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NEMA STANDARDS PUBLICATION

NEMA LE 5A

PROCEDURE FOR DETERMINING LUMINAIRE EFFICACY RATINGS FOR COMMERCIAL, NON-RESIDENTIAL DOWNLIGHT LUMINAIRES

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

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NEMA STANDARDS PUBLICATION LE 5A-1999

Procedure for Determining Luminaire Efficacy Ratings for Commercial, Non-residential Downlight Luminaires

Published by:

National Electrical Manufacturers Association
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Rosslyn, Virginia 22209

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FOREWORD

This Standards Publication was developed to assist the federal government, state governments, electric utilities, and manufacturers of luminaires in performing a standardized test method for determining the luminaire efficacy rating of incandescent, compact fluorescent, and low wattage (≤ 150w) high intensity discharge downlight type luminaires incorporating various shielding media and various types of applicable lamps and ballasts where applicable.

This Standards Publication was prompted by the need of the luminaire manufacturing industry to have a uniform method of determining energy efficiency of their products using various components.

It is not the intent of this Standards Publication to inhibit luminaire design or to impose arbitrary tolerances on any luminaire manufacturer.

The International Association of Lighting Designers and the Illuminating Engineering Society of North America desire to include, in the future, an additional numerical value for lighting quality to accompany the luminaire efficacy rating value. This numerical expression for lighting quality has not yet been fully developed and is intended to be added at an appropriate time.

The preparation of this Standards Publication was done by the Lighting Fixture Section, in close cooperation with the Lamp and Ballast Sections of the NEMA Lighting Systems Division. Input of users and other interested parties has been sought and evaluated. Inquiries, comments, and proposed or recommended revisions should be submitted to the Indoor Lighting Section of NEMA by contacting:

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This standard was developed by the Lighting Fixtures Section. Section approval of the standard does not necessarily imply that all section members voted for its approval or participated in its development. At the time it was approved, the Lighting Fixtures Section was composed of the following members:

American Electric Lighting—Memphis, TN
Cooper Lighting Group—Elk Grove Village, IL
Durolite—Fairfield, NJ
GE Lighting Systems—Hendersonville, NC
Holophane Corporation—Newark, OH
Hubbell Lighting Inc.—Christiansburg, VA
Indy Lighting, Inc.—Fishers, IN
Juno Lighting, Inc.—Des Plaines, IL
Lighting Corporation of America—San Leandro, CA
Lithonia Lighting—Conyers, GA
O-Z Gedney—Tulsa, OK
Paramount Industries, Inc.—Croswell, MI
Red Dot Division, L.E. Mason Co.—Boston, MA
Simkar Lighting Fixture Co.—Philadelphia, PA
SPI Lighting, Inc.—Mequon, WI
The Genlyte Group—Union, NJ
The Jones Metal Products Company—West Lafayette, OH
Thomas Lighting, Inc.—Tupelo, MS

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PURPOSE

The purpose of this standards publication is to:

a. Provide governmental agencies with a practical and uniform method for calculating a metric for evaluating and comparing the "energy efficiency" of downlight luminaires.

b. Create a workable and realistic number of downlight luminaire types, which can be used to evaluate energy usage.

c. Organize the types of luminaires into categories which will reasonably represent the design function, physical and dimensional attributes, and the photometric characteristics of the various types of high volume luminaires.

d. Preserve for the luminaire manufacturers and the lighting industry the flexibility to use laboratory facilities, testing methods, and completed test data that currently exist and are in accordance with approved industry standards.

e. Establish a luminaire efficacy rating (LER) based on rated lumens per watt, in place of a standard based solely on either coefficients of utilization or luminaire efficiency. The word "rated" is used so as not to require the use of absolute photometry and to be able to use published rated lumen values. LER is calculated using both ballast factor, when applicable, and total input watts to establish the rated efficacy of the luminaire. (LER is given in rated lumens per watt.)

NOTE—Photometric tests of luminaires that were completed prior to issue date of this document may be used for calculation of LER values by substituting appropriate ballast factors and input power values as necessary from component manufacturers' reference data or from Tables A-2 and A-3.

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Section 1
GENERAL

1.1 SCOPE

This Standards Publication provides a procedure for the determination of the luminaire efficacy rating of downlight luminaires under laboratory test conditions.

It includes general lighting downlights for space illumination only and does not apply to specialized usage fixtures, such as accent luminaires, track luminaires, wallwashers, color filtered luminaires, aesthetically customized trims, low voltage luminaires, etc. These exceptions have intended uses that are complex *and are critical to the* applications that require their usage. Their effect on energy consumption can best be handled by power budgeting similar to the approaches taken in ASHRAE/IES 90.1-1989. Factors affecting comfort are not addressed at this time, but will be evolved into a future "quality metric." Highlighting luminaires, with beam spreads less than 30 degrees, as well as luminaires with measured aperture diameters less than four (4) inches are not covered by this standard.

Reflector type lamps are excluded from this downlight standard due to their extremely superior lumen utilization over and above bare general service incandescent sources within luminaires. Since luminaire output generally approximates reflector lamp output, energy and performance regulation for reflector type lamps is best addressed by lamp standards.

Self-ballasted high intensity discharge or integrally ballasted compact fluorescent lamps are not considered in the scope of this standard.

Lamps that require ballasts that do not have ANSI standard specifications and an ANSI standard for reference ballast are excluded from this downlight standard.

1.2 REFERENCED DOCUMENTS

The latest editions and revisions of the following publications are adopted as indicated by reference in this Standards Publication.

American National Standards Institute (ANSI)
11 West 42nd Street, 13th Floor
New York, NY 10036

ANSI C78.375-1997	Fluorescent Lamps—Guide for Electrical Measurement
ANSI C78.386-1994	Mercury Lamps—Measurement Characteristics
ANSI C78.387-1995	Metal-halide Lamps—Measurement Characteristics
ANSI C78.388-1994	High Pressure Sodium Lamps—Measurement Characteristics
ANSI C78.4-1995	Fluorescent Lamps—Self Supporting, Single Based Compact Types—Dimensional and Electrical Characteristics
ANSI C82.2-1995	Fluorescent Lamp Ballasts—Methods of Measurement
ANSI C82.3-1995	Reference Ballasts for Fluorescent Lamps
ANSI C82.5-1995	High Intensity Discharge Lamp Reference Ballasts, Specifications FOB

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ANSI C82.6-1996	Ballasts for HID Lamps, Method of Measurement
ANSI/IEEE 100-1988	IEEE Standard Dictionary of Electrical and Electronics Terms

Illuminating Engineering Society of North America (IESNA)
120 Wall Street FL 17
New York, NY 10005-4001

IESNA Lighting Handbook, Eighth Edition, 1993.

LM 66-1991	Single-ended Compact Fluorescent Lamps—Electrical and Photometric Measurements
LM 45-1991	Incandescent Lamps—Electrical Measurements
LM 51-1993	High Intensity Discharge (HID) Lamps—Electrical Measurements
LM 46-1998	Photometric Testing of Indoor Luminaires using HID or Incandescent Filament Lamps
LM 41-1998	Approved Method for Photometric Testing of Indoor Fluorescent Luminaires

1.3 DEFINITIONS

baffle: A light-absorbing element within the luminaire aperture having a stepped surface or a reflectance factor of $\leq$ 25 percent.

ballast: An auxiliary device used with an electrical discharge lamp(s) to obtain the necessary circuit conditions (voltage, current, and wave form) for the proper starting and operation of a particular fluorescent or high intensity discharge (HID) lamp(s) from a particular line voltage and frequency.

ballast factor: A term used to describe the percentage of light output, produced when a fluorescent or HID lamp(s) is energized from a commercially available ballasts, as compared to the light output produced when energized from a reference ballast. Ballast factor tests are run in accordance with ANSI C82.2 and ANSI C82.6.

compact fluorescent lamp: A compact shape fluorescent lamp with a single base that performs the entire mechanical support function.

downlight: A small, direct lighting unit which directs the light downward and can be recessed, surface mounted, or suspended.

fixture: The structural parts of a luminaire, including parts designed to distribute the light, to position and/or protect the lamp(s), to mount and support the ballast(s), when applicable, and to provide a wireway or means of connecting the lamp(s) and ballast(s), when applicable, to the power supply. A fixture includes the ballast(s), when applicable, but does not include lamp(s).

fluorescent lamp: A low pressure mercury electric-discharge lamp in which a fluorescing coating (phosphor) transforms a portion of the ultraviolet energy generated by the arc discharge into visible light.

high intensity discharge (HID) lamp: An electric discharge lamp in which the light producing arc is stabilized by wall temperature, and the arc tube has a bulb wall loading in excess of three watts per square centimeter. HID lamps include groups of lamps known as mercury vapor, metal halide, and high pressure sodium.

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incandescent lamp: A lamp in which light is produced by a filament heated to incandescence by an electric current.

lens: A glass or plastic element used in luminaires to change the direction and control the distribution of light rays.

louver: An element used in luminaires to divide the aperture into multiple light directing cells.

luminaire: A complete lighting unit consisting of a lamp or lamps and ballast(s), when applicable, together with parts designed to distribute the light, to position and protect the lamps, and to connect the lamps through the ballast(s), when applicable, to the power supply.

luminaire efficacy rating (LER): A term used to describe a mathematical method of determining the rated efficacy of a luminaire.

optical enclosure: That part of a luminaire which encloses the light-emitting opening and interacts with a light source to control the luminaire light distribution.

reference ballast: A ballast especially constructed to have certain prescribed electrical characteristics for use in testing electrical discharge lamps and other ballasts in accordance with ANSI C82.3 or ANSI C82.5.

shielding angle (of a luminaire): The angle between a horizontal line through the light center and the line of sight at which the bare source first becomes visible, as viewed from all lateral angles. For the purpose of this standard, a shielding angle of $< 40°$ shall be considered as "less shielded (L)," and an angle of $\geq 40°$ shall be considered to be "highly shielded (H)." For the purpose of this standard, the lens of a lensed system shall be considered the "bare source."

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Section 2
SELECTION OF COMPONENTS

2.1 TEST SPECIMEN—LUMINAIRE

The luminaire selected for test shall be clean and representative of the manufacturer's current and regular production.

2.2 TEST SPECIMEN(S)—COMPACT FLUORESCENT AND HID BALLAST(S)

Ballast(s) chosen for the test shall be typical of current production.

Ballasts shall be tested and certified as having ballast factors that are within +/- 0.025 of established average ballast factors or the manufacturer's published ballast factor, for the particular ballast when tested in accordance with ANSI C82.2 or ANSI C82.6.

2.3 TEST SPECIMEN(S)* —COMPACT FLUORESCENT LAMPS, INCANDESCENT LAMPS, HID LAMPS (REFERENCES: IESNA LM 41 AND LM 46)

Lamps of stable output should be used. They should be constant in light output for constant line voltage and repeated operation.

Lamps selected for tests should be typical of current production and should be selected for uniform luminance, consistent with their geometry.

Lamp Type	Bulb Type	Wattage Limitations
Incandescent	A, PS	100-300 W
Compact Fluorescent	Quad Tube Twin Tube Multi-tube	13-32 W
HID	E, B, BT, ED, T	≤ 150 W

* This standard covers highest usage sources for the categories of downlights. Most HID industrial luminaires with lamp wattages greater than 150w are covered in NEMA Standards Publication LE5B.

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Section 3
TESTING FACILITIES AND EQUIPMENT

3.1 FACILITIES

Because of the importance of obtaining accurate repeatable measurements, a National Voluntary Laboratory Accreditation Program accredited photometric laboratory or an equivalently accredited laboratory is recommended for testing.

The photometric laboratory shall have facilities for performing tests in accordance with all applicable sections of the IESNA LM 41, LM 46 and LM 66.

3.2 GENERAL CRITERIA

Due to the sensitivity of compact fluorescent and to a lesser degree, low wattage HID lamp light output to air flows, all testing should be conducted in a simulated "draft free" environment. A maximum air flow of 4.6 meters (15 ft) per minute is recommended. Although air movement is necessary to avoid thermal stratification, care should be taken to minimize any draft or air flow within the immediate vicinity of the test lamps or luminaire, or both.

Ambient temperature should be controlled to 25° C (77° F) within a tolerance of ± 1° C (1.8° F) for fluorescent products, and ± 5° C (9° F) for incandescent and HID products. (Reference: IESNA LM 41 and 46.)

Lamp base contact connections on compact fluorescent lamps should remain the same throughout the tests both for the calibration and for the luminaire test.

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Section 4
CALCULATIONS

4.1 LUMINAIRE EFFICACY RATING—DOWNLIGHT LUMINAIRES

Luminaire Efficacy Rating (LER) shall be calculated for a given luminaire by the following formula:

LER = (EFF x TLL) / Watts Input — Incandescent Luminaires
LER = (EFF x TLL x BF) / Watts Input — HID and Compact Fluorescent Luminaires

Where:

LER = Luminaire efficacy rating, expressed in rated lumens per watt. This value shall be expressed as a whole number, rounding up ($\geq$ 0.5) or down (< 0.5) as required.
EFF = Luminaire efficiency,* expressed as a two-place decimal, rounding up ($\geq$0.005) or down (< 0.005) as required.
TLL = Total initial lamp lumens, total number of lamps in the test luminaire multiplied by the published rated initial lamp lumens.
BF = Ballast factor of test ballast or the average ballast factor of test ballasts used in the photometric test.**
WATTS INPUT = Total wattage of the luminaire as measured during the photometric test.**

4.2 CALCULATION OF BALLAST FACTOR FOR COMPACT FLUORESCENT LAMPS

Ballast factor should be calculated in the following comparative method:

$BF_T = BF_B \times (CF_T / CF_B)$

Where:

BF_T = Ballast factor of the ballast being tested (unknown ballast factor).
BF_B = Ballast factor of base test ballast for lamp type being tested (known ballast factor.) This BF_B can be traced to a reference ballast test.
CF_T = Calibration flux (measured luminous lamp flux) with ballast being tested.
CF_B = Calibration flux (measured luminous lamp flux) using same lamps as being used in test for which ballast factor is being calculated (same as used for CF_T) and operated on base ballast(s) used for BF_B.

4.3 BALLAST FACTOR FOR HID BALLASTS

HID luminaire photometric testing is based on IESNA LM 46, and, in accordance with this test method, ballast performance is based on nominal wattage delivered to the test lamp. Accordingly, the ballast factor will be shown as 1.0.

---

* The photometric test for luminaire efficiency shall be in accordance with IESNA LM 41 and 46, as applicable.
** Refer to component manufacturer's supplied data when the tested ballast factor or input watts is not available.

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Section 5
PROCEDURES

5.1 LUMINAIRE EFFICACY RATING—DOWNLIGHT LUMINAIRES

Luminaire efficacy rating shall be specified as a minimum value for each luminaire category and classification shown in 5.2.

5.2 LUMINAIRE CATEGORY AND CLASSIFICATION

a. Category "O"—open reflector optical systems, including clear safety shields.

Shielding angle: $< 40^\circ$ or $\geq 40^\circ$, "less shielded" (L), or "highly shielded" (H), measured from horizontal.
Incandescent, compact fluorescent, HID lamp types.

b. Category "B"—baffled optical systems, which are at least 75 percent light absorbing.

Shielding angle: $< 40^\circ$ or $\geq 40^\circ$, "less shielded" (L) or "highly shielded" (H), measured from the horizontal.
Incandescent, compact fluorescent, HID lamp types.

c. Category "L"—lensed optical systems.

Shielding angle: $< 40^\circ$, "less shielded" (L), measured from the horizontal.
Incandescent, compact fluorescent, HID lamp types.

d. Category "V"—louvered optical systems.

Shielding angle: $< 40^\circ$ or $\geq 40^\circ$, less shielding (L) or "highly shielded" (H), measured from the horizontal.
Incandescent, compact fluorescent, HID lamp types.

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Section 6
LIGHTING ENERGY COST—DOWNLIGHT LUMINAIRES

6.1 COMPARATIVE YEARLY ENERGY COST OF LIGHT

The yearly lighting energy cost for comparative purposes in this procedure is to be based on 1,000 lumens and the following:

a. 3,000 average burning hours per year.
b. $ 0.08 / kwh, average electrical energy rate.

Thus, the constant (K) for the comparative yearly lighting energy cost per watt for downlight luminaires is $ 0.24.

6.2 CALCULATION—COMPARATIVE YEARLY LIGHTING ENERGY COST

Comparative Yearly Lighting Energy Cost (in dollars) = (K / LER) x 1,000

Where:

K = $ 0.24/watt ([3,000 average burning hours per year x $ 0.08 / kwh average electrical energy cost] / 1,000 watts/kw).
LER = The LER value in lumens/watt for the given luminaire under consideration.
1,000 = comparative constant representing 1,000 lumens.

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Section 7
RECOMMENDED REPORTING CATEGORIES AND FORMAT

7.1 CATEGORY DESCRIPTION

7.1.1 Pertinent Information

LER values and comparative yearly lighting energy cost values should be shown in promotional literature and catalogs in conjunction with other pertinent information as shown below:

a. Catalog number.
b. Luminaire category.
c. Lamp type and rated initial lumen value.
d. Ballast type.
e. Luminaire lumen output.
f. Total ballast(s) rated input wattage.
g. LER.
h. Comparative yearly lighting energy cost per 1,000 lumens (the cost of light).
i. Voltage.
j. Total efficiency.

7.1.2 Luminaire Category

A three-lettered designation for the luminaire category should be included with the luminaire efficacy rating value whenever it is given. The first letter of the designation is "D" for downlight. The second letter represents the optical configuration of the luminaire. A notation guide for the second letter is given below. (See 5.2.)

O—Open optics
B—Baffled optics
L—Lensed optics
V—Louvered optics

The shielding classification part of the three-letter designation is given as follows:

L—Shielding angle < 40°
H—Shielding angle ≥ 40°

7.2 Recommended Reporting Format (Example Only)

See Figure 7.1 for an example of a recommended reporting format.

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Figure 7-1 – Recommended Reporting Format (Example Only)

Luminaire Catalog #	Luminaire Category	Lamp Type	Ballast Type	Luminaire Lumen Output	Luminaire Watt Input	Ballast Factor	LER	Energy Cost	Percent Efficiency
Cat. No.	DOH	2-26 W CFLs 1,800 Lu/Lamp	Elect-ronic	2,160	52	0.95	39	$6.15	60%

* Comparative yearly lighting energy cost per 1,000 lumens.

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Annex A
RATIONALE FOR DOWNLIGHT LUMINAIRE LER

A.1 LUMINAIRE CHARACTERISTICS

In reviewing downlight luminaires, judging a luminaire by efficiency alone is a poor measure of merit. The most efficient luminaire is basically a "bare lamp." Likewise, judging a luminaire by its coefficient of utilization (CU) alone is inappropriate. A luminaire's coefficient of utilization is not only a function of its efficiency, but its application as well: the CU is dependent in part on the geometry of the room in which it is installed and the reflectivity of the room surfaces.

Luminaires must be classified into various categories and rated within these categories.

This categorization includes general lighting downlights for general space illumination only and does not apply to specialized usage fixtures, such as accent luminaires, wallwashers, color filtered luminaires, aesthetically customized trims, etc. These exceptions have intended uses which are complex and are critical to the markets which require their usage. Their effect on energy consumption can best be handled by power budgeting similar to the approaches taken in ASHRAE 90.1-1989 and the new Department of Energy energy standard for federal office buildings. Factors affecting comfort are not to be addressed.

A.2 BALLAST FACTORS

Ballast factor measurement data is preferred, using actual tests. When such data are unavailable, component manufacturers' data may be used.

A.3 LUMINAIRE EFFICIENCY

Luminaire efficiency is used in lieu of coefficient of utilization because the latter is so application-dependent.

A.4 LUMINAIRE WATTAGE

Calculating the LER using rated ballast(s) input wattage, which is readily available from ballast manufacturers, ensures that all luminaire manufacturers are doing the calculations in the same fashion. While a specific ballast's input wattage can vary depending on operating conditions, such as ambient temperatures, these variables are application sensitive and cannot be quantified. The use of rated ballast(s) input wattage addresses the differences in power consumption between different ballast designs, but does not attempt to quantify the application-sensitive variables.

Since rated ballast(s) input wattage, as determined in accordance with ANSI C82.6, is generated independently from photometric testing, existing photometric tests that have been done per IESNA LM 46 may be used to generate LER values.

The LER should be calculated using the ballast that is the standard product offering for a given luminaire. Because many luminaire designs can accommodate a variety of ballasts, the ballast type must be reported in conjunction with the LER. Optional ballast offerings could list a multiplier to adjust the base LER to the value that would be obtained when using the optional ballast in the luminaire.

Although test measurement is preferred to determine actual input watts, component manufacturer's data or the reference Tables A-2 and A-3 may be used when test data is unavailable.

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Table A-1
MINIMUM LER VALUES

Shielding:	"L" (Less Shielding, < 40 degrees)	"H" (Highly Shielded, ≥ 40 degrees)
Open Optics, "O"		
Luminaire Type		
Incandescent	7	6
Compact Fluorescent	16	14
Mercury	22	21
Metal Halide	25	23
High Pressure Sodium	34	32
White Sodium	16	15
Baffled Optics, "B"		
Luminaire Type		
Incandescent	5	4
Compact Fluorescent	9	6
Mercury	17	15
Metal Halide	20	18
High Pressure Sodium	27	23
White Sodium	13	11
Lensed Optics, "L"		
Luminaire Type		
Incandescent	5	N/A
Compact Fluorescent	9	N/A
Mercury	13	N/A
Metal Halide	18	N/A
High Pressure Sodium	25	N/A
White Sodium	15	N/A
Louvered Optics, "V"		
Luminaire Type		
Incandescent	6	5
Compact Fluorescent	12	8
Mercury	13	12
Metal Halide	20	19
High Pressure Sodium	27	22
White Sodium	13	12

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TABLE A-2
TYPICAL RATED INPUT WATTS

Compact Fluorescent Downlights

Lamps Quantity	Description	Lamp Watts	Ballast Description	Input Watts (120v)	Input Watts(277v)
1	CFT 13W	13	(1) MAG HPF, NPF	14	21
2	CFT 13W	2x13	(2) MAG HPF, NPF	31	25
1	CFQ 13W	13	(1) MAG HPF, NPF	14	17
2	CFQ 13W	2x13	(2) MAG HPF, NPF	38	33
1	CFQ 18W	18	(1) MAG HPF, NPF	25	24
2	CFQ 18W	2x18	(2) MAG HPF, NPF	50	45
1	CFQ 26W	26	(1) MAG HPF, NPF	36	33
2	CFQ 26W	2x26	(2) MAG HPF, NPF	64	62
1	CFT 13W	13	ELECTRONIC	—	—
2	CFT 13W	2x13	ELECTRONIC	28	—
1	CFQ 13W	13	ELECTRONIC	—	—
2	CFQ 13W	2x13	ELECTRONIC	28	—
1	CFQ 18W	18	ELECTRONIC	23	—
2	CFQ 18W	2x18	ELECTRONIC	38	—
1	CFQ 26W	26	ELECTRONIC	24	—
2	CFQ 26W	2x26	ELECTRONIC	45	45
1	CFM 18W	18	ELECTRONIC	TBD	—
2	CFM 18W	2x18	ELECTRONIC	TBD	—
1	CFM 26W	26	ELECTRONIC	32	32
2	CFM 26W	2x26	ELECTRONIC	57	—
1	CFM 32W	32	ELECTRONIC	32	37
2	CFM 32W	2x32	ELECTRONIC	67	—

Where:
CFT = Compact Fluorescent, Twin-tube
CFQ = Compact Fluorescent, Quad-tube
CFM = Compact Fluorescent, Multi-tube
MAG = Magnetic
HPF = High Power Factor (= 0.90)
NPF = Normal Power Factor

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TABLE A-3
TYPICAL RATED INPUT WATTS
LOW WATTAGE (≤ 150w) HID DOWNLIGHTS

Lamps

Quantity	Description	Lamp Watts	Ballast Description	Input Watts
1	M32	32	—	38
1	M50	50	HX-HPF	72
1	M70	70	HX-HPF	95
1	M100	100	HX-HPF	130
1	M150	150	HX-HPF	185
1	HPS35	35	R	46
1	HPS50	50	HX-HPF	65
1	HPS70	70	HX-HPF	94
1	HPS100	100	HX-HPF	128
1	HPS150	150	HX-HPF	188
1	H50	50	CWA	74
1	H75	75	CWA	93
1	H100	100	CWA	120
1	WS35	35	HYBRID	45
1	WS50	50	HYBRID	68
1	WS100	100	HYBRID	120

Where:
M = Metal Halide
HPS = High Pressure Sodium
H = Mercury
WS = White Sodium
HX = High Reactance Ballast
HPF = High Power Factor
R = Reactor Ballast
CWA = Constant Wattage Autoreactor Ballast

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