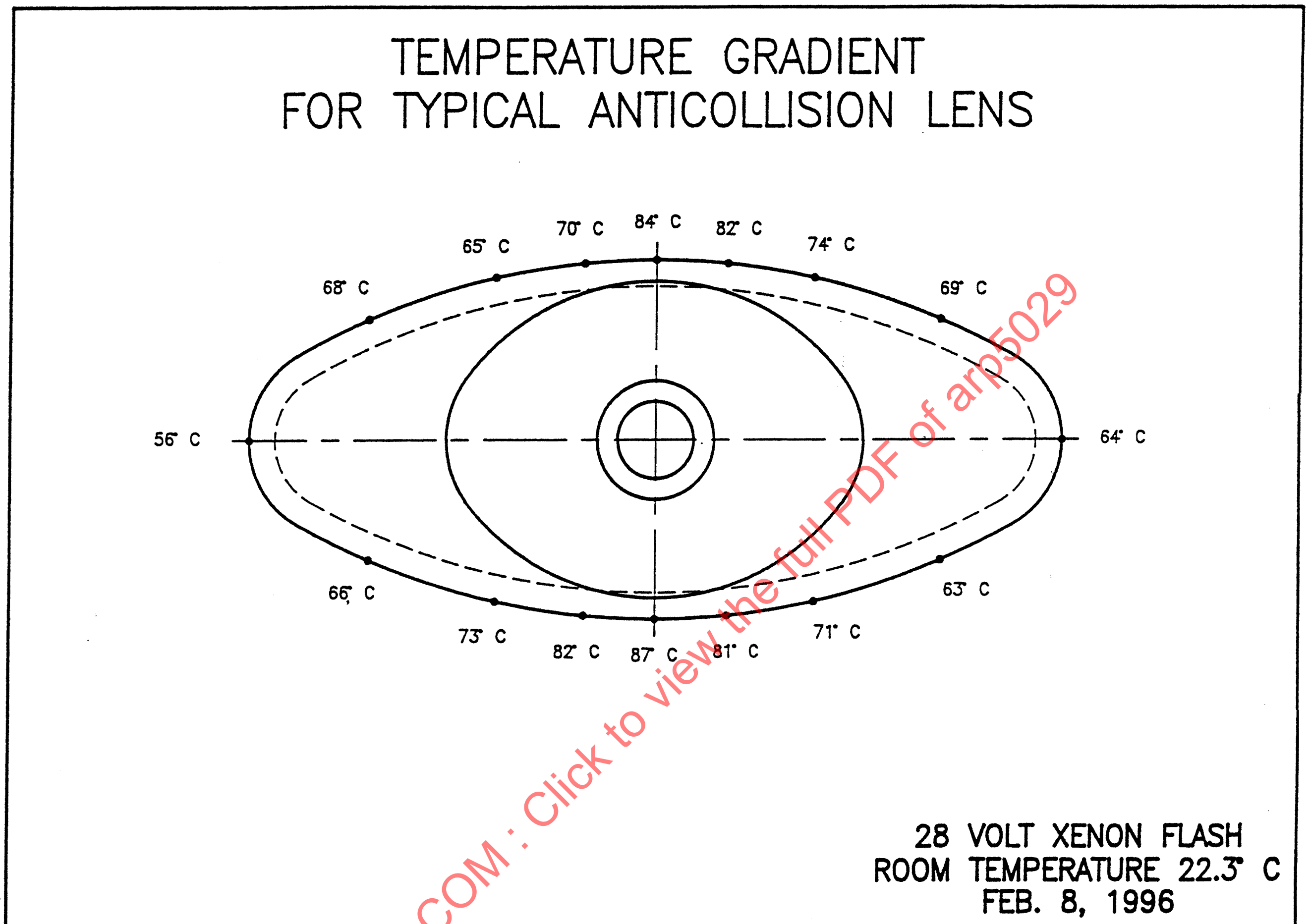

FIGURE E7 - Temperature Gradient for Typical Anticollision Light Lens