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SURFACE VEHICLE INFORMATION REPORT

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Photometry Laboratory Accuracy Guidelines

1. ***Scope*****—**The purpose of this SAE Information Report is to list and explain major equipment, instrumentation, and procedure variables which can affect inter-laboratory differences and repeatability of photometric measurements of various lighting devices listed in SAE Technical Reports. The accuracy guidelines listed in the report are for the purpose of controlling variables that are not a direct function of the lighting device being measured. The control of these individual variables is necessary to control the overall accuracy of photometric measurements. These accuracy guidelines apply to the measurement of the luminous intensities and reflected intensities of devices at the specified geometrically distributed test points and areas. These guidelines do not apply to photometric equipment used to measure license plate lamps.

2. ***References***

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J575—Test Methods and Equipment for Lighting Devices and Components for Use on Vehicles Less than 2032 mm in Overall Width
SAE J1889—LED Lighting Devices
SAE J2009—Discharge Forward Lighting System
SAE J2039—Tests for Lighting Devices, Reflective Devices, and Components Used on Vehicles 2032 mm or More in Overall Width
SAE HS-34—Section IV. ASTM Reports—ASTM E 308-85$^{\varepsilon 2}$

2.1.2 BIBLIOGRAPHY AND OTHER REFERENCES

I.E.S. Lighting Handbook, Sixth Edition, 1982, Illuminating Engineering Society
Journal of I.E.S., October 1971—Practical Guide to Photometry
Illuminating Engineering, March and April, 1955—I.E.S. General Guide to Photometry

3. Accuracy Guidelines and Limitations—The accuracy limit guidelines suggested in this report are intended as a reference guide to photometric laboratories of various accuracy parameters to help maintain correlation of photometric measurements between laboratories. The guidelines are not intended as specifications to be applied to all photometric equipment, test fixtures, and measurements. Actual photometric performance of various functions and the designs of lighting devices and test fixtures may vary considerably. The use of the guideline information in this report as rigid specifications applied to all types of photometric measurements would be impractical and in some cases would result in equipment with unnecessary accuracy restrictions. These guidelines should be used to aid laboratory personnel in their awareness of the major variables and to provide information on equipment, instrumentation, and procedure accuracies which may affect overall laboratory differences and repeatability.

3.1 Accuracy Guidelines for Mechanical Positioning

3.1.1 DEVICE POSITIONING—The lighting device to be photometered should be mounted on a rigid test fixture in a position corresponding to the design nominal operating position of the device on the vehicle. For devices designed for a specific vehicle, the designed nominal position should be determined from the vehicle manufacturer's specifications. For devices designed for multiple vehicle use, the designed nominal position should be determined from the device manufacturer's specifications or instructions. Multiple-use devices should be tested in each position in which they are designed for use, or the equivalent, by mathematically translating axis angles and test points.

One of the factors which can significantly affect the device mounting attitude is the torque used to fasten the device to the test stand. This is particularly important when the device floats on a compression-type gasket. Mounting torques should be specified for all devices, and these torques should be sufficient to compress the specified gaskets so that “floating” of parts does not occur unless certain parts are so designed as a means of absorbing shock and vibration.

3.1.2 TEST FIXTURE POSITIONING—Numerous factors affect the ability of the test fixture to position the test device in its designed nominal position. Some of these accuracy factors are the rigidity and flatness of the base, the rigidity of the test fixture structure, and the length of the machined alignment edge or the spacing between alignment pins. Each test fixture should be built from a manufacturer's test fixture design standard to minimize these errors. One suggested example of a test fixture design guide is shown in Appendix A. Other test fixture designs may be equally satisfactory (for example, specialized fixtures for sealed beam units) if they provide proper positioning accuracy.

3.1.3 POSITIONING TOLERANCE—Tolerance guidelines for positioning the device are listed as follows:

3.1.3.1 Lighting Devices Except Headlamp Units—The tolerance for positioning the device in the test fixture should be ±0.1 degree in each axis.

3.1.3.2 Headlamp Units—The positioning of headlamp units is generally more critical than other lighting devices. The tolerance for positioning of headlamp units in the test fixture should be ±0.05 degree in each axis.

3.2 Measurement of Spatial Distributions of Luminous Intensity—The photometric test point patterns specified in the SAE technical reports are based on measurement of luminous intensity as a function of angular position when using a Type A goniometer (as shown in Appendix B and recommended by SAE J575 and SAE J2039) to position the device with the configuration of horizontal rotation over elevation. The other goniometer configuration is elevation over horizontal rotation (Type B). The use of a Type B goniometer configuration may require the use of a conversion table as given in Appendix B. Methods other than a two-axis goniometer as described previously may be used. For example, a fixed test device with fixed photometer sensors mounted at every specified test point at some suitable distance, or other configurations of fixed and/or moveable sensors may be used. It should be noted that specified luminous intensity maximums or values between test points cannot be measured using fixed sensors with a fixed test device.

3.2.1 POSITIONER ACCURACY DETERMINATION—The accuracy of positioners or goniometers used to measure spatial distributions of luminous intensities can be determined by using a checking procedure such as outlined in Appendix C.

3.2.2 POSITIONER TOLERANCES—The repeatability of photometric measurements stated as a percent difference between laboratories when measuring the same device cannot be solely determined as a function of the accuracy of the Positioner system or goniometer. For example, a difference of 0.1 degree due to mounting/ Positioner accuracy will result in no difference between measurements (other factors being equal) if the light distribution is uniform and does not vary significantly with angle in the area of interest. On the other hand, if the area of interest has a high gradient (rate of change of luminous intensity and angle), one system may, for example, measure 500 cd and another system with a difference of 0.1 degree may measure 550 to 600 cd. The percent difference between the two measurements could then be 10 to 20% even with the small difference in orientation. This example demonstrates that it is not possible to state a specific accuracy for a photometric measurement system as a function of angle accuracy alone, as both the Positioner angular accuracy and the luminous intensity gradient are involved.

Two axis goniometer are available with an accuracy of ±0.05 degree with a resolution of ±0.01 degree. However, in most photometric measurements, a Positioner system accuracy deviation of ±0.1 degree with a resolution of ±0.03 degree is considered adequate (see 3.1.3.2.)

3.3 Power Supplies—Unless otherwise specified, a regulated DC power supply should be used for all photometric measurements. The following are suggested specifications for the DC power supply:

3.3.1 LINE REGULATION—±0.1%

3.3.2 RIPPLE AND NOISE—0.4% maximum

3.3.3 STABILITY—Any power supply that remains stable within ±0.1% during the photometric measurement period is satisfactory.

3.4 Voltage Measurements—A 4-1/2-digit digital voltmeter (DC) with a 10 megohm minimum impedance and with an accuracy of 0.05% of the reading is recommended for measurements up to at least 20 V. Voltage measurements should be taken as close to the device input terminations as practicable.

3.5 Current Measurements—A 4-1/2-digit digital voltmeter reading the output of a precision current shunt is recommended for measurements up to 100 W. The size of the shunt should be sufficient to prevent error due to excessive heat loading. The minimum accuracy of this system should be 0.09% of the value of the current being measured.

3.6 Accurate Rated Bulbs—Unless otherwise specified, accurate rated bulbs should be used for all photometric measurements. When applicable ratings are available, these bulbs should be rated at the current to produce the designed luminous flux (lumens) or mean spherical candela in the attitude in which they are intended to be used with respect to gravity (any attitude for vacuum bulbs). Yellow glass bulbs should also be rated for current to produce their designed luminous flux. Because there are several filament parameters in addition to those controlled in accurate rated bulbs such as coil length, pitch, diameter, and color temperature, some lighting devices may produce significantly different luminous intensity measurements with two different accurate rated bulbs, particularly lighting devices with exceptionally short focal lengths. The light source should be allowed sufficient warm-up period for the luminous flux to stabilize. Yellow glass bulbs should also have a sufficient warm-up period for any color change to stabilize.

3.6.1 NONREPLACEABLE LIGHT SOURCES—Devices employing LEDs or permanently sealed-in light sources should be operated at the voltage specified by the manufacturer and in the attitude they are intended to be used (any attitude for vacuum bulbs or LEDs). The appropriate comments noted in 3.5 should also be heeded. Additional information on testing LEDs is found in SAE J1889.

3.7 Sensor/Photometer System

3.7.1 COLOR RESPONSE—The spectral response of the photometer sensor system should be such that color corrections in the yellow color being tested are less than 2% between the yellow-green limit and the yellow-red limit. Likewise, the red correction should not exceed 3% from the red-yellow limit to medium red. One method to determine this color response requires a 2856 K (C.I.E. Illuminant A) standard lamp and a set of at least four glass color filters calibrated for transmittance at 2856 K. Suggested filters are shown in Table 1:

TABLE 1—SUGGESTED FILTERS

Color Region	Chromaticity Coordinate x	Chromaticity Coordinate y
SAE Yellow-Green Limit Area	0.56	0.44
SAE Yellow-Red Limit Area	0.61	0.39
SAE Red-Yellow Limit Area	0.67	0.33
Medium Red Area	0.69	0.31

In addition, blue filters can be used to check the blue response such as ones with 2856 K chromaticity coordinates of approximately x = 0.16, y = 0.13; and approximately x = 0.12, y = 0.30. Other methods for determinations of color response are acceptable. For example, a calibrated filter may be used whose color matches the color of the light emitted by the device(s) being measured. Special color response calibrations should be made when photometric measurements are made with light sources with high monochromatic ouput, such as LEDs, or on devices which have colors in spectral areas different than the color regions calibrated.

3.7.2 HIGH INTENSITY DISCHARGE SOURCES—High intensity discharge sources, or HID devices, can be measured as white light sources on systems employing proper photopic correction. (Reference IES Lighting Handbook and E 308-85$^{\varepsilon 2}$ in Section IV of HS-34.) It should be noted that rotational movement of HID devices in the vertical plane by a goniometer can cause change in light output distribution and intensity of the light emitted from the discharge source. This change is negligible within a tilt range of 10 degrees up or down from the nominal design position. Photometric measurement accuracy beyond this range may be affected. In cases where extreme up/down angles must be measured (such as for headlight glare) alternative techniques may be used. It is recommended that any variations in measurement method be noted along with the photometric data obtained. Additional information on testing HID sources is found in SAE J2009.

3.7.3 RANGE LINEARITY—The linearity of the sensor/photometer system should be verified at least over the range of the luminous intensities used for the specific type of device being measured. A deviation from linear response over the range from the calibration level to the extreme luminous intensity value measured should not exceed 2.5%. Measurements made over a narrow range of intensities should have a smaller deviation from linear response.

3.7.4 PHOTOMETER SENSOR APERTURE SIZE—Since photometric measurements are allowed at various distances with different lighting device functions, the area of the photosensor aperture determines the intercepted solid angle of the light flux at the measured test point. Use of large diameter photodetectors should be avoided at shorter measurement distances. Unless otherwise specified, the actual effective area of the sensor used for making the photometric measurements should fit within a circle whose diameter is approximately 0.009 times the distance from the measured light source to the sensor. A 0.009 ratio is equivalent to a solid angle formed by a radius of 0.26 degree. At test distances greater than 5 or 10 m, it is common practice for sensor areas to be considerably smaller than the 0.009 maximum. Sensor ratios of 0.003 or less are recommended for the photometry of devices with higher gradients of luminous intensity such as headlamps and front fog lamps.

3.7.5 PHOTOMETER SYSTEM CALIBRATION—The preferred method of photometric calibration is with a calibrated photometric standard lamp. When a calibrating lamp is used for the procedure, it should be calibrated using standard lamps of a higher order of accuracy and be traceable to the National Institute of Science and Technology or other qualified laboratories, through no more than four steps. A minimum of three photometric standard lamps or calibrating lamps should be maintained by the testing laboratory. These lamps should be intercompared periodically and records of the results should be maintained by the laboratory.

3.8 Instrument Calibration—Maintenance of instrumentation calibration is necessary for the photometric laboratory to make measurements with consistent precision. The following are recommendations of calibration intervals on various instruments and standards.

3.8.1 GENERAL INSTRUMENTATION—All instruments including voltmeters, current shunts, standard lamps, and accurate rated bulbs should be recalibrated at least annually by comparison with standards of a higher order of accuracy whose calibration is traceable to the National Institute of Science and Technology or other national laboratories, or by comparison to other like calibrated instrumentation. Records of these checks should be maintained by the laboratory.

3.8.2 SENSOR/PHOTOMETER SYSTEM—The system should be checked for color response and linearity (see 3.7.1 and 3.7.3) at least annually. Records of these checks should be maintained by the laboratory.

3.8.3 STANDARD LAMPS AND BULBS—In addition to the annual recalibration, operating time records should be kept on standard lamps, calibrating lamps, and accurate rated bulbs. Secondary and working calibrating lamps should be recalibrated or replaced at the interval recommended by the calibrating laboratory.

3.9 Environmental Variables—The following environmental variables should be controlled so their effect on photometric measurement accuracy is minimal.

3.9.1 TEMPERATURE AND HUMIDITY—Temperature and humidity can have a significant influence on electrical and photometric measuring instrumentation. Unless special steps have been taken to negate the effects of these factors, such as temperature control (or compensation) and humidity protection on the sensors and amplifiers, the photometry test area should be maintained at a calibrated room temperature within a sufficient temperature and humidity range so as not to have a significant effect on the instrumentation. Typical acceptable tolerances are ±5 °C and a maximum of 80% relative humidity. Large temperature gradients and turbulent air can cause fluctuations in luminous intensity measurements over long test distances of 20 m or more. Uniform temperatures should be maintained in long, enclosed photometric tubes or tunnels. Likewise, high concentrations of smoke or dust in the atmosphere may also influence results.

3.9.2 CONDITIONING PERIODS—Injection-molded plastic optical components may tend to change dimensionally after molding. Final critical photometric measurements should be made after the parts have stabilized. Similar precautions should be taken with devices which have been exposed to extreme temperatures or humidity in shipping or storage. For maximum accuracy and repeatability, parts should be conditioned in the laboratory environment for a minimum of 24 h, immediately prior to testing.

4. Notes

4.1 Marginal Indicia—The change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.

PREPARED BY THE SAE TEST METHODS AND EQUIPMENT STANDARDS COMMITTEE

APPENDIX A

TEST FIXTURE DESIGN GUIDE

To assist the photometric laboratory in using test fixtures which control the main factors influencing the overall positioning accuracy (see 3.2.1), an example of a test fixture design is shown in Figure A1. Othe designs, suitable for specific devices such as sealed beam units or for multipurpose use, and sufficient to provide proper positioning accuracy, may be equally satisfactory.

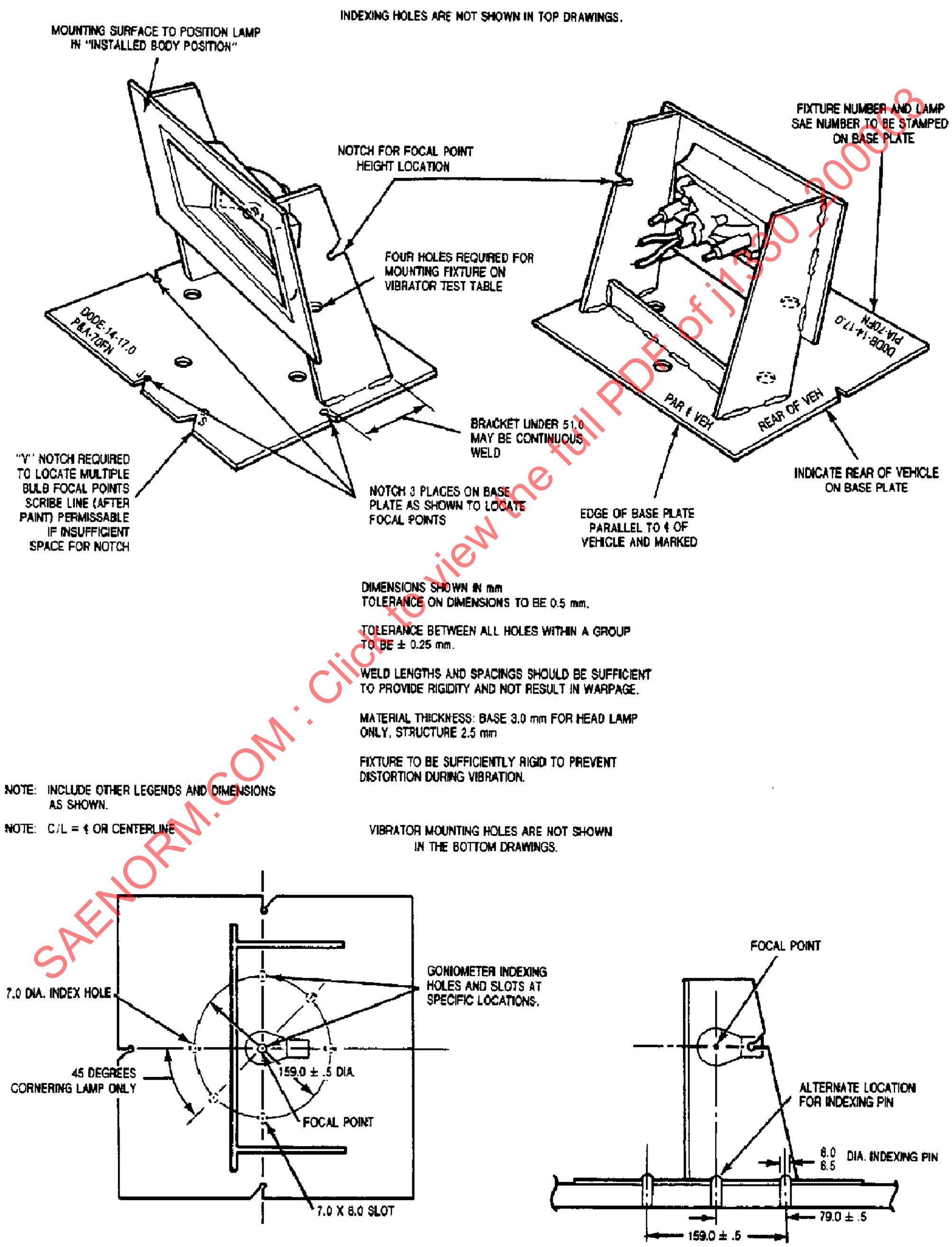


FIGURE A1—LAMP TEST FIXTURE DESIGN

APPENDIX B

GONIOMETER POSITION CONVERSIONS

To assist the laboratory in converting the test position settings from the recommended goniometer configuration in SAE J575 and SAE J2039 (Horizontal Rotation Over Elevation, Type A) to the alternate configuration (Elevation Over Horizontal Rotation, Type B), calculated equivalent positions are given in Table B1. Other positions, not given in the table may be calculated as follows in Equations B1 and B2:

$$V_B \text{ deg} = \tan^{-1}(\tan V_A \text{ deg} / \cos H_A \text{ deg}) \quad \text{(Eq. B1)}$$

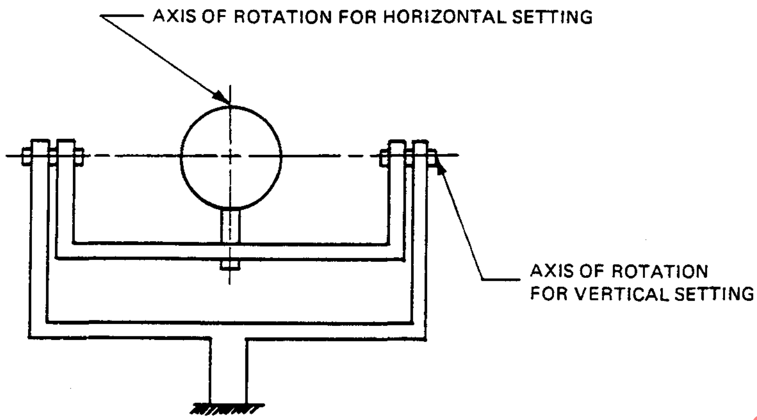
$$H_B \text{ deg} = \sin^{-1}[(\cos V_A \text{ deg})(\sin H_A \text{ deg})] \quad \text{(Eq. B2)}$$

It should be noted that test position settings on both the horizontal and the vertical axes are identical for both goniometer configurations. Differences in the coordinates are also insignificant over a range of 5 degrees in any direction from H-V. Sketches of both goniometer configurations are shown in Figure B1.

TABLE B1—GONIOMETER COORDINATE CONVERSIONS

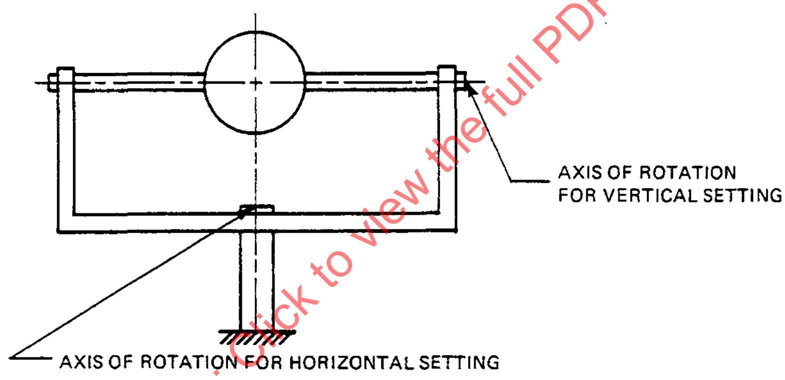
Goniometer Configuration A[1] (Horizontal Rotation Over Elevation) V_A (U or D), deg	Goniometer Configuration A[1] (Horizontal Rotation Over Elevation) H_A (L or R), deg	Goniometer Configuration B (Elevation Over Horizontal Rotation) V_B (U or D), deg	Goniometer Configuration B (Elevation Over Horizontal Rotation) H_B (L or R), deg
5	5	5.02	4.98
	10	5.08	9.96
	20	5.32	19.92
	30	5.77	29.87
	45	7.05	44.78
10	5	10.04	4.92
	10	10.15	9.85
	20	10.63	19.68
	30	11.51	29.50
	45	14.00	44.14
15	5	15.05	4.83
	10	15.22	9.66
	20	15.92	19.29
	30	17.19	28.88
	45	20.75	43.08
20	5	20.07	4.70
	10	20.28	9.39
	20	21.17	18.75
	30	22.80	28.02
	45	27.24	41.64

1. Recommended configuration in SAE J575.



TYPE A GONIOMETER

HORIZONTAL ROTATION OVER ELEVATION



TYPE B GONIOMETER

ELEVATION OVER HORIZONTAL ROTATION

FIGURE B1—GONIOMETER CONFIGURATIONS