HIGH-EFFICIENCY PARKING STRUCTURE LIGHTING SPECIFICATION

Parking structures can gain higher-quality light, which uses less energy and can be more easily controlled, by replacing traditional high-intensity discharge (HID) lighting sources with fluorescent, induction, and light-emitting diode (LED) lighting sources. Each of these high-efficiency sources works better than HIDs with controls, such as occupancy sensors and dimmers, and has the same, if not longer, rated life spans as HID sources. Because lighting improvements can be made without major structural changes, the returns on investment are quick.

The U.S. Department of Energy Commercial Building Energy Alliances (CBEAs) identified parking structures as an area in which fluorescent, induction, or LED light sources can dramatically improve lighting quality and energy performance. A CBEA Project Team comprised of members from the retail, commercial real estate, and hospital sectors, with support from the Pacific Northwest National Laboratory, developed a technical specification that indicates an installed power density that is 40 percent below ASHRAE Standard 90.1-2007 energy code. Additional energy savings are possible from the use of lighting controls and daylighting. Companies can use the specification to stipulate performance expectations as well as warranty and testing information to manufacturers in order to get a product that outperforms traditional HID lighting sources.

For more information on this and other technical specifications being developed by CBEA members, visit http://www1.eere.energy.gov/buildings/alliances/technologies.html.

PART 1 – GENERAL

1.1 SUMMARY

The parking structure lighting performance specification is intended to provide adequate illumination in parking structures (also known as parking garages) and save energy by reducing the installed power density of equipment below code as well as using controls to further reduce energy use. Revisions to this specification may occur in the future.

1.2 REFERENCES

A. The publications listed below form a part of this specification to the extent referenced. Publications are referenced within the text by the basic designation only.

B. American National Standards Institute (ANSI)

1. ANSI/NEMA/ANSLG C78.376-2001 – American National Standard for the Specifications for the Chromaticity of Fluorescent Lamps
2. ANSI/NEMA/ANSLG C78.377-2008 – American National Standard for the Chromaticity of Solid-State Lighting Products
3. ANSI C82.SSL1 – SSL Drivers (in ANSI development)
4. ANSI C82.11-2002 – For Lamp Ballasts, High-Frequency Fluorescent Lamp Ballasts – Supplements
5. ANSI C82.77-2002 – Harmonic Emission Limits – Related Power Quality Requirements for Lighting Equipment

C. American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)

1. Std. 90.1-2010 – ANSI/ASHRAE/IES Standard 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings

D. American Society for Testing and Materials International (ASTM)

1. ASTM A 36 – Structural Steel
2. ASTM A 123 – Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
3. ASTM A 153 – Zinc Coating (Hot-Dip) on Iron and Steel Hardware
4. ASTM A 595 – Steel Tubes, Low-Carbon, Tapered for Structural Use
5. ASTM F 1554 – Anchor Bolts, Steel, 36, 55, and 105-Ksi Yield Strength
6. ASTM B117-97 – Standard Practice for Operating Salt Spray (Fog) Apparatus
7. ASTM G53 – Standard Practice for Operating Light and Water Exposure Apparatus (Fluorescent UV – Condensation Type) for Exposure of Nonmetallic Materials

E. European Commission (EC)

1. RoHS Directive 2002/95/EC – On the restriction of the use of certain hazardous substances in electrical and electronic equipment
2. WEEE Directive 2002/96/EC – On waste electrical and electronic equipment

F. Federal Communications Commission (FCC)

1. CFR Title 47 Part 18 Subpart C – RF Lighting Devices

G. Illuminating Engineering Society of North America (IESNA)

1. DG-13-98 – Guide for the Selection of Photocontrols for Outdoor Lighting Applications
2. LM-10-96 – Photometric Testing of Outdoor Fluorescent Luminaires
3. LM-64-01 – Photometric Measurements of Parking Areas
4. LM-79-08 – IESNA Approved Method for the Electrical and Photometric Measurements of Solid-Sate Lighting Products
5. LM-80-08 – IESNA Approved Method for Measuring Lumen Maintenance of LED Light Sources
6. RP-20-98 – Recommended Practice for Lighting Parking Facilities
7. TM-15-11 – Luminaire Classification System for Outdoor Luminaires

H. Institute of Electrical and Electronics Engineers (IEEE)

1. ANSI/IEEE C2 – National Electrical Safety Code
2. C62.41.1-2002 – IEEE Guide on the Surge Environment in Low-Voltage (1000V and less) AC Power Circuits

3. C62.41.2-2002 – IEEE Recommended Practice on Characterization of Surges in Low-Voltage (1000W and less) AC Power Circuits
4. C62.45-2002 – IEEE Recommended Practice on Surge Testing for Equipment Connected to Low-Voltage (1000 V and Less) AC Power Circuits

I. International Electrotechnical Commission (IEC)

1. IEC 60529 – Degrees of Protection provided by enclosures (IPCode)

J. International Organization for Standardization (ISO)

1. ISO 14021 - Environmental Labels and Declarations

K. National Electrical Manufacturers Association (NEMA)

1. LSD23-2002 – Recommend Practice – Lamp Seasoning for Fluorescent Dimming Systems
2. WD 7-2000 – Occupancy Motion Sensors

L. National Fire Protection Association (NFPA)

1. NFPA 70 – National Electrical Code

M. Underwriter's Laboratory (UL)

1. UL 773 – Standard for Safety of Plug-In, Locking Type Photo Controls for Use with Area Lighting
2. UL 935 – Standard for Fluorescent-Lamp Ballasts
3. UL 1449 – Surge Protective Devices
4. UL 1598 – Luminaires
5. UL 8750 – Light-Emitting Diode (LED) Equipment for Use in Lighting Products

N. U.S. Department of Defense

1. MIL-HDBK 217F (Change 2) – Reliability Prediction of Electronic Equipment

1.3 SECTION INCLUDES

Luminaires, including light sources, ballasts/drivers, wiring, and lighting controls for lighting in parking structures.

1.4 QUALITY ASSURANCE

A. Testing shall be conducted in accordance with the applicable IES and ANSI-approved methods for products using the applicable sources.

1. Provide a test report from a laboratory that is either:

a. Accredited by the National Voluntary Laboratory Accreditation Program (NVLAP) or one of its Mutual Recognition Arrangement (MRA) signatories. If the laboratory used for this test is accredited by NVLAP or one of its MRA signatories it must also have a scope of accreditation that includes the method of measurement reference standard for this performance characteristic;

or,

b. A CALiPER-recognized laboratory: http://www1.eere.energy.gov/buildings/ssl/test_labs.html.

2. LM-79 and LM-80 laboratory test results must be produced using the specific LED package(s)/module(s)/array(s) and power supply combination that will be used in production.

1.5 SITE LIGHTING SYSTEM PERFORMANCE

A. Energy Conservation

1. Lighting within the parking structure (excluding dedicated emergency lighting) shall not exceed a maximum of 0.18 W/ft^2 lighting power density.

B. Light Loss Factors (LLF)

1. Assume Luminaire Dirt Depreciation (LDD):
   a. Use http://www.epa.gov/airtrends/pm.html#pmloc to determine the particulate matter (PM) for the site and determine the applicable LDD for the site based on the PM per RP-20.
2. Assume the following Lamp Lumen Depreciation (LLD):
   a. Estimated LLD values at fluorescent/induction (70% of rated life) and LEDs (70% of initial light output) for the light sources allowed within this specification:
      - 0.92 for fluorescent luminaires
      - 0.70 for LED-dedicated luminaires
      - 0.60 for induction luminaires.
3. Luminaire ambient temperature factor (LATF): Assume the appropriate effects from temperature on the lumen output of the luminaire.
   a. Locations where the mean number of days annually with a minimum temperature equal or less to 0° C (32° F) number more than 120 (see Appendix A) are considered “COLD” places. Use a LATF of:
      - 0.80 in the fluorescent calculations
      - 0.80 in the induction calculations
      - 1.0625 in the LED calculations.

b. Locations where the mean number of days annually with a minimum temperature equal or less to 0° C (32° F) number less than 120 (see Appendix A) are considered "WARM" places. LATF of:

- 1.00 in the fluorescent calculations
- 1.00 in the induction calculations
- 0.90 in the LED calculations.

c. Refer to Appendix A for sample temperature information for different locations in the United States.

C. Lighting Requirements (see Appendix B for diagrams of parts of the structure)

Area of Parking Structure	**Minimum Horizontal[1] Requirement**		**Uniformity Max:Min**	**Vertical[2] Illuminance Requirement**	
	Lux	**fc**		**Lux**	**fc**
Covered Parking Areas (Basic)	20.0	2.0	7:1	12.0	1.2
Ramps					
Day	20.0	2.0	10:1	10.0	1.0
Night	20.0	2.0	10:1	5.0	0.5
Vehicle Entry/Exit					
Day[3]	600.00	60.0	10:1	300.00	30.0
Night	10.00	1.0	10:1	12.0	1.2
Uncovered Parking Areas (Top Deck)[4]	7.5	0.75	10:1	4.0	0.4

Note:

1. Measured on the parking surface, without any shadowing effect from parked vehicles or columns.
2. Vertical measurements shall be taken at 5 ft (1.5 m) vertically above parking surface at the point of lowest horizontal illuminance facing inward toward the flow of traffic.
3. Contributions from daylight may be factored into these values.
4. Uncovered parking requirements **not** from RP-20.

1.6 SUBMITTALS

A. Performance Reports: Submit the following for approval when required by the Site owner:

1. Computer-generated photometric analysis of proposed **DAY 1** (defined as the initial illuminance values) of the lighting installation. Submittal should include the following requirements:

   a. Provide horizontal illuminance measurements (in footcandles) at grade. Spacing between measurement points shall be 5 ft on center.

   b. Computer calculation should use the following applicable LLF values: 1.0 LLD and 1.0 LDD.

2. Computer generated photometric analysis of proposed **FUTURE DATE (**defined as assuming numerous thousands of hours of operation specified by site) of the lighting installation. Submittal should include the following requirements:
    a. Provide horizontal illuminance measurements (in footcandles) at grade. Spacing between measurement points shall be 10 ft on center.
    b. Computer calculation should use the LLF values as specified above.

B. Fluorescent Product Data: For each type of lighting luminaire, arranged in order of luminaire designation. Include data on features, accessories, finishes, and the following:

1. Physical description of luminaire, including dimensions.
2. Ballast, including ballast type (e.g., programmed rapid-start), ballast factor, catalog code, input watts for ballast when operating the applicable number of light sources, and device reliability.
    a. Device reliability shall be calculated per MIL-HDBK-217F(2) using mean time before failures (MTBF) as metric, including load condition and temperature under which MTBF was calculated.
3. Initial lumen output of light source and operating temperature in degree Celsius (°C) at which the lumens are rated.
4. Luminaire coefficient of utilization (CU) data for reflectance values of 30/0/20 for both room cavity ratios (RCRs) 2 and 3.
5. Luminaire efficiency (also known as fixture efficiency).
6. Mean (also known as design) lumen output of light source and percentage of rated life in which mean/design value derived.
7. Target efficacy rating (TER)[1] of luminaire (initial lumens × ballast factor × (average of CU values for 30/0/20 at RCR 2 and 3) / ballast input watts).
8. Mean lumens per watt of lamp + ballast (mean lumens / ballast input watts).
9. Luminaire efficacy of luminaire (initial lumens × ballast factor × luminaire efficiency / ballast input watts).
10. Table of zonal lumen output in 10° vertical increments showing both the lumen value and the percentage of total output per 10° increment.
11. Correlated color temperature (CCT) of light source.
12. Color-rendering index (CRI) of light source.
13. See Appendix C for information to highlight in the product submittal.

C. Induction Product Data: For each type of lighting luminaire, arranged in order of luminaire designation. Include data on features, accessories, finishes, and the following:

1. Physical description of luminaire, including dimensions.

[1]TER – Target efficacy rating is a metric developed by NEMA. This metric supersedes luminaire efficacy rating. More information about TER in NEMA LE6-2008 can be found at http://www.nema.org/stds/le6.cfm. This specification requires the necessary data for TER calculations in section 1.6 Submittals.

2. Generator information, including generator efficiency (rated lamp wattage/input wattage), catalog codec input watts, and device reliability.
    a. Device reliability shall be calculated per MIL-HDBK-217F(2) using MTBF as metric, including load condition and temperature under which MTBF was calculated.
3. Luminaire photometric reports per IESNA LM-10-96, including laboratory name, report number, date, luminaire catalog number, luminaire, and light source specifications.
4. Initial lumen output of light source and temperature at which the lumens are rated.
5. Mean (also known as design) lumen output of light source and percentage of rated life in which mean/design value derived.
6. Luminaire CU data for reflectance values of 30/0/20 for both RCRs 2 and 3.
7. Luminaire (also known as fixture) efficacy.
8. TER of luminaire (initial lumens × (average of CU values for 30/0/20 at RCR 2 and 3) / input watts).
9. Table of zonal lumen output in 10° vertical increments showing both the lumen value and the percentage of total output per 10° increment.
10. CCT of light source.
11. CRI of light source.
12. See Appendix C for information to highlight in the product submittal.

D. LED Product Data: For each type of lighting luminaire, arranged in order of luminaire designation. Include data on features, accessories, finishes, and the following:

1. Physical description of luminaire including dimensions.
2. Driver including driver efficiency, catalog code, input watts, and device reliability.
    a. Device reliability shall be calculated per MIL-HDBK-217F(2) using MTBF as metric, including load condition and temperature under which MTBF was calculated.
3. Luminaire Lighting Facts Label (www.lightingfacts.com)
    a. It is acknowledged that a label is not possible for every possible configuration of a product line. However, the label is important. Manufacturer must demonstrate the label for at least one parking structure luminaire that they manufacture.
4. Luminaire photometric reports per IES LM-79, including laboratory name, report number, date, luminaire catalog number, luminaire, and light source specifications.
5. Initial lumen output of luminaire and ambient temperature and drive current at which the lumens are rated.
6. Luminaire coefficient of utilization data for reflectance values of 30/0/20 for both RCRs 2 and 3 for LED luminaires used in the covered section of the parking structure.

7. Luminaire (also known as fixture) efficacy.
8. TER of luminaire (initial lumens × (average of CU values for 30/0/20 at RCR 2 and 3) / input watts) – only for LED luminaires used in the covered section of the parking structure.
9. Table of zonal lumen output in 10° vertical increments showing both the lumen value and the percentage of total output per 10° increment.
10. CCT of light source with Duv values.
11. CRI of light source.
12. A minimum of 6,000 hours of continuous operation of the LEDs at three different temperatures in accordance with LM-80.
13. See Appendix C for information to highlight in the product submittal.
14. Provide documentation of the expected useful life as defined in Appendix D.

E. Provide safety certification and file number as required for the luminaire family which shall be listed, labeled, or identified in accordance with NFPA 70. Applicable testing bodies are determined by the U.S. Occupational Safety and Health Administration (OSHA) as Nationally-Recognized Testing Laboratories (NRTL) and include: CSA (Canadian Standards Association), ETL (Edison Testing Laboratory), and UL (Underwriters Laboratory).

1.7 WARRANTY

A. Fluorescent Luminaire Warranty

1. Provide a comprehensive written **5-year** warranty for including luminaire finish, on-site replacement of material, and workmanship. On-site replacement includes transportation, removal, and installation of new products. Finish warranty shall include warranty against failure or substantial deterioration such as blistering, cracking, peeling, chalking, or fading.
2. Provide a written **5-year** replacement material warranty on all power supply units (PSU).
3. Provide a written **3-year** warranty that fluorescent color shift from initial color shall be less than 0.007 on the CIE 1976 (u',v') diagram. This requirement is comparable to a seven-step MacAdam ellipse.

B. Induction Luminaire Warranty

1. Provide a comprehensive written **5-year** warranty for including luminaire finish, on-site replacement of material, and workmanship. On-site replacement includes transportation, removal, and installation of new products. Finish warranty shall include warranty against failure or substantial deterioration such as blistering, cracking, peeling, chalking, or fading.
2. Provide a written **5-year** replacement material warranty on all PSUs.
3. Provide a written **5-year** replacement on light source.

4. Provide a written **5-**year warranty that the induction color shift from initial color shall be less than 0.007 on the CIE 1976 (u',v') diagram. This requirement is equivalent to a 7-step MacAdam ellipse.

C. LED Luminaire Warranty

1. Provide a comprehensive written **5-year** warranty for including luminaire finish, on-site replacement of material, and workmanship. On-site replacement includes transportation, removal, and installation of new products. Finish warranty shall include warranty against failure or substantial deterioration such as blistering, cracking, peeling, chalking, or fading.
2. Provide a written **5-year** replacement material warranty for defective or non-starting LED source assemblies.
3. Provide a written **5-year** replacement material warranty on all PSUs.
4. Provide a written **5-year** replacement warranty for non-maintained illuminance levels (see section 1.5 C) on all light sources (LED package, LED array, or LED module) including, but not limited to the LED die, encapsulate, and phosphor. If the expected useful life of the luminaire system as defined in section 2.4 C is not maintained, then the manufacturer shall replace the light source(s) or luminaire as needed.
5. Provide a written **5-year** warranty that LED color shift from initial shall color be less than 0.007 on the CIE 1976 (u',v') diagram. This requirement is comparable to a seven-step MacAdam ellipse.

PART 2 – PRODUCTS

2.1 GENERAL

A. Luminaire shall be the type indicated on Drawings and as specified. Luminaires of same type shall be of one manufacturer.

B. Luminaires shall be of the types and manufacturers described in section 2.2, with light source, wattage and voltage as indicated on Drawings. Specific manufacturer and model number references are indicated as a standard of performance and quality; other manufacturers' models may be suppled provided the product meets or exceeds the specifications. The alternate luminaires must achieve the equal or better photometric levels and uniformity ratios.

C. All luminaires shall be baked-on enamel or powder-coated, unless otherwise specified in subsections below.

2.2 LUMINAIRE REQUIREMENTS

A. Covered Parking Structure Luminaire General Requirements

1. The luminaire shall produce a minimum of 20% of total output in the 60° to 70° vertical zones.
2. Luminaires shall have a TER greater than 30.

3. The luminaire shall have an initial ***luminaire efficacy*** greater than 60 lumens per watt (lm/W).
4. Electrical system cavity shall be wet-location rated and be field accessible for service or repair needs.
5. Optical cavity shall be a minimum IP-65 in accordance with IEC 60529.
6. Luminaires shall be fully assembled and electrically tested before shipment from factory.
7. Luminaires shall have country appropriate governing mark and certification.
8. Color of the luminaire shall be as specified by the site owner.
9. If a lens not integral to an LED is used, the luminaire optical enclosure (lens/window) shall be constructed of a one piece, UV resistant, clear, polycarbonate, acrylic or glass, sealed to IP-65.
10. 80% of the luminaire material by weight should be recyclable at end of life. Luminaire shall be designed for end-of-life disassembly per ISO 14021.

B. Uncovered Parking Structure Luminaire General Requirements

1. Luminaires used in the uncovered portion (top deck) of the parking structure can only be LED.
2. Luminaire shall have a maximum BUG Rating of U3-G3.[2]
3. The luminaire shall have an initial ***luminaire efficacy*** greater than 50 LPW.
4. Electrical system cavity shall be wet-location rated and be field accessible for service or repair needs.
5. Optical cavity shall be a minimum IP-65 in accordance with IEC 60529.
6. Uncovered parking structure luminaires shall meet the “basic” electrical immunity requirements in Appendix E. Site owner might request that the electrical immunity meet “elevated.”

C. Electromagnetic interference

1. Shall have a total harmonic distortion (THD) of ≤ 20% at full input power and across specified voltage range.
2. Shall comply with FCC 47 CFR part 15 non-consumer radio frequency interference / electromagnetic interference standards.

2.3 POWER-SUPPLY UNIT (BALLAST, DRIVER, OR GENERATOR) REQUIREMENTS

A. Fluorescent ballasts shall meet the following requirements:

1. Ballasts shall be class P, electronic high-frequency (20 to 33 kHz or ≥ 40 kHz) programmed rapid-start-type ballasts.

[2] BUG Ratings – Refer to IESNA TM-15-11 and Addendum A for values.

2. Ballasts shall have the following ballast efficacy factors (BEF), defined as BF × 100 / input watts.
    a. One-lamp configuration: ≥ 2.84.
    b. Two-lamp configuration: ≥ 1.48.
3. Ballasts shall have a minimum relative system efficiency (RSE) of 95%, defined as BEF × total rated lamp power / 100.
4. Ballasts shall have a power factor (PF) of: ≥ 0.95.
5. Input voltage capable of 120 – 277 or 347 – 480 (±10%) volt, single phase or as required by the site.
6. Ballasts shall be color coded per ANSI C82.11.
7. Ballasts shall be Class A noise rated.
8. Ballasts shall be Reduction of Hazardous Substances (RoHS) compliant.
9. Ballasts shall comply with ANSI C62.41.2 Category A for transient protection.
10. Ballasts shall not contain any polychlorinated biphenyl.
11. Ballasts shall have a minimum starting temperature of -18° C (0° F) for standard fluorescent lamps.

B. Induction generators shall meet the following requirements:

1. Generators shall have a minimum efficiency of 85%.
2. Generators shall have a PF of: ≥ 0.90.
3. Input voltage shall be capable of 120 to 480 (±10%) volt, single phase or as required by the site.
4. Generators shall be Class A noise rated.
5. Generators shall be RoHS compliant.
6. Generators shall have a minimum starting temperature of -18° C (0° F).

C. LED drivers shall meet the following requirements:

1. Drivers shall have a minimum efficiency of 85% at specified loading.
2. Drivers shall have a starting temperature -40° C.
3. Input voltage shall be capable of 120-277, 347, or 480 (±10%) volt, single phase or as required by the site.
4. Power supplies can be UL Class I or II output.
5. Drivers shall have a PF of: ≥ 0.90.
6. Drivers shall be RoHS compliant.

2.4 LIGHT SOURCE REQUIREMENTS

A. Fluorescent lamps shall meet the following requirements:

1. Light sources in this application can be:
   a. 4 ft linear T8: F32T8 (32W nominal) [do not use "energy saving" T8 lamps]
   b. ≈ 4 ft linear T5: F28T5, F54T5HO, F49T5HO lamps
   c. ≈ 2 ft compact fluorescent linear T5: FT40, FT55, and FT80 lamps.
2. All lamps shall have the following characteristics:
   a. Low-mercury meeting Toxicity Characteristic Leaching Procedure (TCLP) standards
   b. Produce at least 2,900 lumens (initial) when measured on a reference ballast
   c. A CCT between 3000 – 4100 K
   d. A CRI ≥ 80
   e. LLD shall be 92% or greater at 20,000 hours.

B. Induction lamps shall meet the following requirements:
1. Produce at least 3,500 lumens (initial) when measured on a reference generator
2. A CCT between: 3000 – 5000 K
3. A CRI ≥ 80
4. LLD shall be 80% or greater at 40,000 hours.

C. LED sources shall meet the following requirements:
1. CCT: 2700 – 6500 K, nominal and target CCT, Duv, and tolerances listed below:

White Color Range	Manufacturer-Rated Nominal CCT (K)	Allowable Chromaticity Values	
		Measured CCT (K)	Measured Duv
Warm	2700	2580 to 2870	-0.006 to 0.006
	3000	2870 to 3220	-0.006 to 0.006
	3500	3220 to 3710	-0.006 to 0.006
Neutral	4000	3710 to 4260	-0.005 to 0.007
	4500	4260 to 4746	-0.005 to 0.007
Cool	5000	4745 to 5311	-0.004 to 0.008
	5700	5310 to 6020	-0.004 to 0.008
	6500	6020 to 7040	-0.003 to 0.009

2. CRI ≥ 70.
3. The device (LED chip or package) manufacturer shall subject all products to the tests listed in Appendix B.
4. The device (LED chip or package) shall meet the requirements in section 2.4 D.

D. LED-dedicated Luminaire Expected Useful Life and Depreciation
1. The LED light source(s) have been tested according to LM-80.

2. The LED driver current specified by the luminaire manufacturer is less than or equal to the driver current specified in the LM-80 test report.
3. The LED light source(s) manufacturer prescribes/indicates a temperature measurement point (T_s) on the light source(s).
4. The Ts is accessible from outside the luminaire to allow temporary attachment of a thermocouple for measurement of in situ temperature. Access via temporary hole in the luminaire housing, tightly resealed during testing with putty or other flexible sealant is allowable.
5. For the hottest LED light source in the luminaire, the temperature measured at the T_s during ISTMT is less than or equal to the temperature specified in the LM-80 test report for the corresponding driver current or higher, within the manufacturer's specified operating current range.
    a. The ISTMA laboratory must be approved by OSHA as an NRTL; or must be qualified, verified and recognized through the CALiPER program; or must be recognized through UL's Data Acceptance Program.
    b. The ISTMT must be conducted with the luminaire installed in the appropriate application as defined by ANSI/UL 1598 (hardwired luminaires).

2.5 CONTROL REQUIREMENTS

A. Daylighting Controls

1. All luminaires located along the perimeter zone (20 ft from the face of the structure) and in areas where the openness-to-wall ratio is greater than or equal to 40% shall be connected to individual photosensors and a daylight harvesting strategy sought.[3]
2. The photocell control system shall have the following characteristics:
    a. 15- to 30-second built-in time delay to prevent response to momentary lightning flashes, car headlights, or cloud movements.
    b. Set the sensor set point to energize the lighting system when daylight and the electric lighting provide less than 10 footcandles on the parking surface below the sensor. When more than 10 footcandles is provided on the parking surface below the sensor for more than 30 minutes, turn off the electric lighting connected to the sensor.
    c. Mounted in an un-obscured location for measuring the daylight and electric light on the parking surface with a separate control/calibration module mounted separately and in an accessible location.
    d. Use relays that are UL 773 or UL 773A listed and designed to fail in the "on" position.
3. Luminaires located in the vehicle entry/exit area needed during daylight hours shall be connected to either a photosensor or astronomical timeclock to reduce the lighting in this area during non-daylight hours.

[3] Openness-to-wall ratio is defined as the area of the vertical plane of the structure (wall) that is open (e.g., fenestration, not enclosed and open to the air/environment) compared to the area of the wall that is solid/opaque.

B. Occupancy Sensor Controls

1. Install one occupancy sensor per luminaire and aim sensors in locations to achieve coverage of areas indicated. Coverage patterns shall be de-rated as recommended by manufacturer based on mounting height of sensor, column locations, and dropped beams. Do not simply use gross rated coverage in manufacturer's product literature.
2. Occupancy/vacancy sensors shall comply with NEMA Standard WD 7-2000 which provides for testing requirements on the issues of performance sensitivity.
3. Sensor type: Infrared or ultra high frequency (microwave). Detect occupancy by sensing a change in sensor pattern in area of coverage.
4. Sensors shall be located or shielded or controlled by software to adjust sensitivity based on ambient temperature or air temperature variations.
5. Sensor must incorporate a failsafe feature such that lamps fail "on" in the event of sensor failure.
6. Occupancy sensors can either dim or switch the luminaires from a "high" to a "low" setting or from on to off. Site owner to specify.

PART 3 – EXECUTION

3.1 INSTALLATION

A. Disconnect all power sources prior to installation.

B. Follow manufacturers' recommended installation procedures.

3.2 TESTING AND COMMISSIONING

A. Ultrasonic sensors should have their sensitivity adjusted when interference from air movement is at its maximum.

3.3 MANUFACTURER SERVICES

A. Manufacturers must provide installation and troubleshooting support via telephone.

END OF SECTION

Appendix A – Ambient Temperature Information

Location	# of Days	Location	# of Days	Location	# of Days
Flagstaff, AZ	209	Chicago, IL	131	Charlotte, NC	63
Phoenix, AZ	6	Indianapolis, IN	116	Oklahoma City, OK	78
Los Angeles, CA	0	Wichita, KS	109	Portland, OR	43
Fresno, CA	21	Louisville, KY	88	Eugene, OR	55
Sacramento, CA	16	New Orleans, LA	14	Charleston, SC	33
San Francisco, CA	2	Shreveport, LA	37	Nashville, TN	76
Denver, CO	155	Kansas City, MO	111	Dallas, TX	39
Jacksonville, FL	15	Jackson, MS	49	Houston, TX	19
Orlando, FL	2	Las Vegas, NV	30	Salt Lake City, UT	123
Atlanta, GA	52	Reno, NV	166	Richmond, VA	84
Savannah, GA	28	Albuquerque, NM	116	Seattle, WA	31

Note: This table is Table 9-9 from Parking Structures: Planning, Design, Construction, Maintenance and Repair by Chrest et al. The source for the data is from the National Weather Service Climatological Data Center.

Appendix B – Sample Parts of the Parking Structure

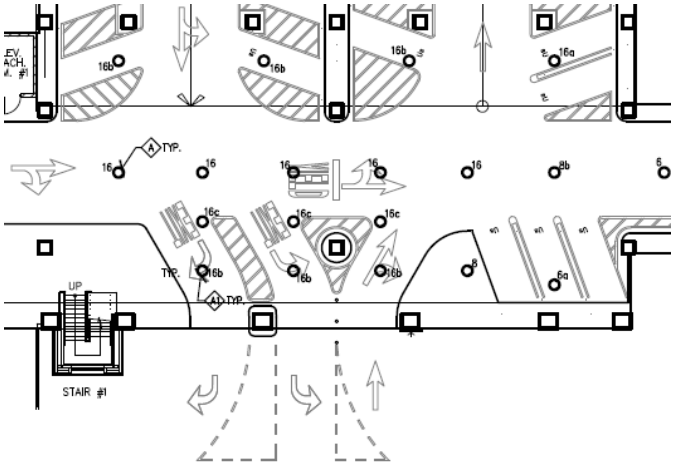

Figure 1 – Covered Vehicle Entry/Exit

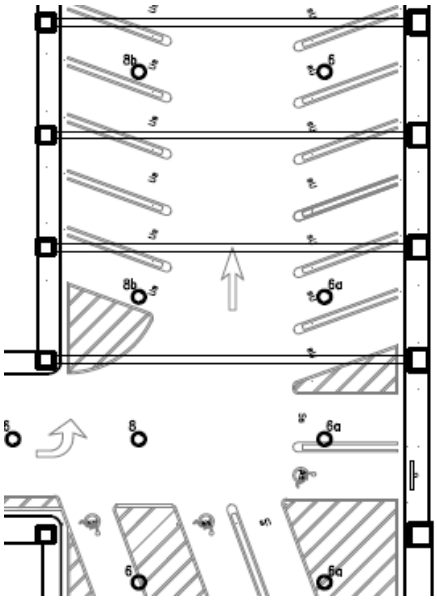

Figure 2 – Covered Parking Area

Appendix C – Sample Manufacturer Submittal Information

Manufacturer should highlight this information when submitting to site

Luminaire Submittal #1 – Physical Description
Luminaire is 18 in. wide × 18 in. long × 6 in. deep. The luminaire is constructed of die-cast aluminum with a powder-coat finish. Luminaire weighs 15 pounds. Means of mounting luminaire.

Luminaire Submittal #2 – Driver Information
Philips/Advance Transformers – LED120A0024V10D
Input Power Max (W): 31.9
Output Power (W): 25.5
Driver Efficiency: 25.5 / 31.9 = 79.9%
Min. / Max/ Ambient Temperature: -40° C / 60° C

Luminaire Submittal #3 – LED Lighting Facts Label

Luminaire Submittal #4 – Coefficient of Utilization

Coefficients of Utilization - Zonal Cavity Method
Effective Floor Cavity Reflectance 0.20

RC	50			30			10			0
RW	50	30	10	30	10	0	50	30	10	0
0	111	111	111	106	106	104	102	102	102	100
1	93	89	85	85	82	79	85	82	80	77
2	76	69	63	67	62	**57**	70	65	60	58
3	63	55	48	53	47	**41**	57	51	46	44
4	53	44	37	43	37	31	48	42	36	33
5	46	36	29	35	29	23	41	34	29	26
6	40	31	24	30	23	16	36	29	23	21
7	35	26	20	25	19	13	32	25	19	17
8	31	23	16	22	16	12	29	21	16	14

9	28	20	14	19	14	9	26	19	14	12
10	26	18	12	17	12	5	24	17	12	10

Luminaire Submittal #5 – Luminaire Efficacy

- Initial Lumens: 6011
- Input Power: 63W
- Luminaire Efficacy: 95 LPW

Luminaire Submittal #6 – Target Efficacy Rating Calculation

- Initial Lumens: 6011
- Ballast Factor: 1.0 (LED Device)
- CU 30/0/20 RCR 2: 57
- CU 30/0/20 RCR 3: 41
- CU 30/0/20 Average: 49
- Input Power: 63W
- TER: 6011 × .49 / 63W = 47 LPW

Luminaire Submittal #7 – Table of Zonal Lumen Output

Zone	Zonal Lumens	Percent of Total Luminaire Output
0-10	59.949	1.00%
10-20	190.1865	3.16%
20-30	209.424	3.48%
30-40	389.31	6.48%
40-50	1044.692	17.38%
50-60	1610.0307	26.78%
60-70	1589.0928	26.43%
70-80	843.3712	14.03%
80-90	75.51	1.26%
90-100	0	0.00%
100-110	0	0.00%
110-120	0	0.00%
120-130	0	0.00%
130-140	0	0.00%
140-150	0	0.00%
150-160	0	0.00%
160-170	0	0.00%
170-180	0	0.00%

Luminaire Submittal #8 – Correlated Color Temperature

- CCT: 4152 K
- Duv tolerance of 0.002

Luminaire Submittal #9 – Color Rendering Index

- CRI: 82

Appendix D – Estimating LED Lumen Maintenance

IES TM-21 allows for extrapolation of expected lumen maintenance from available test data. The extent of such extrapolation is limited by the duration of testing completed and the number of samples used in the testing. The TM-21 methodology shall be used by the manufacturer to determine lamp lumen depreciation at end of lumen maintenance life per section 1.6 C.

The applicant may estimate lumen maintenance in one of the following two ways:

Option 1: Component Performance

Under this compliance path, the applicant must submit calculations per TM-21 predicting lumen maintenance at the luminaire level using In Situ Temperature Measurement Testing (ISTMT) and LM-80 data. To be eligible for the component performance option, ALL of the conditions below must be met. If ANY condition is not met, the component performance option may not be used and the applicant must use Option 2 for compliance.

- The LED light source(s) have been tested according to LM-80.
- The LED drive current specified by the luminaire manufacturer is less than or equal to the drive current specified in the LM-80 test report.
- The LED light source(s) manufacturer prescribes/indicates a temperature measurement point (T_S) on the light source(s).
- The T_S is accessible to allow temporary attachment of a thermocouple for measurement of in situ temperature. Access via a temporary hole in the housing, tightly resealed during testing with putty or other flexible sealant is allowable.
- For the hottest LED light source in the luminaire, the temperature measured at the T_S during ISTMT is less than or equal to the temperature specified in the LM-80 test report for the corresponding drive current or higher, within the manufacturer's specified operating current range.
    - The ISTMT laboratory must be approved by the Occupational Safety and Health Administration as a Nationally Recognized Testing Laboratory; or must be qualified, verified, and recognized through DOE's CALiPER program; or must be recognized through UL's Data Acceptance Program.
    - The ISTMT must be conducted with the luminaire installed in the appropriate application as defined by ANSI/UL 1598 (hardwired luminaires), with bird-fouling appropriately simulated (and documented by photograph) as determined by the manufacturer.

Option 2: Luminaire Performance

Under this compliance path, the applicant must submit TM-21 calculations based on LM-79 photometric test data for no less than three samples of the entire luminaire. Duration of operation and interval between photometric tests shall conform to the TM-21 criteria for LED light sources. For example, testing solely at 0 and 6000 hours of operation would not be adequate for the purposes of extrapolation.

Between LM-79 tests, the luminaire test samples must be operated long-term in the appropriate application as defined by ANSI/UL 1598 (hardwired luminaires). The test laboratory must hold National Voluntary Laboratory Accreditation Program accreditation for the LM-79 test procedure

or must be qualified, verified, and recognized through the U.S. Department of Energy's CALiPER program. The extent of allowable extrapolation (either 5.5 or 6 times the test duration) depends on the total number of LED light sources (no less than 10 and preferably more than 19) installed in the luminaire samples in accordance with TM-21.

This compliance path poses a greater testing burden to luminaire manufacturers but incorporates long-term testing of other components in the system, such as drivers.

Under either compliance path, values used for extrapolation shall be summarized in accordance with TM-21 Tables 1 and 2. Submitted values for lumen maintenance lifetime and the associated percentage lumen maintenance shall be "reported" rather than "projected" as defined by TM-21. Supporting diagrams are requested to facilitate interpretation by the Owner.

Appendix E – Electrical Immunity

Test Procedure

- Electrical Immunity Tests 1, 2, and 3, as defined by their test specifications, shall be performed on an entire powered and connected luminaire, including any control modules housed within the luminaire, but excluding any control modules mounted externally, such as a National Electrical Manufacturers Association socket connected photo-control. A shorting cap should be placed across any such exterior connector.
- The luminaire shall be connected to an AC power source with a configuration appropriate for nominal operation. The AC power source shall have a minimum available short-circuit current of 200A. The luminaire shall be tested at the nominal input voltage specified, or at the highest input voltage in the input voltage range specified.
- Electrical immunity test waveforms shall be superimposed on the input AC power line at a point within 6 in. (15 cm) of entry into the luminaire using appropriate high-voltage probes and a series coupler/decoupler network appropriate for each coupling mode, as defined by ANSI/IEEE C62.45-2002. The test area for all tests shall be set up according to ANSI/IEEE C62.45-2002, as appropriate.
- Prior to electrical immunity testing a set of diagnostic measurements shall be performed, and the results recorded to note the pre-test function of the luminaire after it has reached thermal equilibrium. These measurements should include at a minimum:
    a) For all luminaires, real power, input roote-mean-square (RMS) current, power factor and total harmonic distortion at full power/light output
    b) For luminaires specified as dimmable, real power, input RMS current, power factor and total harmonic distortion at a minimum of four additional dimmed levels, including the rated minimum dimmed level.
- Tests shall be applied in sequential order (Test 1, followed by Test 2, followed by Test 3). If a failure occurs during Test 3, then Test 3 shall be re-applied to a secondary luminaire of identical construction.

Following the completion of Tests 1, 2, and 3, the same set of diagnostic measurements performed pre-test should be repeated for all tested luminaires, and the results recorded to note the post-test function of the luminaire(s).

A luminaire must function normally and show no evidence of failure following the completion of Test 1 + Test 2 + Test 3 (for a single tested luminaire), or the completion of Test 1 + Test 2 on a primary luminaire and Test 3 on a secondary luminaire. Abnormal behavior during testing is acceptable.

A luminaire failure will be deemed to have occurred if any of the following conditions exists after the completion of testing:

a) A hard power reset is required to return to normal operation
b) A noticeable reduction in full light output (e.g., one or more LEDs fail to produce light, or become unstable) is observed
c) Any of the post-test diagnostic measurements exceeds by ±5% the corresponding pre-test diagnostic measurement
d) The luminaire, or any component in the luminaire (including but not limited to an electrical connector, a driver, a protection component or module) has ignited or shows evidence of

melting or other heat-induced damage. Evidence of cracking, splitting, rupturing, or smoke damage on any component is acceptable.

Test Specifications

Note: L1 is typically "HOT," L2 is typically "NEUTRAL," and PE = Protective Earth.

- **Ring Wave**: The luminaire shall be subjected to repetitive strikes of a "C Low Ring Wave" as defined in ANSI / IEEE C62.41.2-2002, Scenario 1, Location Category C. The test strikes shall be applied as specified by Table 1.

  Prior to testing, the ring wave generator shall be calibrated to simultaneously meet BOTH the specified short circuit current peak and open circuit voltage peak MINIMUM requirements. Note that this may require that the generator charging voltage be raised above the specified level to obtain the specified current peak. Calibrated current probes/transformers designed for measuring high-frequency currents shall be used to measure test waveform currents.

  Test waveform current shapes and peaks for all strikes shall be compared to ensure uniformity throughout each set (coupling mode + polarity/phase angle) of test strikes, and the average peak current shall be calculated and recorded. If any individual peak current in a set exceeds by ±10% the average, the test setup shall be checked, and the test strikes repeated.

Table 1. 0.5 µS – 100Hz Ring Wave Specification

Parameter	Test Level/Configuration
Short Circuit Current Peak	0.5 kA
Open Circuit Voltage Peak	6 kV
Coupling Modes	L1 to PE, L2 to PE, L1 to L2
Polarity and Phase Angle	Positive at 90° and Negative at 270°
Test Strikes	5 for each Coupling Mode and Polarity/Phase Angle combination
Time between Strikes	1 minute
Total Number of Strikes	= 5 strikes × 3 coupling modes × 2 polarity/phase angles = 30 total strikes

- **Combination Wave**: The luminaire shall be subjected to repetitive strikes of a "C High Combination Wave" or "C Low Combination Wave," as defined in ANSI/IEEE C62.41.2-2002, Scenario 1, Location Category C. The test strikes shall be applied as specified by Table 2. The "Low" test level shall be used for luminaires with **Basic** Electrical Immunity requirements, while the "High" test level shall be used for luminaires with **Elevated** Electrical Immunity requirements.

  Prior to testing, the combination wave generator shall be calibrated to simultaneously meet BOTH the specified short circuit current peak and open circuit voltage peak MINIMUM requirements. Note that this may require that the generator charging voltage be raised above the specified level to obtain the specified current peak. Calibrated current probes/transformers designed for measuring high-frequency currents shall be used to measure test waveform currents.

  Test waveform current shapes and peaks for all strikes shall be compared to ensure uniformity throughout each set (coupling mode + polarity/phase angle) of test strikes, and the average peak

current shall be calculated and recorded. If any individual peak current in a set exceeds by ±10% the average, the test setup shall be checked, and the test strikes repeated.

Table 2: 1.2/50µS – 8/20 µS Combination Wave Specification

Parameter	Test Level/ Configuration	
1.2/50 µS Open Circuit Voltage Peak	Low: 6 kV	High: 10kV†
8/20 µS Short Circuit Current Peak	Low: 3 kA	High: 10kA
Coupling Modes	L1 to PE, L2 to PE, L1 to L2	
Polarity and Phase Angle	Positive at 90° and Negative at 270°	
Test Strikes	5 for each Coupling Mode and Polarity/Phase Angle combination	
Time Between Strikes	1 minute	
Total Number of Strikes	= 5 strikes × 3 coupling modes × 2 polarity/phase angles = 30 total strikes	

† This is a MINIMUM requirement. Note that for most combination wave generators, which have a source impedance of 2Ω, the generator charging voltage will need to be raised above the specified level (to somewhere in the vicinity of 20kV) to obtain the specified current peak.

- **Electrical Fast Transient**: The luminaire shall be subjected to "Electrical Fast Transient Bursts," as defined in ANSI/IEEE C62.41.2 -2002. The test area shall be set up according to IEEE C62.45-2002. The bursts shall be applied as specified by Table 3. Direct coupling is required; the use of a coupling clamp is not allowed.

Table 3: Electrical Fast Transient (EFT) Specification

Parameter	Test Level/Configuration
Open Circuit Voltage Peak	3 kV
Burst Repetition Rate	2.5 kHz
Burst Duration	15 milliseconds
Burst Period	300 milliseconds
Coupling Modes	L1 to PE, L2 to PE, L1 to L2
Polarity	Positive and Negative
Test Duration	1 minute for each Coupling Mode and Polarity combination
Total Test Duration	= 1 minute × 3 coupling modes × 2 polarities = 6 minutes