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Document Name: IESNA LM-45: Method for Electrical and Photometric Measurements of General Service Incandescent Filament Lamps

CFR Section(s): 10 CFR 430 Subpart B

Standards Body: Illuminating Engineering Society of North America

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

LM-45-00

IESNA Approved Method *for* Electrical and Photometric Measurements *of* General Service Incandescent Filament Lamps

IES

The LIGHTING AUTHORITY®

Publication of this document has been approved by the IESNA. Suggestions for revisions should be directed to the IESNA.

Prepared by The Subcommittee on Photometry of Light Sources of the IESNA Testing Procedures Committee

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Approved by the IESNA Board of Directors, May 8, 2000, as a Transaction of the Illuminating Engineering Society of North America.

Published by the Illuminating Engineering Society of North America, 120 Wall Street, New York, New York 10005.

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ISBN # 0-87995-171-0

Printed in the United States of America.

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Contents

Foreword 1

1.0 Introduction 1
1.1 General 1
1.2 Nomenclature and Definitions 1

2.0 Ambient Conditions 1
2.1 General 1
2.2 Temperature 1
2.3 Air Movement 2
2.4 Vibration 2

3.0 Power Source Characteristics 2
3.1 Waveshape 2
3.2 Voltage or Current Regulations 2

4.0 Circuits 2

5.0 Lamp Stabilization 2
5.1 Preburning 2
5.2 Lamp Orientation 2

6.0 Electrical Circuits 3

7.0 Electrical Instrumentation 3
7.1 Uncertainties 3
7.2 Impedance Limitations 3

8.0 Photometer 3
8.1 Luminous Intensity and Illuminance Measurements 4
8.2 Integrating Sphere System 4

9.0 Photometric Test Procedures 4
9.1 Normal Intensity (candela) 4
9.2 Intensity (candela) Distribution 4
9.3 Integrating Sphere Measurement 4

10.0 Color Measurements 4

11.0 Test Report 4

References 6
Annex A 7
Glossary 8

IESNA Approved Method for Electrical and Photometric Measurements of General Service Incandescent Filament Lamps

Prepared by the Subcommittee on **Photometry of Light Sources of the IESNA Testing Procedures Committee**

Foreword

This approved method is a revision of *IESNA LM-45-1991, IESNA Approved Method for the Electrical and Photometric Measurements of General Service Incandescent Filament Lamps.* Significant changes have been made to update information, to give clearer guidelines for requirements and to promote uniformity in measurement procedure. Measurement of incandescent reflector lamp shapes are not included in this approved method.

1.0 INTRODUCTION

1.1 General

This approved method describes the procedures to be followed and the precautions to be observed in performing uniform and reproducible measurements of the electrical and photometric characteristics of general service incandescent filament lamps under standard conditions. Incandescent filament lamps produce radiant power as a result of electric current passing through a tungsten filament, which is surrounded by an inert atmosphere or vacuum within a glass or quartz envelope. Some lamps contain halogens that are employed to maintain a clean bulb wall. Such lamps may also employ bulb coatings that redirect infrared energy back to the filament for improved efficacy or to filter radiation for color control.

As long as the filament remains intact, current will flow, heating the filament to incandescence. Since the desired incandescence occurs at high filament temperatures, the surface of the tungsten filament is continually vaporized during lamp operation. As a result, the filament wire diameter is non-uniformly decreased along its length until, at some point, the high current density causes excessive local heating and vaporization, which causes the filament to fail. The rate of evaporation is dependent on the local filament temperature, plus gas density and pressure.

Incandescent filament lamps are typically affected by variables such as operating cycle, conditions imposed by the fixture, orientation and vibration. In general, the test conditions should not diverge widely from conditions of service. Practical considerations require that any test conditions and programs be designed to give comparable results when used by various laboratories. The recommendations of this IESNA Approved Method have been made with these objectives in mind.

For special purposes, it may be desirable to determine the characteristics of lamps when they are operated at other than the standard conditions described in this approved method. Where this is done, such results are meaningful only for the particular conditions under which they were obtained. All such non-standard operating conditions shall be stated in the test report.

The photometric information usually required is total luminous flux (lumens), luminous intensity (candelas) in one or more directions, and color. For the purposes of this approved method, the determination of these data will be considered photometric measurements.

The electrical characteristics usually measured are lamp current, lamp voltage, and lamp power. Incandescent filament lamps are usually measured on DC and the power can be calculated from voltage and current. For the purpose of this approved method, the determination of these data will be considered electrical measurements.

1.2 Nomenclature and Definitions[1]

The units of electrical measurement used in this approved method are volts, amperes and watts. The units of photometric measurement are lumens and candelas. Color is specified in terms of the CIE recommended systems.[2] For further explanation of the terminology used in this approved method, see the Glossary.

2.0 AMBIENT CONDITIONS

2.1 General

It is good laboratory practice that the storage and testing of lamps should be undertaken in a relatively clean environment. For lamps that operate at high bulb temperature, contaminants can be etched into glass bulb surfaces during operation. Therefore, lamps should be cleaned before measurement.

2.2 Temperature

For practical purposes, an ambient temperature of 25°C ± 10°C (77° F ± 18° F) is recommended. Although temperature is not critical for incandescent filament lamps, care must be given to the requirements of the measurement instrumentation and the temperature coefficient of the detector.

2.3 Air Movement

No special precautions against normal room air movement are necessary.

2.4 Vibration

Lamps should not be subjected to excessive vibration or shock during measurement.

3.0 POWER SOURCE CHARACTERISTICS

3.1 Waveshape

If AC is used, the AC power source, while operating the test lamp, shall have a sinusoidal voltage waveshape such that the RMS summation of the harmonic components does not exceed 3 percent of the fundamental.

3.2 Voltage or Current Regulation

The DC voltage or current shall be regulated to within ± 0.02 percent. The RMS voltage or current of the AC power source shall be regulated to within ± 0.02 percent.

4.0 CIRCUITS

The measurement circuits employed for incandescent filament lamps are shown in **Figure 1**. Usually a variable power source capable of providing DC or AC voltages as required by the lamp is used. In either case, the lamp input voltage or current must meet the requirements of **Section 3**.

Figure 1(a) shows the method of connecting instruments into a DC circuit. The voltmeter V is connected at the base of the lamp socket. The switch is provided to remove the instrument from the circuit if it is necessary to determine a correction factor to compensate for its presence in the circuit. The switch should have low resistance and be rated at several times the actual current in the test.

Figure 1(b) shows the method of connecting an instrument or instruments into an AC circuit with capabilities of measuring wattage, current and voltage. The voltmeter V and the potential element of the wattmeter W are connected at the base of the lamp socket. Corrections to compensate for the presence of the measuring elements in the circuit can be calculated from the impedance specification data provided by the manufacturer of the instruments, or they can be determined by using switches to remove instruments from the circuit.

5.0 LAMP STABILIZATION

5.1 Preburning

Prior to taking initial measurements, the lamps must be seasoned.[3] Before any measurements are taken, the seasoned lamps shall be operated long enough to reach stabilization and temperature equilibrium. A period of one-minute continuous operation, or up to three minutes for tungsten halogen types, is usually sufficient. However, it is always better to judge stability from periodic checks of light output, lamp voltage-current, or both, rather than elapsed time. When light output, and/or lamp voltage current become stable, the lamp is stable.

Here is a generally accepted three-step method for determining if an incandescent filament lamp is stable:

Step 1. Take five measurements of the lamp light output at fifteen second intervals (total time = 1 minute). This time period is in addition to the recommended preburning time.

Step 2. Calculate the *percent difference* between the maximum measured value and the minimum measured value for the five consecutive measurements.

Step 3. If the value calculated in *Step 2* does not exceed 1/4 percent, the lamp is considered stable.

These criteria should be considered *guidelines* and not sharp cut-offs; there are *degrees* of lamp stability. Further, when the criteria are exceeded, the photometry results are not necessarily invalid. It should be recognized, however, that the more the criteria are exceeded, the greater the probability that another laboratory will obtain dissimilar measurement results on the same lamp, even when standard practice is followed. Should the recommended criteria be exceeded it shall be so noted in the test report.

5.2 Lamp Orientation

Lamp seasoning, preburning and photometric measurements shall be done with the lamp in the same orientation. The operating position should be as specified by the manufacturer. For special application or test purposes, orientation other than that specified by the manufacturer or determined by customary usage

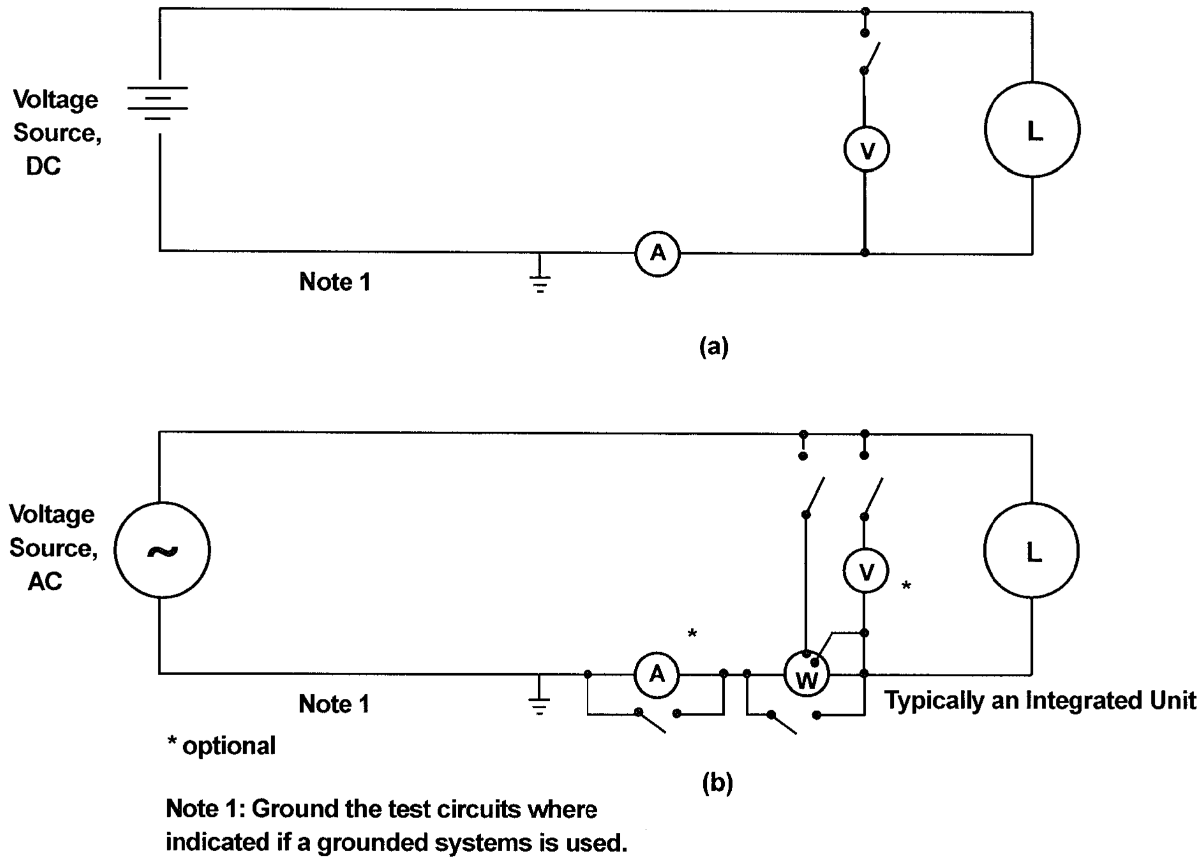

Figure 1. The methods of connecting instrument(s) into a DC circuit (a) and into an AC circuit (b).

may be used if noted in the test report. If no orientation is specified, use base up.

6.0 ELECTRICAL SETTINGS

The standard method of photometering incandescent filament lamps shall be with the lamp stabilized and operating at the rated lamp voltage or lamp current. If the lamp is rated to operate over a range of voltage or current, the center value of that range shall be used. Any departure from this standard method must be indicated in the test report.

7.0 ELECTRICAL INSTRUMENTATION

7.1 Uncertainties

The measurement uncertainty of voltage and current shall not exceed ± 0.05 percent. The actual uncertainties shall be stated in the test report. The instrument(s) chosen shall have a specified accuracy adequate to ensure that these requirements are met. [4,5]

7.2 Impedance limitations

Voltmeters shall have high input impedance and ammeters shall have low input impedance to reduce the disturbance by these instruments on the lamp circuit.

A test instrument connected in parallel with the lamp shall not draw more than 1 percent of the rated lamp current.

A test instrument connected in series with the lamp shall have an impedance such that the voltage across the instrument does not exceed 2 percent of the rated lamp voltage.

8.0 PHOTOMETER

The photometer detector shall have a relative spectral responsivity which approximates the V(λ) function. Refer to **Annex A** for a discussion of spectral mismatch errors and the methods for calculating and applying measurement corrections. A quantitative assessment of specific errors with the detector and associated electronics, such as linearity, fatigue, surrounding field response, and readout error shall be performed and reported.[6,7] In addition to (or instead of) employing a broadband detector, a spectroradiometer may be used to measure the spectral power distribution of the test source.[8]

8.1 Luminous Intensity and Illuminance Measurements

The detector shall have an approximate cosine response. This requirement is particularly important if the calibration source subtends a small viewing angle while the test source subtends a large angle.

8.2 Integrating Sphere System

The spectral responsivity of an integrating sphere photometer is a combination of the relative spectral throughput of the sphere and the detector spectral responsivity. Methods for determining the necessary corrections are described in **Annex A**.

The detector shall have a wide field of view so as to "see" as much of the sphere wall as possible. A detector combined with a knife edged integrating sphere or diffuser mounted flush with the main sphere wall are methods used to achieve an approximate cosine response.

An integrating sphere for luminous flux measurements shall be large enough to allow the ambient temperature to reach thermal equilibrium and to permit the internal baffle to be small (relative to the integrating sphere's size). To minimize spatial non-uniformity errors, the baffle size at any location (1/3 to 2/3 times the sphere radius from the detector port) is reduced so it just shields the detector port from direct illumination by the largest lamp to be tested. The integrating sphere should be equipped with an auxiliary lamp to permit the determination of self-absorption corrections.[9]

9.0 PHOTOMETRIC TEST PROCEDURES

9.1 Normal Intensity (candela)

Directional light output may be measured with one or more detectors at an appropriate distance from the lamp. The recommended minimum distance is at least five times the longest dimension of the lamp. Total luminous flux may be computed if the flux/intensity ratio for the type of lamp is well established; if so, the test report shall state that the flux is computed using the flux/intensity ratio.

Some possible sources of error are:

- Light reflection material, including supports for the lamp or detector
- Stray light

9.2 Intensity (candela) Distribution

The luminous intensity distribution around a lamp may be determined with a photometer similar to that used for normal luminous intensity measurements, but set up so the angles between the detector assembly and the lamp axis can be varied. The preferred method of angular scanning is to physically or optically (e.g., with the use of a mirror) move the detector around the lamp keeping the lamp from tilting during the scan.

9.3 Integrating Sphere Measurement[9]

The integrating sphere method gives total luminous flux of the test lamp with one measurement. Appropriate corrections shall be made unless substitution standards agree in spectral power distribution, physical size, and shape with the lamps under test. When the test lamps and the calibrating lamp are not of the same physical size, finish, degree of blackening, and shape, compensation for differences in self-absorption shall be made.[9]

10.0 COLOR MEASUREMENTS

Photometric measurements frequently include the measurement of color, which is specified in terms of the CIE colorimetry system and the color rendering index (CRI).[2,8,10,11]

11.0 TEST REPORT

The test report shall list all significant data for each lamp tested, together with performance data. The report shall also list all pertinent data concerning conditions of testing, type of equipment, and lamps. Typical items reported are:

a) Date and testing agency
b) Manufacturer's name and lamp designation
c) Type of test
d) Number of lamps tested
e) Rated electrical values for the lamp tested
f) Number of hours operated and operating cycle
g) Ambient temperature
h) Lamp orientation during test
i) Stabilization time

j) Type of standard used and correction factors, if any
k) Photometric method
l) Sphere diameter or test distance
m) Circuit conditions and fixed parameters
n) Measured light output (lumens and/or candelas) and electrical values (volts, amperes, watts) of each lamp and group averages
o) Spectral power distributions
p) Color data
q) Flux intensity ratio (if lumens were calculated from intensity measurement data)
r) Test equipment used
s) Statement of uncertainties[5]
t) Any deviation from standard operating procedures
u) Observations of any unusual behavior of the lamps

References

1. IESNA Nomenclature Committee, *ANSI/IESNA Nomenclature and Definitions for Illuminating Engineering*, RP-16-96. New York: Illuminating Engineering Society of North America.

2. CIE Publication 15.2-1986, *Colorimetry*. Commission Internationale de l'Eclairage (CIE). Vienna: Bureau Central de la CIE.

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5. ANSI/NCSL Z540-2-1997, *U.S. Guide to the Expression of Uncertainty in Measurement*. New York: American National Standards Institute.

6. CIE Publication 69-1987, *Methods of Characterizing the Illuminance Meters and Luminance Meters: Performance, Characteristics and Specifications*. Commission Internationale de l"Eclairage (CIE). Vienna: Bureau Central de la CIE.

7. CIE Publication No53-1982, *Methods of Characterizing the Performance of Radiometers and Photometers*. Commission Internationale de l"Eclairage (CIE). Vienna: Bureau Central de la CIE.

8. Subcommittee on Photometry of Light Sources of the IESNA Testing Procedures Committee, *IESNA Guide to Spectroradiometric Measurements*, LM-58-94. New York: Illuminating Engineering Society of North America.

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11. CIE Publication 13.3-1982, *Methods of Measuring and Specifying Colour Rendering of Light Sources*. Commission Internationale de l'Eclairage (CIE). Vienna: Bureau Central de la CIE.

References may be ordered from:

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TLA-Lighting Consultants, Inc.
7 Pond Street
Salem, MA 01970-4819

In Canada:

National Research Council
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Montreal Road
Ottawa, Ontario K1A 0R6, Canada

Annex A — Measurement Errors Due to the Deviation in System Response from V(λ)

A1.0 Illuminance

Commercially available photometric detectors only approximate the standard V(λ) response due to limitations in the manufacturing process. Generally, the closer the "fit" to V(λ), the more expensive the detector. A numerical term used to express the accuracy of fit is f_1'. [1,2] But be aware that this term provides an indication of the average closeness of the detector response to the ideal curve (i.e., its overall conformance to the standard); f_1' does not provide information about the magnitude of deviation of the response from V(λ) at specific wavelengths. To determine the magnitude of error of a particular measurement due to detector spectral mismatch, the following must be known:

- The relative spectral response of the detector
- The spectral distribution of the source being measured
- The spectral distribution of the source used to calibrate the detector

The relative spectral response of a detector is often available from the manufacturer and it can be measured at The National Institute of Standards and Technology or at one of a number of commercial laboratories. Provided that the necessary equipment and the expertise are available, the detector response can be measured using reference 3 in this annex. The spectral distributions of the source under test and the calibration source must be determined using a spectroradiometer. A correction factor can then be calculated and applied using reference 1 in the annex.

A2.0 Total Luminous Flux

For the measurement of total luminous flux, the detector is positioned at the exit port of an integrating sphere. Integrated, diffuse radiation from a light source is then incident upon the detector. Since the reflectance of the sphere wall varies with wavelength, the relative response of the detector/sphere combination will differ from the response of the detector alone. As in the case with the illuminance measurements (see **Section A1.0**), the inaccuracies introduced into the measurement depend on the difference in spectral power distribution of the source under test from that of the calibration source. For example, if the test source and the calibration source are both incandescent lamps operating at the same color temperature, the error in the calibration is canceled out by the same error in the measurement of the test source. On the other hand, if the calibration source is an incandescent source and the test source is a discharge lamp, the error may be significant. As in the case of the detector used directly for illuminance measurements, the magnitude of error can be determined and corrections applied using the same method described in **Section A1.0**, however, the effects of the sphere must be taken into account.[4,2]

To the novice who wishes to make a simple light output measurement, applying the analytical procedure just described may seem cumbersome. Also, a spectroradiometer is an expensive, complex instrument that may not be readily available. Hence, in the real world, the recommended procedure is not often used and *assumptions* are consequently made when a particular detector is deployed. Unfortunately such assumptions can be, and often are, incorrect.

The percent error possible in a measurement for any detector is, in essence, the maximum percent deviation from the V(λ) curve. Knowledge of the detector's response when not accompanied by knowledge of the spectra of the source under test can lead to large errors even for a detector with a small f_1'. An example is the measurement of light emitting diodes (LEDs), which have all their energy in a narrow frequency band.

In some cases, the unknown errors are not significant and if the person making the measurement ignores them there are no serious consequences. In other situations, relative readings suffice and absolute levels are not important. If, however, the objective is to obtain a light output measurement with a known level of accuracy, the cited references must be consulted and the recommended procedures carried out.

References (for Annex A)

1. CIE Publication No. 69- 1987, *Methods of Characterizing Illuminance Meters and Luminance meters*. Commission Internationale de l'Eclairage (CIE). Vienna: Bureau Central de la CIE.

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3. CIE Publication No. 64- 1984, *Determination of the Spectral Responsivity of Optical Radiation Detectors*. Commission Internationale de l'Eclairage (CIE). Vienna: Bureau Central de la CIE.

4. Collins, R. G., "A Sphere Photometry System for the Nineties", *Journal of the Illuminating Engineering Society*, Vol. 26, No. 1, Jan. 1997, p. 44.

Glossary

candela, cd the SI unit of luminous intensity, equal to one lumen per steradian.

color the characteristic of light by which a human observer may distinguish between two structure-free patches of light of the same size and shape (see reference 4 in the main document).

color rendering index (of a light source) (CRI) a measure of the degree of color shift objects undergo when illuminated by the light source as compared with those same objects when illuminated by a reference source of comparable color temperature.

color temperature (of a light source) the absolute temperature of a blackbody radiator having a chromaticity equal to that of the light source.

Commission Internationale de l'Éclairage (CIE) the International Commission on Illumination.

correlated color temperature (of a light source) the absolute temperature of a blackbody whose chromaticity most nearly resembles that of the light source.

lumen, lm the SI unit of luminous flux. Photometrically, it is the luminous flux emitted within a unit solid angle (1 steradian) by a point source having a uniform luminous intensity of 1 candela.

lumen maintenance the lumens measured at a specific operating interval of a light source expressed as a percent of the initial lumens. Typically, the interval is at 40 percent of the rated life.

regulation the constancy of the RMS voltage applied to the equipment under test.

seasoning (or aging) time is the initial operation of the lamp generally performed at rated voltage for a minimum period of 1/2 of 1 percent of rated life (see reference 3 in the main document).

stabilization the operation of test lamps for a sufficient period of time such that the electrical and the photometric values are constant. This is sometimes called warm-up time.