

NECA 500



Standard for Installing and Maintaining Indoor Commercial Lighting Systems

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(This foreword is not a part of the Standard)

Foreword

National Electrical Installation Standards™ (NEIS™) are designed to improve communication among specifiers, purchasers, and suppliers of electrical construction services. They define a minimum baseline of quality and workmanship for installing electrical products and systems. NEIS™ are intended to be referenced in contract documents for electrical construction projects. The following language is recommended:

Indoor commercial lighting systems shall be installed and maintained in accordance with NECA/IESNA 500, *Standard for Installing and Maintaining Indoor Commercial Lighting Systems* (ANSI).

Use of NEIS™ is voluntary, and the National Electrical Contractors Association (NECA) and the Illuminating Engineering Society of North America (IESNA) assumes no obligation or liability to users of this publication. Existence of a Standard shall not preclude any member or non-member of either organization from specifying or using alternate construction methods permitted by applicable regulations.

This publication is intended to comply with the National Electrical Code (NEC). Because they are quality Standards, NEIS may in some instances go beyond the minimum safety requirements of the NEC. It is the responsibility of users of this publication to comply with state and local electrical Codes and Federal and state OSHA safety regulations as well as follow manufacturer installation instructions when installing electrical products and systems.

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1. Scope

1.1 Products and Applications Included

This Standard describes installation and maintenance procedures for permanently installed incandescent, halogen, fluorescent, LED, and high-intensity discharge (HID) lighting systems operating at 1000 Volts or less installed indoors and commonly used in commercial and retail buildings, including, but not necessarily limited to, the following:

1. Recessed lighting systems, such as troffers, downlights, wallwashers, valance lights, and accent lights.
2. Surface mounted lighting systems, such as surface troffers, wraparounds, surface downlights, monopoints, and decorative fixtures.
3. Suspended lighting systems, such as pendant luminaires, direct, indirect, and uplight systems, and decorative luminaires.
4. Wall mounted lighting systems, such as sconces or wallpacks.
5. Track lighting systems.
6. Power over Ethernet (PoE) lighting systems.

In addition to luminaires, this Standard includes construction materials related to luminaires, including, but not necessarily limited to, lamps, conductors, wiring methods, various special screws and clips, and structural suspension components.

1.2 Products and Applications Excluded

This Standard does not cover the design of lighting systems or lighting control systems, or the installation or maintenance procedures for the following:

1. Outdoor lighting systems, including recessed-mounted, pole and bollard mounted, and ground-mounted (See NECA 501).
2. Industrial lighting systems and warehouse luminaires, including high-intensity discharge (HID) low-bay and high-bay lighting systems and lighting systems supported from industrial lighting track or wireway systems (See NECA 502).
3. Fiber optic lighting systems (see NECA 503).
4. Site lighting and area lighting, such as athletic fields or parking lots, and roadway and high mast lighting (See NECA 505).
5. Lighting systems designed for hazardous (classified) locations, as defined by NEC Article 500, in which special equipment listings or ratings are required, such as corrosive environments or cooking or fume hoods.
6. Lighting systems designed for manufacturing clean rooms, food preparation areas, showcases, refrigerated cases, and other special conditions.
7. High voltage lighting systems, such as neon or cold cathode.
8. Low voltage lighting systems in which the transformer is not integral to the luminaire and secondary wiring is required.
9. Exit signs and other forms of dedicated emergency lighting.
10. Temporary or portable lighting.
11. Lighting installed in elevators.
12. Luminaires installed as components of listed equipment or special assemblies.
13. Special lighting requirements for health care facilities.

- 210 14. Submerged and submersible systems such as luminaires for swimming pools, fountains, and
211 similar installations.
212 15. Horticultural lighting equipment.
213 16. Germicidal irradiation luminaires.
214
215

216 **1.3 Regulatory and Other Requirements**

217
218 All information in this publication is intended to conform to the National Electrical Code (ANSI/NFPA
219 70). Installers shall follow the NEC, applicable state and local Codes, manufacturer instructions, and
220 contract documents when installing and maintaining indoor commercial lighting systems.
221

222 Only qualified persons as defined in the NEC familiar with the construction and installation of indoor
223 commercial lighting systems shall perform the technical work described in this publication.
224 Administrative functions, such as receiving, handling and storing required in Section 4.1, and other tasks
225 shall be performed under the supervision of a qualified person. All work shall be performed in
226 accordance with NFPA 70E, *Standard for Electrical Safety in the Workplace*.
227

228 General requirements for installing electrical products and systems are described in NECA 1, *Standard*
229 *Practices for Good Workmanship in Electrical Construction (ANSI)*. Other NEIS provide additional
230 guidance for installing particular types of electrical products and systems. A complete list of *NEIS* is
231 provided in Annex D.
232
233

234 **1.4 Mandatory Requirements, Permissive Requirements, Quality and Performance** 235 **Recommendations, Explanatory Material, and Informative Annexes**

236
237 Mandatory requirements in manufacturer instructions, Codes, or other mandatory Standards that may or
238 may not be adopted into law are those that identify actions that are specifically required or prohibited and
239 are characterized in this Standard by the use of the terms “must” or “must not,” “shall” or “shall not,” or
240 “may not,” or “are not permitted,” or “are required,” or by the use of positive phrasing of mandatory
241 requirements. Examples of mandatory requirements may equally take the form of, “equipment must be
242 protected...,” “equipment shall be protected...,” or “protect equipment...,” with the latter interpreted
243 (understood) as “(it is necessary to) protect equipment...”
244

245 Permissive requirements of manufacturer instructions, Codes, or other mandatory Standards that may or
246 may not be adopted into law are those that identify actions that are allowed but not required or are
247 normally used to describe options or alternative means and methods and are characterized in this Standard
248 by the use of the terms “may,” or “are permitted,” or “are not required.”
249

250 Quality and performance recommendations identify actions that are recommended or not recommended to
251 improve the overall quality or performance of the installation and are characterized in this Standard by the
252 use of the terms “should” or “should not.”
253

254 Explanatory material, such as references to other Codes, Standards, documents, references to related
255 sections of this Standard, information related to another Code, Standard, or document, and supplemental
256 application and design information and data, is included throughout this Standard to expand the
257 understanding of mandatory requirements, permissive requirements, and quality and performance
258 instructions. Such explanatory material is included for information only and is identified by the use of the
259 term “NOTE,” or by the use of italicized text.

Non-mandatory information and other reference Standards or documents relative to the application and use of materials, equipment, and systems covered by this Standard are provided in informative annexes. Informative annexes are not part of the enforceable requirements of this Standard and are included for information purposes only.

2. Definitions

NOTE: The following terms are used in this Standard. The definitions below apply only to the context in which the terms are used in this Standard.

ANSI. American National Standards Institute.

Branch Circuit, Multiwire. A branch circuit that consists of two or more ungrounded conductors that have a voltage between them, and a grounded conductor that has equal voltage between it and each ungrounded conductor of the circuit and that is connected to the neutral or grounded conductor of the system.

Downlight. A recessed, surface mounted or suspended luminaire, usually cylindrical, with an opening on the bottom to direct light downward. Also called “cans” or “top hats,” downlights generally house single-ended incandescent, compact fluorescent, HID, or LED lamps. Recessed downlights have a housing above the ceiling and a finish trim installed from below the ceiling. Downlights using compact fluorescent and high intensity discharge lamps typically include the necessary ballast for the lamp within the luminaire.

Electric-Discharge Lighting. Systems of illumination utilizing fluorescent lamps, high-intensity discharge (HID) lamps, or neon tubing. *NOTE: Neon tubing is not covered by this Standard.*

Glare. Light that is directed in the line of sight or reflected from a lens or highly reflective surface in the line of sight toward an observer.

Group Re-lamping. A maintenance program where all lamps in a given area or space are replaced at a certain time interval to avoid replacing individual lamps that fail.

HVAC. Heating Ventilation and Air Conditioning. *NOTE: Some indoor luminaires, such as recessed troffers, may have air handling capabilities.*

Industrial Luminaire. Luminaires designed for industrial applications, typically either open-bottom LED or fluorescent or open or lensed high intensity discharge (HID) luminaires. *NOTE: NECA 502 describes installation procedures for installing industrial lighting systems.*

Lampholder. A device which serves to connect a lamp to a circuit in addition to providing mechanical support.

Light Fixture. A luminaire designed for permanent attachment to a building.

Lighting Outlet. An outlet intended for the direct connection of a lampholder or luminaire.

Lighting Track (Track Lighting). A manufactured assembly designed to support and energize luminaires that are capable of being readily repositioned on the track. Its length can be altered by the addition or subtraction of sections of track.

Luminaire. A complete lighting unit consisting of a light source such as a lamp or lamps, together with the parts designed to position the light source and connect it to the power supply. It may also include parts to protect the light source or the ballast or to distribute the light. A lampholder itself is not a luminaire.

NEC. National Electrical Code.

NETA. InterNational Electrical Testing Association.

Overcurrent Protective Device, Supplementary. A device intended to provide limited overcurrent protection for specific applications and utilization equipment such as luminaires and appliances. This limited protection is in addition to the protection provided in the required branch circuit by the branch-circuit overcurrent protective device.

Owner. For the purpose of this Standard, the owner, tenant, architect, builder, general contractor, or consultant who represents the interests of the party for whom the project is being constructed.

Portable Luminaire. A luminaire designed for cord-and-plug connection and designed to be located and connected to a receptacle by the building occupants. *NOTE: Portable luminaires are not covered by this Standard.*

Power Over Ethernet (PoE) Lighting. Lighting that is powered and controlled through communications cables, such as Cat5, Cat5e, or Cat6 Ethernet cables.

Reflected Ceiling Plan. A drawing, usually prepared by the architect, which indicates ceiling systems, finishes, and the location and coordination of systems or devices of all trades.

Staging Area. An area in which luminaires are removed from packing and prepared for installation, including installing whips, and accessories.

Trim. A finishing piece usually intended to cover a joint or hole. In recessed luminaires, the trim is often a substantial part which may include a reflector, lampholder, and/or a flange or ring designed to cover the joint between the luminaire and the ceiling.

Troffer. A recessed luminaire consisting of a metal box with lamps inside, and having the light emitting aperture on the bottom side. The two principal types of troffers are lensed troffers, in which the lamps are shielded from view by a plastic or glass lens, and parabolic troffers, in which the lamps are shielded from view by metal louver blades.

Type IC. A recessed luminaire that is identified for installation in contact with insulation.

UL. Underwriter’s Laboratories.

Whip. A flexible wiring connection from a junction box or other termination to a luminaire, usually an unsupported cable or conductors in a flexible raceway.

Wraparound Lighting Fixture. A surface-mounted or suspended luminaire in which a lens surrounds the lamp(s) on three or more sides.

3. Electrical Safety

This section encompasses electrical safety for installing, maintaining, trouble-shooting, repairing, and replacing luminaires. *NOTE: Failure to observe these precautions may result in severe personal injury or death.*

3.1 General

Consider all circuits to be energized until they are confirmed to be de-energized by testing and are locked out of operation. Consider all ungrounded and grounded metal parts of equipment and devices to be energized at the highest voltage to which they are exposed unless they are tested and are positively known by testing to be de-energized.

Perform preliminary inspections and tests prior to beginning work to determine existing conditions. Check existing conditions against available record documents. Visually verify electrical connections.

Do not work on energized equipment. Before installing, maintaining, trouble-shooting, repairing, or replacing luminaires, de-energize and electrically isolate equipment in accordance with NFPA 70E, established safety practices, and Section 3.2. Guard energized conductors and equipment in close proximity to work.

Use appropriate Personal Protective Equipment in accordance with established safety procedures when working on or near energized electrical equipment. Do not touch water, damp surfaces, ungrounded metal, or any wires barehanded.

Use portable ladders with non-conductive side rails near energized parts. Use insulated tools and/or handling equipment when equipment might make accidental contact with energized components. Protect insulated tools from damage to insulation.

Provide temporary lighting for areas where lighting circuits are de-energized for installation, maintenance, trouble-shooting, or repair of luminaires.

3.2 De-Energizing Equipment

Apply lockout/tagout procedures in accordance with documented and established policies and practices. Comply with requirements of NFPA 70E, written lockout/tagout procedures, and this Section.

Use safe work practices appropriate for the circuit voltage and energy level where electrical conductors and circuit parts have been disconnected, but are not locked out/tagged out and grounded, where appropriate.

Render electrical circuit conductors and circuit parts electrically safe by removing all sources of energy, locking and tagging out the disconnecting means, verifying the absence of voltage by an approved voltage testing device, and guarding any exposed energized components.

Identify and locate all possible sources of electrical supply, including back-feed, emergency, and control circuit sources such as lighting contactors, to the specific equipment to be de-energized. Check applicable up-to-date drawings, diagrams, and identification tags. Label backfeed and emergency sources with warning labels.

Shut down equipment using control devices, pushbuttons, selector switches, on-off switches, dimmers, and lighting contactors.

After interrupting the load current using established equipment and load shutdown procedures, open the circuit disconnecting means, such as load-rated switches, circuit breakers, or other devices specifically designed as disconnecting means, for each source. Do not use control devices, pushbuttons, selector switches, or snap switches as the primary isolating means.

Test that the equipment is de-energized by operating the equipment controls. Leave controls in the OFF position.

Using an adequately rated portable voltage detector, test each phase conductor and circuit component to verify that they are de-energized. Test the voltage detector for proper operation using a known source before and after each test.

3.3 Energizing Equipment

Visually inspect the system to ensure that all tools, electrical jumpers (temporary wiring), and test devices have been removed.

Visually inspect equipment and areas around equipment to ensure that all persons are clear from circuits and equipment to be re-energized.

Remove locks and tags only after work is complete and tested, and all personnel are clear of the area.

Test for short circuits or ground faults.

Energize circuits using established switching procedures. Close disconnect devices starting at the source, working towards the load.

Operate controls and inspect luminaires and controls for proper operation.

3.4 Branch Circuit and Switching Conductors

Verify phase, neutral, and ground conductors and all connections for switching. Be wary of crossed neutral conductors, keeping in mind that lighting circuits supplied from phase and neutral conductors connected to separate panelboards may appear to operate properly.

Do not interrupt or disconnect spliced conductors when working on energized circuits. Phase and neutral conductors can continue to carry current from other downstream loads and may arc when interrupted or disconnected.

Exercise caution around ballast secondary conductors, which can frequently develop voltages that exceed 600 Volts.

4. Preliminary Installation Procedures

Follow these general procedures for all lighting installations. Procedures for installing luminaires are described in Section 5. Procedures for finishing lighting installations are described in Section 6.

4.1 Receiving, Handling, and Storage

4.1.1 Receiving

Unload shipments carefully, observing all packing warning labels. Use forklifts or other loading equipment for all palletized shipments.

Visually inspect packaging for physical damage upon delivery. Carefully unpack luminaires sufficiently to inspect for concealed damage resulting from shipping and handling. Use extreme caution when unpacking lenses, louvers, trim pieces, lamps, and other parts that can easily be broken, marred, or damaged. Notify the shipper and the manufacturer in writing immediately if damage has occurred.

Compare luminaires and accessories received with the bill of materials to verify that the shipment is complete. Verify that the luminaires and accessories received conform with approved submittals and manufacturer quotations. Verify receipt of manufacturer literature on luminaire installation and maintenance. Notify the manufacturer in writing immediately if the shipment is not complete. *NOTE: Maintain copies of manufacturer instructions for inspections and to comply with Section 6.7.*

Set aside breakable parts and store separately, using extra padding or other means to prevent damage if light fixtures and accessories are to be stored prior to installation. Restore other original packing materials to protect luminaires and accessories from exposure to environmental conditions. Leave the packing materials intact until ready for installation when conditions permit. *NOTE: Depending on specifications, company policy, or project circumstances, it may be necessary to receive, unpack, and check all material at the company shop or other remote staging area, in which case careful repacking is essential.*

4.1.2 Handling

In general, move luminaires and accessories as few times as possible. Move luminaires and accessories

carefully by hand, dolly, or other device in a manner to avoid personal injury and to avoid damaging the materials. Avoid impact, jolting, jarring, and rough handling. Maintain the original packaging to the greatest extent possible until ready for installation.

4.1.3 Storage

Store luminaires and accessories in a clean, dry location. Avoid storage spaces where water might accumulate or where significant airborne dust or dirt is present. Store materials on shelves, pallets, or other means to raise materials above the floor and above possible water levels, and wrap in protective plastic sheeting. Protect materials against physical damage and vandalism during storage.

Observe warnings and stacking instructions on packaging or shipping materials. Exercise care to avoid damage when stacking materials. Do not stack boxes which are partially crushed even if the products are intact.

If an event occurs which could damage stored material, such as a water leak, immediately inspect luminaires and accessories. Replace damaged materials with new.

4.2 Site Preparation

Because portions of luminaires and accessories are frequently exposed finishes, install luminaires toward the end of the construction period, and protect from damage during on-going construction activities.

In general, do not install complete luminaires until other trades, such as drywallers and painters, have completed work in the space. Verify that all general construction is sufficiently complete to allow installation of lighting systems without future removal or damage from continuing construction activities.

Verify that structural support provisions for luminaires are in place. Verify that framing and other preparations are in the correct locations and of the proper dimensions. Install rough-in housings as required. Ensure that coves constructed for cove lighting have adequate space and are located and arranged such that lamps and equipment can be properly installed and maintained.

Verify that electrical systems are sufficiently complete and coordinated to allow installation of lighting systems without compromising design or requiring future removal or damage. Where appropriate, verify that conduit systems and wiring methods are sufficiently complete for installation of luminaires.

Clean the staging and work areas, removing trash and construction debris to prevent scratching or damaging luminaires and accessories. Organize material and the trash area. When recycling options are available at the job site, separate used packing materials by type and recycle. Dispose of non-recyclable packing materials in accordance with all federal, state, and local regulations.

4.3 Coordination with Other Trades

Do not install luminaires where known conflicts exist. Refer conflicts to the general contractor, architect/engineer, or owner to coordinate building systems and to reconcile interferences prior to installing luminaires. Resolve conflicts in accordance with applicable Codes and Standards, giving

lighting locations preference over other ceiling-mounted equipment whenever possible.

Review the reflected ceiling plan. Verify that reflected ceiling plans coordinate the various systems and allow scaling of dimensions. In general, luminaire locations should take precedence over other devices or systems unless specific building Code requirements are involved. Obtain direction from Code officials or the owner when conflicts arise involving Code issues.

Verify that fire suppression sprinkler locations are coordinated with lighting. Verify that HVAC (heating, ventilating and air conditioning) systems, plumbing, and fire protection systems are sufficiently complete to allow installation of lighting systems without future removal or damage to material.

Make certain that plumbing and fire protection piping, mixing boxes, ductwork, diffusers, grilles and concealed mechanical system elements are located to permit lighting systems to be installed.

Verify that luminaires that serve a mechanical HVAC function are suitable for the intended function. Coordinate with the HVAC contractor and remove knock-outs or slot covers as required. Assist the HVAC contractor as necessary to assure proper connection of HVAC devices, such as supply and return air boots, onto the luminaires.

Coordinate the installation of recessed luminaires with ceiling contractors. Some recessed-mounted wallwashers and other troffer-like luminaires may not completely fill the ceiling opening and are furnished with flanges or pans to trim out or otherwise finish the ceiling opening.

5. General Installation Procedures

5.1 General

Install luminaires and accessories in accordance with manufacturer instructions and the NEC.

Verify the suitability of installation instructions for recessed luminaires for other ceiling materials such as wood or plaster. Exercise care when installing recessed luminaires in suspended gypsum wallboard ceilings or gypsum wallboard ceilings directly attached to structural framing, as in conventional wood frame construction, to avoid damaging finished ceiling surfaces.

All luminaires, lampholders, and retrofit kits are required to be listed. Verify that luminaires are of the types specified and approved for the application. Advise the owner if any luminaire appears to be of the incorrect type, improper voltage, or not properly listed for its intended application. Verify that luminaire mounting requirements and ceiling systems are compatible. See Annex A. Do not install luminaires that do not comply with the installed conditions.

Unpack, pre-wire, and set up luminaires and accessories ready for installation in a staging area using a soft work surface such as plywood or wallboard for layout, when appropriate. To install whips on luminaires in the staging area, ensure that the connector fitting is compatible with the wiring method and is appropriate for the conduit entry or knockout in the luminaire. Install the connector fitting onto the whip and connect the whip to the luminaire. For luminaires supplied with manufactured or modular wiring systems, attach manufactured wiring harnesses to luminaires in accordance with manufacturer instructions prior to installing luminaires.

Inspect luminaires and accessories for damage prior to installation. Do not install damaged materials. Replace damaged materials with new.

After installation and prior to securing in place, ensure luminaires are level, plumb, and adjusted as required.

Provide an accessible internal or external disconnecting means for each fluorescent or LED luminaire that uses double-ended lamps and contains one or more ballasts or LED drivers that can be serviced in place in accordance with NEC Section 410.71. When connected to multiwire branch circuits, the disconnecting means shall simultaneously break all the supply conductors to the ballast, including the grounded conductor or neutral. Locate disconnecting means to be accessible to qualified persons before servicing or maintaining ballasts or drivers. Disconnecting means that are external to the luminaire must be a single device that is attached to the luminaire or located within site of the luminaire.

Make electrical connections to supply conductors while supply conductors are accessible. Do not install luminaires prior to making electrical connections when the luminaire installation renders the supply conductors inaccessible. Ensure that conductors comply with the length requirements of NEC Article 300 for the purposes of making splices or for the connection of luminaires at outlets, junctions, and switch points. Size lighting outlet boxes such that outlet boxes, along with luminaire canopies and internal luminaire wiring space, provide sufficient space so that luminaire conductors and their connecting devices are capable of being installed in accordance with NEC Section 314.16. Also, see Section 6.1.

5.1.1 Environmental Considerations

Install luminaires in wet or damp locations such that water cannot enter or accumulate in wiring compartments, lampholders, or other electrical parts. Verify that luminaires and components installed in wet locations are marked, "Suitable for Wet Locations," and that luminaires and components installed in damp locations are marked either "Suitable for Wet Locations" or "Suitable for Damp Locations."

Verify that HID lamps of luminaires subject to physical damage installed in playing and spectator seating areas of indoor sports, mixed-use, or all-purpose facilities are of the type that protects the lamp with a glass or plastic lens. Such luminaires are permitted to have an additional guard, such as a wire mesh screen.

Connect luminaire wiring to supply conductors in accordance with Section 6.1. Use conductors having insulation suitable for the environmental conditions, current, voltage, and temperature to which the conductors will be subjected. See NEC Article 402 for ampacity, maximum operating temperature, voltage limitations, minimum wire size, and other information for fixture wire. For PoE luminaires, provide plenum rated cables when required.

5.1.2 Installation in Fire Resistive Construction

Verify the suitability of luminaires for recessed installation in fire-resistive construction, if applicable. UL Standards for fire rating of construction may permit recessed luminaires, provided they are listed and/or properly enclosed to meet UL requirements.

Where a luminaire is recessed in fire-resistant material in a building of fire-resistive construction, a

temperature higher than 90°C (194°F) but not higher than 150°C (302°F) is considered acceptable if the luminaire is plainly marked for that service.

5.1.3 Installation in Combustible Construction

Install luminaires with exposed ballasts, transformers, LED drivers, or power supplies such that these components are not in contact with combustible materials unless listed for such condition.

Verify that recessed incandescent luminaires have thermal protection and are identified as thermally protected.

Ensure that luminaires and components, including luminaires installed in recessed cavities in walls or ceilings, including suspended ceilings, are constructed, installed, or equipped with enclosures or guards so that combustible material is not subjected to temperatures in excess of 90°C (194°F).

Type IC luminaires are permitted to be installed in contact with combustible materials at recessed parts, points of support, and portions passing through or finishing off the opening in the building structure. Ensure that thermal insulation is not installed above a recessed luminaire or within 75 mm (3 in.) of the recessed luminaire's enclosure, wiring compartment, ballast, transformer, LED driver, or power supply unless the luminaire is identified as Type IC for insulation contact.

Provide a minimum of 13 mm (1/2 inch) separation between all recessed parts of a non-Type IC luminaire (luminaire not identified for contact with insulation) and combustible materials. *NOTE: The points of support and the trim finishing off the opening in the ceiling, wall, or other finished surface is permitted to be in contact with combustible materials.*

Provide a minimum separation of 38 mm (1-1/2 inch) between a surface-mounted luminaire that contains a ballast, transformer, LED driver, or power supply and combustible low-density cellulose fiberboard unless the luminaire is marked for such condition.

5.1.4 Retrofit Kits

Retrofit kits are required to be listed by a third-party testing laboratory, such as a National Recognized Testing Laboratory (NRTL). Install retrofit kits in accordance with manufacturer instructions and wiring diagrams. Disconnect and remove existing ballasts that are not reused as part of the retrofit kit. For LED retrofit kits, mount separate drivers and heat sinks as instructed. Locate drivers and heat sinks away from combustible construction and combustible materials in accordance with the NEC.

5.2 Hangers and Supports

Support luminaires in accordance with manufacturer instructions and in accordance with the NEC.

Luminaires are permitted to be supported by outlet boxes or fittings installed as required by NEC Section 314.23 and complying with the provisions of NEC Section 314.27(A)(1) and 314.27(A)(2). Support luminaires that weigh more than 23 kg (50 lbs.) independently of a ceiling outlet box, unless the outlet

box is listed and marked on the interior of the box with the maximum weight the box is capable of supporting.

Where suspended or grid ceilings are installed, provide luminaire supports that are independent of the ceiling system and ceiling supports. Coordinate luminaire supports with the ceiling contractor. Framing members of suspended ceiling systems used to support luminaires must be securely fastened to each other and securely attached to the building structure at appropriate intervals. Additionally, luminaires must be securely fastened to the ceiling framing member by mechanical means such as bolts, screws, or rivets, or by listed clips identified for use with the type of ceiling framing members and luminaires.

Verify that raceway fittings used to support luminaires are capable of supporting the weight of the complete fixture assembly and lamps.

Use metal raceway, nonmetallic raceway, Type MC cable, Type AC cable, nonmetallic sheathed cable, or by flexible cord (as permitted in NEC Section 410.62(B) or 410.62(C)) for branch circuit wiring for electric-discharge and LED luminaires supported independently of the outlet box.

Where required by local Codes, support luminaires by additional seismic slack supports capable of bearing the weight of the luminaires. Attach safety and seismic supports for luminaires to main structure, concrete or steel floor deck, beams, or columns. Safety supports for luminaire components, such as reflectors, may be attached to the luminaire itself.

5.3 Lay-In Luminaires

Lay-in luminaires are installed recessed in suspended ceilings consisting of a support grid with a ceiling surface of acoustic tile, metal pan, or other removable element. Verify that framing members of suspended ceiling systems are securely fastened to each other and are securely attached to the building structure at appropriate intervals.

Confirm adequate clearance above luminaire locations for installation and proper operation.

Lift luminaires into place in openings in ceiling.

Securely fasten luminaires to ceiling framing members by mechanical means such as bolts, screws, or rivets, or by listed clips identified for use with the type of ceiling framing members and the type of luminaires. Attach any additional supports as required. See Section 5.2.

5.4 Downlights

This section applies to recessed downlights and similar luminaires, such as wallwashers, floodlights, spotlights, and accent lights, having a housing above the ceiling and a finish trim installed from below the ceiling.

Verify that luminaires are properly rated for the application. See Section 5.1 for additional requirements. Also, see Annex B.

5.4.1 *Suspended Accessible (Grid) Ceilings*

Follow these procedures when installing luminaires in suspended ceilings consisting of a support grid with a ceiling surface of acoustic tile, metal pan, or other removable elements.

Determine the exact locations of luminaires. *NOTE: While a downlight typically looks best at the center of the ceiling tile, for functional reasons it may be desirable to locate the luminaire toward one side or a corner of the ceiling tile.*

Coordinate with the ceiling system contractor, if applicable, to cut holes in uninstalled ceiling tiles to match the aperture flange of the housing. After the ceiling tile is installed, install the luminaire housing over the ceiling tile. Carefully support the housing to avoid breaking the tile. Center the housing over the hole in the ceiling tile so that the plaster flange fits into the hole.

Secure the housing to the ceiling suspension system using hanger bars or C-channels. Ensure that the housing is raised slightly above the ceiling tile, and that all of the weight of the luminaire is supported by the hanging support system. Adjust the luminaire so that the plaster flange is as flush with the ceiling surface as possible. Attach any additional supports as required. See Section 5.2.

Install the trim onto the housing from below. Wear cotton gloves if necessary to prevent smudges or fingerprints on finished surfaces. Carefully seat the trim to fully cover the hole in the ceiling tile and to prevent light leaks.

5.4.2 *Wallboard and Other Inaccessible Hard Ceilings*

Follow these procedures when installing recessed downlights in suspended gypsum wallboard ceilings or gypsum wallboard ceilings directly attached to structural framing, as in conventional wood frame construction.

Determine the exact locations of luminaires. Note that luminaire locations may have to be moved slightly to avoid structural members or framing in hard ceiling applications.

Verify that luminaires are designed to accommodate the ceiling thickness. If the ceiling thickness exceeds the adjustment range of the luminaire, provide extension rings or other components to assure that the finish trim will fit properly.

Verify that luminaires include a sloped ceiling adapter if they are being installed on a sloped ceiling.

Using C-channels or hanger bars, secure luminaires in place, solidly attached to the structure. Adjust the height of the luminaire housing so that the flat bottom of the housing (if any) rests atop the ceiling surface, and the flange of the aperture protrudes into the hole through the ceiling sufficiently far to permit proper installation of the trim. Ensure that the bottom of the luminaire housing does not extend below the height of the finished ceiling.

Coordinate with the ceiling system contractor, if applicable, to cut the hole matching the aperture flange of the housing as the ceiling is installed. Ensure that the hole aligns with the housing during ceiling installation so that the plaster flange fits into the hole.

Provide temporary protection for the interior luminaire components from damage from on-going construction, such as the painting of the ceiling. After the ceiling is completed and painted, remove the temporary protection from the luminaire and install the trim into the housing. Wear cotton gloves if necessary to prevent smudges or fingerprints on finished surfaces. Seat the trim carefully to completely cover the cutout hole and to prevent light leaks.

5.5 Recessed Troffers

This section applies to recessed troffers and similar luminaires installed in wallboard and other inaccessible hard ceilings:

Determine whether troffers are “flanged” troffers (NEMA style F) or grid-style lay-in troffers supplied with a “flange frame.”

Coordinate with the ceiling system contractor, if applicable, to cut a hole in the ceiling with framing as a minimum along the long sides of the luminaire. For plaster ceilings, use a plaster frame to serve as a straight edge and plaster screed.

For flanged luminaires, raise luminaires into position from below and tighten clamps against the framing.

For grid luminaires, install the flange frame and secure to framing. Lift luminaires into openings. *NOTE: A troffer installed in this manner may be used as an access panel.*

5.6 Other Recessed Luminaires

Coordinate the installation of continuous row trough and wall slot luminaires with the ceiling contractor and install in accordance with the manufacturer instructions.

Most other recessed or semi-recessed luminaires installed in wallboard and other inaccessible hard ceilings are designed to be installed in a manner similar to downlights. See Section 5.4. Follow the manufacturer instructions for installation.

5.7 Surface and Suspended Lighting Systems

Follow these procedures when installing luminaires onto ceiling surfaces or beneath ceiling surfaces.

Install a minimum of one center support, or one structural support at each end of luminaires shared at end-to-end joints. Depending on luminaires and ceiling types, install additional supports as necessary to support or stabilize luminaires.

Align continuous rows of luminaires to produce a straight row. Install structural supports in accordance with manufacturer instructions.

Use specialized suspension devices or components by the manufacturer in accordance with manufacturer

instructions. See Annex C.

For suspended ceiling systems, coordinate with the ceiling system contractor, if applicable, to cut holes in ceiling tiles as needed. Install outlet boxes secured to the building structure by threaded rods or wire suspension. Connect outlet boxes to the power source using a suitable wiring method. *NOTE: Outlet boxes are permitted to be secured to a fire-rated suspended ceiling system only when specifically permitted by the product listing. Refer to manufacturer literature.*

For wallboard or other hard ceilings, secure flush lighting outlet boxes to structure at locations corresponding with the power feed knockout on the luminaire body

For exposed structures with no finished ceiling, secure outlet boxes to the ceiling structure or other structural members using anchoring or attaching methods suitable for the weight and moment arm of luminaires, and in accordance with the NEC. Make electrical connections to the power source in accordance with Section 6.1.

Provide a minimum of 38 mm (1 1/2 in.) clearance between luminaires installed in exposed or concealed locations under metal-corrugated sheet roof decking measured from the lowest surface of the roof decking to the top of the luminaire.

5.8 Surface-Mounted Luminaires

This section applies to surface-mounted wraparound and other enclosed luminaires.

Install luminaires onto outlet or junction boxes after wallboard or other hard ceilings are finished and painted. Install supplemental T-bar clips, or stabilizing screws into structure, or provide screw anchors as required.

Depending on the luminaire, the luminaire may be supplied with power from whips, provided end supports are structurally secure and stabilizing attachments hold the luminaire properly onto the ceiling surface. Make electrical connections to the power source in accordance with Section 6.1.

5.9 Close-to-Ceiling Luminaires

This section applies to industrial-type and other luminaires mounted close to ceilings on short spacers or stems, often in continuous rows.

Ensure that outlet boxes and means of attachment are rated for the weight and/or moment arm of the luminaire to be supported. For suspended ceiling systems not rated for the load, provide threaded rod suspension from structure. Use a minimum of two structural support points for each luminaire shared at end-to-end joints.

For wallboard or other hard ceilings, secure the lighting outlet box to structure at the location corresponding to the power feed knockout on the luminaire body. Install luminaires onto outlets using spacer feeds. Add stabilizing and support spacers along luminaires as required.

Depending on the luminaire, the luminaire may be supplied with power from the outlet box through a stem, cord, or whip. Support wiring methods in accordance with the NEC. Make electrical connections to the power source in accordance with Section 6.1.

5.10 Suspended Direct, Indirect, and Direct/Indirect Lighting Systems

Most suspended luminaires have different mounting systems for different ceiling conditions. Refer to manufacturer instructions for specific ceiling conditions and lighting configurations. See Annex C.

For suspended ceiling systems not rated for the load, provide threaded rod suspension from structure. Use a minimum of two structural supports for each luminaire shared at end-to-end joints.

For wallboard or other hard ceilings, secure an outlet box to building structure at the location corresponding to the power feed on the luminaire body. Suspend the luminaire below the outlet box by pendant rods, aircraft cable, or other provision furnished with the luminaire.

Depending on the luminaire, the luminaire may be supplied with power from the outlet box through a flexible cord, stem, or whip. Support wiring methods in accordance with the NEC. Make electrical connections to the power source in accordance with Section 6.1.

5.11 Pendant Luminaires

The following procedures apply to ordinary luminaires generally weighing less than 25 pounds each. For heavier luminaires and/or luminaires having an unusually long suspension, ensure that structural supports are capable of bearing the luminaire's weight and/or moment arm.

For suspended ceiling systems, identify the final luminaire locations. Coordinate with the ceiling system contractor, if applicable, to cut holes in uninstalled ceiling tiles to accommodate lighting outlet extension rings. Once cut ceiling tiles are installed, install electrical box hangers or C-channels spanning across and secured to the ceiling grid at the center of holes in ceiling tiles. Install outlet boxes in the holes in the ceiling tiles on the supports with lighting outlet extension rings, if required. Install luminaires using the outlet box ring as support. Route luminaire supply conductors through the outlet box.

For wallboard or other hard ceilings, secure lighting outlet boxes to structure at the required locations. Use outlet extension rings where required. Set the height to permit the mounting flange to fit into the hole in the ceiling. Once the ceiling is completed and painted, install luminaires onto outlet box rings. Route luminaire supply conductors through the outlet box.

Suspend pendant lampholders with permanently attached leads from separate stranded rubber-covered conductors that are soldered directly to the circuit conductors. Provide independent supports or strain relief for such cables. Unless part of a listed cable assembly, twist pendant conductors longer than 900 mm (3 ft) together. Use pendant conductors not smaller than 14 AWG for mogul base or medium base screw shell lampholders and not smaller than 18 AWG for intermediate or candelabra base lampholders unless the conductors are part of listed decorative lighting assemblies,

Lampholders must be constructed, installed, or equipped with shades or guards so that combustible

material is not subjected to temperatures in excess of 90°C (194°F).

5.12 Track Lighting Systems

The following procedures apply to most types of surface or pendant track lighting systems. For raceway lighting track, recessed lighting track, and other special systems, follow the manufacturer specific instructions.

Permanently install lighting track and permanently connect to a branch circuit. Install only lighting track fittings on lighting track. Do not install general purpose receptacles on lighting track. *NOTE: Fittings identified for use on lighting track are designed specifically for the track on which they are to be installed, are securely fastened to the track, maintain polarization and connections to the equipment grounding conductor, and are designed to be suspended directly from the track.*

Install manufacturer standard connectors, fittings, and components. When possible, use standard manufacturer lengths of lighting track. When required, field-cut lighting track to custom lengths in accordance with the manufacturer instructions, such as using a miter box saw with an appropriate blade.

Verify that the connected load on the lighting track does not exceed the rating of the lighting track.

Verify that the branch circuit supplying the lighting track does not exceed the rating of the lighting track.

Do not install lighting track where subject to physical damage, in damp or wet locations, where subject to corrosive vapors, in storage battery rooms, in hazardous (classified) locations, where concealed, where extended through walls or partitions, or where less than 1.5 m (5 feet) above the finished floor except where protected from physical damage or where track operates at less than 30 volts rms open-circuit voltage.

Provide individual overcurrent protection for each fitting installed on lighting track rated more than 20 amperes.

Unless identified for supports at greater intervals, a single section 1.2 m (4 feet) or shorter in length must have two supports, and, where installed in a continuous row, each individual section of not more than 1.2 m (4 feet) in length must have one additional support. Each support must be suitable for supporting the maximum weight of the luminaires that can be installed.

For suspended ceiling systems, coordinate with the ceiling system contractor, if applicable, to cut holes in the ceiling tile at the end or floating feed locations for the lighting track. Install junction boxes with lighting outlet extension rings as required, secured to the building structure by threaded rods or wire suspensions. Connect the junction boxes to the power source using a suitable wiring method.

For wallboard ceilings, install outlet boxes secured to the building structure at the required locations. Set the box height to permit the mounting flanges to fit into the holes in the ceiling. Once the ceiling is completed and painted, install track feed connectors using the junction box ring as support. Provide additional supports in accordance with the manufacturer instructions and the NEC, using screws into structure or wallboard anchors as needed. Use joints, intersections, ells and other track components as required to complete the layout.

For pendant track, use the manufacturer pendant mounting assembly. Provide structural supports in accordance with the manufacturer instructions and the NEC.

For track lighting mounted with its opening not in the horizontal plane, provide additional supports and secure as required to prevent torquing or twisting when lampholders are attached to the track.

5.13 Wall-Mounted Luminaires

This section applies to wall sconces, wall brackets, and other luminaires designed for wall mounting.

NOTE: The Americans with Disabilities Act (ADA) restricts luminaire projection to 4 inches when mounted along the path of egress at or below 80 inches above finished floor.

Locate lighting outlet boxes corresponding with the power feed knockout on the luminaire body. Add extension rings as needed to bring the outlet box opening to the face of the wall.

Install the luminaire onto the outlet box after wall finishes are complete. Adjust luminaires, level and plumb. Add stabilizing screws into the structure or wallboard anchors as needed to secure the luminaire in place.

5.14 Power Over Ethernet (PoE) Lighting Systems

Install PoE lighting systems, cables, and components in accordance with manufacturer instructions and contract documents, drawings and specifications. Check PoE lighting system manufacturer product literature and installation manuals for any recommended wiring characteristics or limitations for the system including minimum wire size, maximum cable lengths, and any minimum/maximum loading characteristics.

PoE lighting systems integrate sensors and actuators that provide data and control options such as automated curtains, daylight harvesting, and dimming systems, along with maintenance and management that can provide monitoring and notification when fixtures require maintenance, and that can integrate control of HVAC systems, such as perimeter heating and cooling systems.

PoE lighting systems can be integrated into a Building Management System and can gather data that can be used to manage energy efficiency. PoE lighting systems can typically be re-configured via programming in lieu of removing conduit, boxes, conductors, controls, and fixtures.

Program PoE lighting component network cards, such as for light fixtures, switches, sensors, and actuators, in accordance with manufacturer instructions. Maintain a list of IP addresses for each device. Program addressable IP addresses in accordance with contract documents, drawings and specifications. In the absence of contractual requirements, consult the designer, architect/engineer, and manufacturer for recommendations for assigning IP addresses.

Program light levels and light color temperature in accordance with contract documents, drawings and specifications. In the absence of contractual requirements, consult the designer, architect/engineer, and manufacturer for recommendations for light levels and light color temperature.

In general, install PoE luminaires capable of maintaining constant input power and light output to minimize the impact of cable length and voltage drop on lighting performance.

Install PoE lighting system cabling in accordance with IEEE 802.3 and ANSI C137.3 guidance. Verify that PoE power source equipment, such as switchports and PoE luminaires, lighting loads, and other powered devices with RJ45 jacks are compatible with all cabling in accordance with IEEE 802.3 Standards.

Cable power and energy losses are dependent on conductor resistance. Use only copper conductors for PoE cables. Where excessive power losses are encountered, consider reducing the length of cabling, using larger conductors, and reducing the number of twists per unit length of cable or using non-twisted pair cable.

Limit PoE conductor voltage drop and power losses to less than 5% in accordance with ANSI C137.3, keeping in mind that the lighting output of PoE luminaires that do not maintain constant input power may be appreciably affected by cable power losses. Limit the average cable length to 50 m (164 feet).

Power losses can be expected to be greater when cables are loaded with powered devices with an input power approaching 90W, connected via patch cords, and/or cables are bundled in conduits. PoE lighting systems operating in higher ambient temperatures will also experience higher power losses due to increase DC resistance.

In general, ANSI C137.3 recommends unshielded twisted pair Ethernet cables with a minimum of 24 AWG for PoE powered devices with input power of 55W and less, and a minimum of 23 AWG for power devices greater than 55W. Larger diameter conductors may be required for specific projects or specific circuits to address powered devices with higher input power, cabling connections using patch cords, bundled cables in conduits, high ambient temperatures, or other reasons as required by contract documents, drawings and specifications.

Install cables with CMP rated jacketing in plenum applications.

Maintain a minimum internal bending radius of four times the outer cable diameter for unshielded twisted pair cables. Excessive cable bending can potentially damage the cable jacket and conductor insulation, can compromise connectivity via crosstalk and attenuation, and can increase impedance.

Bundle size is known to affect conductor temperature and DC resistance through mutual heating. In general, limit bundle size to 24 cables, limit temperature rise to 15°C, use Cat 6A cables for new installations (Cat 5E and Cat 6 cables are acceptable for existing installations), and use cables with metallic screens or shields in accordance with TIA TSB-184-A recommendations.

Limit maximum pulling tension in accordance with manufacturer instructions. In the absence of manufacturer instructions, limit pulling tension to 110 Newtons (N) (25 pounds-force (lbf)) for installing individual cables in raceways in accordance with TIA-568.0-E recommendations.

6. Final Installation Procedures

6.1 Electrical Connections

Verify that wiring methods used for luminaires comply with NEC Chapter 3.

Verify that the insulation temperature rating of supply wires matches those specified on labels for luminaires and ballasts, transformers, and drivers. Conductors installed within 75 mm (3 inches) of a ballast, LED driver, power supply, or transformer must have an insulation temperature rating not less than 90°C (194°F), unless supplying a luminaire marked as suitable for a different insulation temperature. Provide Code-compliant length pigtails of appropriate gauge and temperature rating, if necessary, to match luminaire requirements. Use whips rated for luminaire fixture supply. Use suitable wire connectors of the proper type and rating.

When installed, provide tap conductors of a type suitable for the temperature encountered to run from the luminaire terminal connection to an outlet box placed at least 300 mm (1 ft) from the luminaire. Install tap conductors in suitable raceway or use Type AC or MC cable of at least 450 mm (18 in.) but not more than 1.8 m (6 ft) in length.

Where making electrical connections within luminaires, train and neatly arrange conductors to protect them from physical damage, such as being pinched by doors, panels, or covers when they are installed. Do not install excess lengths of conductors. Do not splice or tap conductors within luminaire arms or stems. Do not make unnecessary splices or taps within or on a luminaire.

Secure conductors in a manner that does not tend to cut or abrade the insulation. Protect conductors from abrasion where passing through metal. For luminaires mounted to a lighting outlet or junction box, knock out and deburr the metal in the fixture body, if required, making certain to protect finished parts of the luminaire from damage. Install a connector fitting on the luminaire that is compatible with the wiring method, if required.

Provide stranded conductors for wiring on luminaire chains or on other flexible or movable parts. Arrange conductors in a manner that the weight of the luminaire or of movable parts does not put tension on the conductors, connections, or terminations. Chain-supported luminaires used in a show window are permitted to be externally wired. No other externally wired luminaires shall be used.

Locate identifying and testing devices for luminaires with self-contained emergency power where readily visible, but not offensive, as directed by the owner.

When luminaires are through-wired, either from luminaires installed end-to-end or to carry branch circuit conductors through luminaires, make certain that luminaires are listed for use as a raceway or are listed for through-wiring, and that wiring splices and terminations are made properly. Install appropriate connectors or nipples between through-wired luminaires as needed. *NOTE: Typically, one circuit is used for continuous row-mounting of luminaires. Through-wiring is permitted, although each luminaire is not required to be listed as a raceway if only one two-wire branch circuit or one multi-wire branch circuit is supplied.*

For luminaires connected to electric power via a whip or manufactured wiring system or modular connector, install a connector fitting compatible with the wiring method in an appropriate conduit entry or knockout in the luminaire, connect the whip to the luminaire, and terminate supply conductors. For luminaires with whips pre-assembled, ensure that the connector fitting is compatible with the wiring method and is appropriate for the conduit entry or knockout in the junction box of the conduit system. Connect the whip to the junction box, and terminate supply conductors.

Ensure that each luminaire is equipped with a disconnecting means in accordance with the NEC. Supplemental overcurrent protection, such as individual fusing for each luminaire, is permitted for specific applications in addition to the protection provided by the required branch circuit overcurrent protective device.

Ground luminaires in accordance with the NEC. Exposed conductive metal parts of luminaires and related accessories and equipment must be connected to an equipment grounding conductor, must be insulated from the equipment grounding conductor and other conductive surfaces, must be inaccessible to unqualified persons, or must be supplied from a GFCI-protected circuit.

6.1.1 Cord-and-Plug Connected Luminaires

A luminaire or a listed assembly is permitted to be cord connected provided the luminaire is located directly below the outlet or busway, the cord is not subject to strain or physical damage, and the cord is visible over its entire length except at terminations.

Cord-and-plug connected luminaires are permitted to be connected to a grounding-type attachment plug or busway plug.

A luminaire assembly equipped with strain relief and a canopy is permitted to use a cord connection between the luminaire assembly and the canopy. The canopy is permitted to include a section of raceway not over 150 mm (6 in.) in length and intended to facilitate the connection to an outlet box mounted above a suspended ceiling.

Listed luminaires connected using listed assemblies that incorporate manufactured wiring system connectors in accordance with NEC Section 604.100(C) are permitted to be cord connected.

6.1.2 Lighting Controls and Switching

Install controls, emergency ballasts, and switching in accordance with applicable Codes, contract documents, shop drawings, and manufacturer instructions, keeping in mind that multi-lamp, multi-ballast luminaires may be supplied from separate switched circuits. If no specific switching arrangements are specified, ensure that luminaires appear uniformly illuminated under all switching positions.

Verify that circuit breakers used as switches for 120 Volt and 277 Volt fluorescent lighting circuits are listed and are marked either SWD or HID. Verify that circuit breakers used as switches in high-intensity discharge lighting circuits are listed and are marked HID.

Verify that all switching, including three-way and four-way switching, is only done in ungrounded circuit conductors. Do not switch the neutral conductor of lighting circuits. For switches controlling lighting loads supplied by a grounded general-purpose branch circuit, verify that the grounded circuit conductor is provided at the switch location, when required by NEC Article 404.

For multi-circuit track lighting, connect the ungrounded conductors of multi-wire branch circuits (two-, three-, or four-circuit track with a common neutral) onto separate phases of the power supply. For track

lighting with two ungrounded conductors and two grounded or neutral conductors, supply circuits may be of the same phase.

Where luminaires, lampholders, and auxiliary equipment is supplied only by ungrounded circuit conductors, switching devices must simultaneously disconnect all conductors.

6.1.3 Power Over Ethernet (PoE) Cabling

Install power over ethernet (PoE) lighting circuits in accordance with NEC Articles 725.144 and 840.160. *NOTE: PoE lighting systems are powered and controlled through data cables, such as Cat 5, Cat 5e, Cat 6, or Cat 6A Ethernet cables.* Use copper conductors for PoE lighting applications.

Ensure that power circuit current does not exceed the current limitation of the conductors, connectors, and Ethernet switches. See NEC Table 725.144 for conductor ampacities when 4-pair Class 2 or Class 3 data cables used to carry power are bundled. Use the correction factors from Table 310.15(B)(2) for ambient temperatures above 30°C (86°F).

Install PoE cables in accordance with ANSI C137.3, including minimum AWG sizes to limit cable energy losses and voltage drop to 5%. Ensure that the average cable length does not exceed 50m (164 feet) in length.

6.2 Interior Cleaning

Clean luminaire surfaces that have become dirty or paint-spattered. Remove dirt or paint using a clean, lint-free cloth, water, and a non-abrasive cleaner in accordance with manufacturer instructions.

Replace visible luminaire component finishes that are damaged, scratched, scraped, or painted, with new parts.

6.3 Installing Lamps

Verify that lamps are compatible with luminaires. Install the specified lamps in each luminaire. If none are specified, install the lamp type recommended by the luminaire manufacturer.

Provide lamps of the same manufacturer, color temperature, and color rendering index (CRI), unless otherwise specified in contract documents. Lamps with higher CRI (90 and above) are recommended for better color clarity and intensity.

Ensure that lamps are fully engaged mechanically and electrically in the lampholders.

6.4 Final Cleaning and Completion of Luminaire Installation

Upon completion of the fixture installation and at the time of final inspection, ensure that luminaires are clean, and free from marks, dust, spotting or other defects. Replace any broken or defective parts prior to

1219 final inspection. Resolve all defects revealed during the final inspection.

1220
1221 Install trims, special lenses, louvers, and/or other accessories specified or called for by the application.
1222 Wear cotton gloves if necessary to prevent smudges or fingerprints on finished surfaces. Remove
1223 protective coverings from lenses and reflectors.

1224
1225 Verify that there is adequate airspace between lamps and shades or other enclosures of combustible
1226 material.

1227
1228 Clean all surfaces as recommended by the manufacturer, paying close attention to surfaces such as glass
1229 and polished aluminum. Remove fingerprints, dust, and other dirt from visible surfaces. Wipe lamps
1230 clean. In the absence of manufacturer instructions, wipe down luminaires and components using a clean,
1231 dry, lint-free cloth as necessary to remove accumulations of dust and dirt. If necessary to wash luminaires
1232 or components, wipe luminaires and components with a clean, damp, lint-free cloth using non-abrasive
1233 cleaning solutions. Rinse luminaires and components with a clean damp cloth and clear distilled water,
1234 and wipe dry using a clean, dry, lint-free cloth. Repeat the process until all surfaces are clean and free
1235 from streaks or smudges.

1236
1237 Install safety, instruction, identification, and warning labels on luminaires. Identify luminaires with
1238 remote emergency sources as emergency sources for safety and maintenance. Provide identification
1239 labels for luminaires with remote-mounted ballasts identifying the location of the remote ballasts and
1240 identifying which ballasts serve which luminaires. Provide labels for luminaires with tandem-wired
1241 ballasts that indicate which additional luminaires are supplied from that ballast. Provide labels for
1242 luminaires that do not contain ballasts identifying the supply luminaires that contain the ballasts. Consult
1243 with the owner and make labels as inconspicuous as possible.

1244
1245 Close and latch doors and louvers.

1248 **6.5 Energizing and Testing**

1249
1250 Energize circuits and equipment in accordance with Section 3.3.

1251
1252 Verify that all lamps operate properly. Verify that switching of luminaires and lamps match the project
1253 plans and specifications. Verify proper operation of emergency and backup power supplies. Walk-test
1254 occupancy sensors. Set occupancy sensors to the minimum time delay during the walk-test. After
1255 testing, adjust final occupancy sensor time delay settings in accordance with contract requirements or
1256 owner preferences.

1257
1258 Adjust lamp sockets/holders/screw shells, if adjustable, to position devices according to the intended lamp
1259 and/or light distribution. Adjust luminaire orientation and tilt to focus light in the intended direction and
1260 to avoid glare. *NOTE: It may be necessary to perform adjustments after nightfall to eliminate the*
1261 *contribution of daylighting.*

1262
1263 Set or adjust other equipment or devices on luminaires in accordance with manufacturer instructions.

1264
1265 Verify proper mechanical operation of luminaires equipped with air handling features.

Burn-in lamps which require a specific aging period to operate properly. Complete burn-in prior to occupancy by owner or tenant, if possible. *NOTE: It is critical that fluorescent and compact fluorescent lamps intended to be dimmed are burned-in for at least 100 hours at full voltage prior to dimming operation.*

Measure light levels to ensure compliance with project requirements.

Repair or replace defective components and repeat testing, as necessary.

Under full lighting load, measure the operating voltage of the source and of branch circuits at the farthest lighting outlet to verify that voltage drop does not exceed 3 percent for branch circuits and does not exceed a maximum of 5 percent for both feeders and branch circuits in accordance with NEC Articles 210 and 215. Notify the general contractor, project manager, owner and/or engineer of record where voltage drop exceeds NEC requirements.

6.6 Punchlist and Acceptance

Prior to walk-through by the owner and any consultants, walk through and survey the site. Identify, touch-up, and repair all defects.

In the presence of the owner, demonstrate switching configurations and controls. Adjust lighting control options in accordance with owner approval.

In the presence of the owner, adjust luminaire orientation and tilt to focus light in the intended direction. Adjust lighting for artistic effect or for specific tasks such as retail sales. *NOTE: It may be necessary to perform adjustments after nightfall to eliminate the contribution of daylighting.*

6.7 Project Deliverables

Deliver all contractually required spare parts and special tools where required for luminaire adjustment or tamper-proof hardware, to the owner or general contractor. Obtain a delivery receipt.

Deliver all contractually required installation, operating, and maintenance manuals to the owner or general contractor. In the absence of contractual requirements, deliver one set of all installation and maintenance instructions for each type of luminaire and component installed. Obtain a delivery receipt.

Deliver a list of all lamp types installed to the owner or general contractor. List lamps using the appropriate ANSI and manufacturer codes. Obtain a delivery receipt.

For PoE lighting systems, provide training for user adjustable parameters, such as light levels, including dimming, and light color temperature. Provide the list of IP addresses for each device. Provide a copy of all programming. Obtain a delivery receipt.

7. Maintenance

7.1 General

General maintenance of luminaires includes periodic cleaning of visible components, such as the trim, lens, reflectors, housing interior, and lamps, and replacement of failed lamps. Clean luminaires and components in accordance with manufacturer instructions.

Check luminaires periodically for proper light output and lamps cycling on and off, discoloration, dim operation, slow-starting, and outages.

Visually inspect luminaires for accumulations of dust or dirt and for obvious defects such as broken, loose, or missing components such as lampholders, end caps, screws, cover plates, ballast covers, lenses, and door frames.

De-energize luminaires in accordance with Section 3 prior to cleaning, inspections, maintenance, repairs, trouble-shooting, or replacing luminaires.

Open doors and remove cover plates to inspect for broken, loose, or missing components such as lampholders, end caps, screws, and ballast covers. Check for loose electrical connections. Inspect conductors and power supplies, ballasts, transformers, and/or drivers for indications of overheating. Replace broken, loose, or missing components. Tighten or rework loose electrical connections. Correct causes of overheating. Replace damaged ballasts and conductors.

Troubleshoot luminaire mis-operation in accordance with Section 8. Replace noticeably dim, discolored, and failed lamps. See Section 7.2.2. For lamps nearing the end of useful life, consider scheduled group relamping during cleaning and maintenance as opposed to periodically replacing lamps as they fail.

Replace High Intensity Discharge (HID) lamps that have exceeded their life expectancy. *NOTE: Some types of HID lamps have an increased risk of exploding when operated significantly beyond their life expectancy.* Replace erratically operating lamps or lamps demonstrating a significant color change or a noticeable reduction in light output over the course of a few weeks or less. Replace lamps with an unusual bulge or "bubble" on the arc tube.

For luminaires equipped with air handling capabilities, clean supply and return air aperture slots on side or on top of luminaires using a vacuum with brush attachment. Remove dust, dirt, and lint.

Wipe down visible luminaire parts and components, such as lamps, louvers, reflectors, and lenses, using a clean, dry, lint-free cloth as necessary to remove accumulations of dust and dirt. If necessary, wipe luminaires and components with a clean, damp, lint-free cloth using non-abrasive cleaning solutions recommended by the manufacturer. Rinse luminaires and components with a clean damp cloth and clear distilled water, and wipe dry using a clean, dry, lint-free cloth.

Verify that lamps are suitable for the installed ballast, transformer, or driver.

Verify that line voltage is within ballast, transformer, or driver ratings. Verify that phase and neutral connections are correct. Verify proper grounding of luminaires.

Replace defective components in accordance with manufacturer instructions. Energize luminaires in accordance with Section 3.3 after replacing components. Check for proper operation in accordance with

Section 6.5.

7.2 Replacing Luminaire Components

Use manufacturer recommended replacement components compatible with the luminaire, lighting system, operating voltage, lamps, and ballasts, transformers, or drivers.

Conform to all regulations regarding the proper disposal of components, including but not limited to lamps containing mercury and ballasts containing PCBs.

7.2.1 Non-Electrical Components

Replace non-electrical luminaire components such as trim, housing, ballast cover, lens, doors, door frames, screws, clips, and cover plates, using manufacturer recommended replacement parts, or components acceptable to the owner.

7.2.2 Lamps

Numerous types of lamps with different characteristics are available for most lighting applications. If the intent of replacing lamps is to change the characteristics of the lighting system, consult the luminaire, ballast, and lamp manufacturers, or an illumination engineer for recommendations.

Remove and install lamps in accordance with manufacturer instructions.

Select lamps that are compatible with the luminaire system and ballast, transformer, or driver, and that closely match the characteristics of the existing lamps. Verify the ratings of the existing lamps, such as the wattage, initial lumen output, color rendering index, and color temperature ratings prior to replacement. Select replacement lamps with a high lamp lumen depreciation value.

Burn-in new lamps in accordance with Section 6.5.

7.2.3 Lampholders

Replace broken lampholders. Provide lampholders suitable for the lamps and luminaire, and that properly position the lamps in the luminaire with the optically correct spacing and relationship to any louvers, reflectors, filters, and baffles.

Follow ballast, transformer, or driver manufacturer wiring instructions for lampholder electrical connections.

Ensure that lampholders are properly secured to the luminaire housing.

7.2.4 Ballasts, Transformers, and Drivers

Numerous types of ballasts, transformers, and drivers with different characteristics are available for most lighting applications. If the intent of replacement is to change the lighting characteristics of the lighting system, consult the luminaire, lamp, and ballast, transformer, or driver manufacturers, or an illumination

engineer for recommendations.

Remove and install lighting ballasts, transformers, and drivers in accordance with the manufacturer instructions.

Select replacements that are compatible with the luminaire system and lamps, and that closely match the characteristics of the existing ballast, transformer, or driver. Verify the type of existing lamps. Verify the ratings of the existing ballast, transformer, or driver, such as the operating voltage, input wattage, crest factor, ballast factor, power factor, and total harmonic distortion (THD) ratings, as applicable, prior to replacement. Select high energy efficiency devices where possible.

Select replacements with the appropriate physical dimensions for installation in the cavity of the existing luminaire.

Do not use multi-lamp ballasts to supply fewer lamps than their ratings.

Ground replacement ballasts and transformers in accordance with the NEC.

For existing luminaires that contain double-ended lamps and one or more ballasts or LED drivers that can be serviced in place and that do not have an individual disconnecting means, install an accessible disconnecting means either internal or external to the luminaire at the time the ballast, transformer, or driver is replaced when required by the NEC.

8. Trouble-Shooting Procedures

Use the following tables as a guide in conjunction with the inspection, maintenance, and testing procedures outlined in this Standard.

8.1 Incandescent Luminaires

The standard procedure for troubleshooting incandescent luminaires is first to verify power to the fixture, and second to replace the lamp.

Table 8.1: Troubleshooting Incandescent Luminaires

Symptom	Possible Cause	Remedy
Lamps burn out prematurely	Lesser quality lamps	Purchase higher quality lamps.
	Extended luminaire operation	Check expected lamp life and compare with actual operational hours.
	Excessive line voltage	Measure line voltage for excessive voltage. Contact local electrical utility if line voltage is excessive. Alternatively, use long life or 130-volt lamps.

	Lamps exceeding maximum wattage as recommended by luminaire manufacturer	Replace lamps with those conforming to the maximum recommended wattage for the luminaire.
	Excessive lamp vibration	Install vibration-resistant lamps.
	Socket is damaged	1) Change socket with new one that is approved by the manufacturer if remainder of fixture is in good shape and replacement parts are available from the manufacturer. 2) Remove fixture and inspect manufacturer provided wire leads and branch circuit wiring for possible sign of overheating or damage to the insulation. 3) Replace entire fixture with new if unable to repair and maintain listing.
Lamps break or burn out prematurely and lamps have a white smoky appearance indicating that air has oxidized the filament	Lesser quality lamps	Purchase higher quality lamps.
	Moisture contacted lamps while energized	Check for and remove sources of moisture near lamps.
	Lamps exceeding maximum wattage as recommended by luminaire manufacturer	Replace lamps with those conforming to the maximum recommended wattage for the luminaire.
	Broken lamp	Check for cause of lamp breakage. Protect lamps from physical contact.
	Thermal shock (less likely)	Check for and remove sources of cold air.
	Thermal shock plus condensation (less likely)	Check for and remove sources of cold and moisture.
Long life lamps burn out prematurely	Lesser quality lamps	Replace with higher quality lamps. Alternatively, replace with traffic-light lamps.
	Socket is damaged	1) Change socket with new one that is approved by the manufacturer if remainder of fixture is in good shape and replacement parts are available from the manufacturer. 2) Remove fixture and inspect manufacturer provided wire leads and branch circuit wiring for possible sign of overheating or damage to the insulation. 3) Replace entire fixture with new if unable to repair and maintain listing.
Lamps break or pop off their bases when they burn out	Internal lamp wiring explodes during “burnout arc”	Some lamps lack an internal fuse wire. Replace the lamp with different brand.

Lamps periodically dim and/or flicker, then fail. <i>NOTE: Poor electrical contact, such as flickering and dimming, is evidence of arcing and is a possible fire hazard. Correct poor electrical contact immediately.</i>	Corroded contacts on lamps or sockets	Clean socket and lamp contacts, or replace lamps and sockets.
	Poor contact between lamp and socket contacts	Check for poor fit or mashed-down center socket contact. De-energize and adjust location of center socket contact. Do not over-tighten lamps.
	Poor wiring contact	Check luminaires, conductors, and terminations for poor electrical contact. Tighten loose terminations. Replace sockets, lamps, or luminaires, as necessary.
	Socket or riveted connection on socket is damaged	1) Change socket with new one that is approved by the manufacturer if remainder of fixture is in good shape and replacement parts are available from the manufacturer. 2) Remove fixture and inspect manufacturer provided wire leads and branch circuit wiring for possible sign of overheating or damage to the insulation. 3) Replace entire fixture with new if unable to repair and maintain listing.
Lamps regularly dim or become brighter when other appliances are operated, and burn out prematurely	Disconnected neutral supply conductor, or poor neutral supply connection	Ensure neutral conductors are properly terminated. Check multiwire branch circuit for loose/missing neutral connection. <i>NOTE: Disconnected or poor neutral conductivity is a possible fire and shock hazard.</i>
Lamps seem dim	Long life lamps are installed	Long-life lamps are less bright than standard-life lamps.
	130 Volt lamps are installed	130 Volt lamps are less bright than 120 Volt lamps.
	Vibration resistant lamps are installed	Vibration and shock resistant and rough service lamps are less bright than standard lamps.
	Lesser quality lamps are installed	Replace with higher quality lamps
	Line voltage is low	Check line voltage. Shift loads to other available circuits. Upgrade the wiring.
Lamps damage dimmers or electronic switching devices when they burn out	Wattage rating of dimmer or switching device is below connected load	Replace dimmer or switching device with one with higher wattage rating.
	Lamps lack internal fuse wire	Replace lamps with different brand.

8.2 Halogen Luminaires

Table 8.2: Troubleshooting Halogen Luminaires

Symptom	Possible Cause	Remedy
Non-Operational Luminaires, low-voltage	Loose connection(s), or failed transformer.	Clean and tighten connections. Replace transformer if necessary.
Lamps blacken and burn out prematurely	Short-cycling lamps	Operate lamps long enough to reach normal operating temperatures.
	Dimmer operation	Install higher quality lamps.
	Lesser quality lamps	Install higher quality lamps.
Lamps crack, explode, or burn out with a smoky appearance	Lamp has been contaminated	Avoid touching halogen lamps. Handle lamps using the original packaging. Clean contaminated lamps with a clean, dry cloth, paper towel, or tissue soaked with alcohol.
	Lamp has been damaged	Use care in installing lamps.
	Lesser quality or old lamp	Install new, higher quality lamps.

8.3 Fluorescent Luminaires

Non-operational fluorescent luminaires or fluorescent luminaires that flicker can be caused by number of problems including tripped breakers or blown fuses, ballast failure, starter failure if so equipped, or lamp failure. The Standard procedure for troubleshooting fluorescent luminaires is first to verify power to the fixture, second to check the lamps for proper operation, third to check the starter for proper operation if so equipped, and finally to check the ballast. Keep in mind that the replacement cost for a ballast may exceed the cost for a new luminaire.

Inspect fluorescent lamps. Lamps that appear very dark at either end are defective or are close to failure regardless of light output. Test lamps one at a time in another luminaire that is known to function properly. Replace defective lamps. Alternatively, replace all suspect lamps within a luminaire. All lamps powered by any one ballast should be changed at the same time.

When lamps are not defective, replace the starter, or starting capacitor, if so equipped. Most modern fluorescent luminaires contain self-starting ballasts and do not contain a starter. Replace the starter with one properly rated for the lamp wattage that it supplies. Remove starters by twisting counterclockwise to unlock, and withdraw from the socket. Installation is the reverse; press into socket and turn clockwise to lock into place.

When lamps and starters are not defective, replace the ballast. Compare ballast replacement costs with purchasing new luminaires. Consider that new luminaires may not match existing luminaires, and that building finishes may require touching up. When considering aesthetics, replacing the ballast may be the only option, regardless of cost. Select ballasts compatible with the lamps and type of switching, such as whether a dimming ballast is required. Install ballasts in accordance with manufacturer instructions and in accordance with ballast wiring diagrams.

Table 8.3: Troubleshooting Fluorescent Luminaires

Symptom	Possible Cause	Remedy
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Lamps burn out prematurely	Lamp-ballast mismatch	Read the ballast label and install suitable lamps.
	Defective ballast	Compare ballast input current to ballast label. Replace ballast.
	Excessive number of lamp starts	Replace lamps. Consider installing an electronic programmed-start ballast.
	Poor contact between lamps and lampholders	Clean lamp ends, replace lamps, or clean or replace lampholders as required.
	Lesser quality lamps and ballasts	Install higher quality lamps. Replace ballast or luminaire as required.
Lamp is out or very dim and ends glow dim orange	Lamp has failed and a rapid start ballast is making the filaments hot enough to visibly glow.	Replace the lamp.
Lamp blinks from once to several times a second	Pre-heat lamp has failed	Remove the lamp immediately to preserve the ballast and starter. Replace lamps. If symptoms persist for a relatively long time, replace starter.
Lamps burn out in pairs	Ballasts with series-wired lamps	Check for discoloration or darkening at each end of each lamp. Test lamps. Replace defective lamps.
	One lamp glows, one lamp out	Check for discoloration or darkening at each end of each lamp. Test lamps. Replace failed lamps. Prolonged operation with one lamp glowing and one out will damage the good lamp. If symptoms persist for a relatively long time, replace both lamps.
Lamps in luminaires with a starter have end-glow. <i>NOTE: Stuck starters can cause excessive current to flow through the ballast and are a fire hazard.</i> <i>Immediately remove lamps with end-glow, that blink, or that have end-glow and blink.</i>	Starter is bad; lamp may be bad.	Remove the lamp until the starter can be replaced. Replace the starter and the lamp. <i>NOTE: A bad lamp can ruin a good starter over time, and a bad starter can ruin a good lamp over time.</i>

Lamps cycle on and off from once every few minutes to once or twice an hour	Overheated ballast with thermal cutout switch	Compare ballast input current to ballast label. Replace bad ballasts. Read ballast label and ensure that lamps are compatible. Replace lamps. Check with luminaire manufacturer and ensure that luminaire and ballast are properly mounted for adequate ventilation. Check for a problem related to thermal insulation around the luminaire.
Lamps appear different in color	Lamps have different color temperatures and/or color rendering indices	Match color temperature and color rendering indices of lamps. Match brand of lamp. <i>NOTE: Minor color differences between lamps or brands are normal.</i>
Lamps do not start in the dark	Starter is dependent upon the photoelectric effect to operate	Replace starter with a different brand.
Lamps only start when someone touches or brushes lamps or subjects the lamps to static electricity	Improper grounding of luminaire or ballast	Verify proper grounding. Verify that white supply wires are neutral conductors and that black or other color supply wires are phase conductors. Verify that lamps are physically located properly within luminaire.
	Component problems (less likely cause)	Problems may include lamp-ballast mismatch, lamp failure, low operating temperature, corroded or damaged socket or lamp contacts, low line voltage, lesser quality ballast, failing ballast, and/or incorrectly wired ballast. Test components. Replace defective components.
Lamps fail to start in cold temperatures	Low ambient temperature	Verify that ballasts are rated for low temperature starting. For pre-heat ballasts, replace the starter with a different brand.
	Component problems	Verify electrical and grounding connections. Verify that lamps are properly located physically within the luminaire. Check for lamp-ballast mismatch. Verify proper line voltage. Replace components as required.

Lamp start is unreliable	Component problems	Check for lamp-ballast mismatch, lamp failure, low operating temperature, corroded or damaged socket or lamp contacts, low line voltage, photoelectric-dependent starter, improper grounding, lesser quality ballast, failing ballast, and/or incorrectly wired ballast. Replace components as required.
	Ballast cannot start lamps	For lamps with reduced output or flickering during start up, replace lamps with a different brand, replace the ballast, or replace the luminaire as required.
Lamps appear dim	Low Ambient Temperature	Allow lamps to warm up for several minutes to verify dim operation. Install tube guards or plastic protective sleeves on lamps to allow heat to build. Do not install sleeves on lamps operating only slightly cooler than normal. Replace open luminaires with enclosed luminaires
	Lesser quality ballast	Replace ballast.
	Type of lamps installed	Broad spectrum lamps are typically rated for fewer lumens than standard lamps or tri-phosphor lamps.
	Lower wattage rating of lamps	Lower wattage lamps produce less light than higher wattage lamps.
	Aging lamps	Install new lamps.
	Lamp-ballast mismatch	Verify that lamps are compatible with ballasts.
	Ballasts are rated for multiple types of lamps	Lamps with higher wattage ratings may appear dim when supplied by ballasts capable of supplying several types and wattages of lamps.

8.4 High-Intensity Discharge Luminaires

Typical end of life characteristics for HID lamps include changing color, starting difficulties, and cycling on and off. HID lamps eventually fail and will not start. Additional components may fail if operation is continued with a failed lamp.

Table 8.4: Troubleshooting High-Intensity Discharge (HID) Luminaires

Symptom	Possible Cause	Remedy
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Lamp will not start	Incorrect lamp	Check label on the fixture and verify that ballast type is the same as the lamp. Check to make sure that an enclosed lamp is not operating on an open rated (pink color mogul socket) fixture.
	Defective HID lamp	Inspect lamp for broken components. Use a known functional lamp in the luminaire to confirm that the existing lamp has failed. Replace defective lamps.
	Incorrect ballast voltage wiring	Verify the open circuit voltage at the socket without the lamp. If voltage is off by more than 10%, confirm that voltage leads on the ballast match incoming voltage. If necessary, rewire the ballast to the correct voltage lead.
	Blown fuse	For fixtures with fusing option, remove fuse and test. If necessary, replace defective fuse.
	Defective socket	Remove lamp and inspect socket screw shell and center contact for damage. Replace socket if defective.
Delayed lamp ignition	Low Input Voltage	Verify the open circuit voltage at the socket without the lamp in accordance with manufacturer instructions. If voltage is off by more than 10%, confirm that voltage leads on the ballast match incoming voltage. If necessary, rewire the ballast to the correct voltage lead.
	Defective HID lamp	Inspect lamp for broken components. Use a known functional lamp in the luminaire to confirm that the existing lamp has failed. Replace defective lamps.
Decreased lamp life	Incorrect Lamp	Check label on fixture and verify that ballast type is the same as the lamp.
	Incorrect Lamp Burning Position	Check lamp for specifications (BU-base up, BD- base down, V-vertical, and HOR-horizontal). Replace the lamp with the appropriate type.
	Overheated Lamp	Verify that the ambient temperature rating for fixture complies with its environment.
Abnormal lamp operation	Incorrect ballast voltage wiring	Verify the open circuit voltage at the socket without the lamp. If voltage is off by more than 10%, confirm that voltage leads on the ballast match incoming voltage. If necessary, rewire the ballast to the correct voltage lead.
	Incorrect lamp	Check label on fixture and verify that ballast type is the same as the lamp. Check to make sure that an enclosed lamp is not operating on an open rated (pink color mogul socket) fixture.

	Inadequate wiring connections	Check for bad connections. Replace connections if necessary. <i>NOTE: Always use rated wiring connections.</i>
	Variable input voltage	Check input voltage during operation. If there is a fluctuation it may be necessary to remove other intermittent electrical loads from the lighting circuit.
Low lamp light output	Dirty environment	Start a maintenance program to regularly clean luminaires with excessive dirt accumulation.
	Lamp has reached its end of life	Check maintenance records to verify burning time. If near the end of lamp life, Replace the lamp.
Color shifting	Incomplete lamp burn-in	Lamp has not operated for at least 100 hours to allow for lamp stabilization.
	Incorrect ballast voltage wiring	Verify the open circuit voltage at the socket without the lamp. If the voltage is off by more than 10%, confirm that voltage leads on the ballast match incoming voltage. If necessary, rewire the ballast to the correct voltage lead.
	Using different lamp types/manufacturers	If using more than one type of lamp, combine like lamps in groups to blend color differences. <i>NOTE: All lamps have different color characteristics based on operating specifications and the date manufactured.</i>
	Lamp has reached its end of life	Check maintenance records to verify burning time. If near the end of lamp life, Replace the lamp.
High Pressure Sodium lamp repeatedly goes out for 1-3 minutes after warming up	Lamp has reached its end of life	Replace the lamp.
	A reflector is returning light to the lamp and overheating the lamp (less likely).	Check the reflector for proper alignment.
High Pressure Sodium lamp turns off for 1-3 minutes when a heavy electrical load is started	Lamp has reached its end of life	Replace the lamp.
	A reflector is returning light to the lamp and overheating the lamp (less likely).	Check the reflector for proper alignment.
	Voltage drop is causing the ballast to drop out (less likely).	Check the voltage at the ballast input. Check supply circuits for possible upgrade.
Lamps cycle on-off and go out before warm-up is complete	Lamp has reached its end of life	Replace the lamp.
	Lamp-ballast mismatch	Replace the lamp. Match lamp type to ballast. Match lamp wattage to ballast.
	Lamp is mounted in violation of mounting position, either vertical or horizontal.	Replace the lamp with one suitable for burning position, either horizontal, vertical, or universal.
Mercury retrofit Sodium lamp is unreliable in brightness, becoming brighter with age	Lamp-ballast mismatch	Determine whether lamps are suitable for the ballast and operating voltage. Replace the lamp.

Metal Halide Lamps change color and do so in unlike ways as they age	Lamp has reached its end of life	Replace the lamp.
Lamp is flickering and has not flickered before	Lamp has reached its end of life	Replace the lamp.
High Pressure Sodium lamp has short life or otherwise is not right	Lamp-ballast mismatch	Determine whether lamps are suitable for the ballast. Replace the lamp.
Replacement lamp is dim or fails to fully warm up	Lamp-ballast mismatch	Determine whether lamps are suitable for the ballast. Replace the lamp.
Lamp Explodes	Lamp-ballast mismatch	Determine whether lamps are suitable for the ballast. Replace the lamp.
	Incorrectly wired ballast	Verify ballast wiring diagram. Correct wiring.
	Excessive line voltage	Measure line voltage. Remedy excessive voltage.
	Ballast failure	Replace failed ballast. Replace the lamp.
	Lamp has exceeded its life expectancy	Replace the lamp.
	Overheated lamps	De-energize continuous operation metal halide and mercury lamps a minimum of 30 minutes once every two weeks. Lamps approaching catastrophic failure either do not restart or operate erratically when re-energized.

8.5 LED Luminaires

Table 8.5: Troubleshooting LED Luminaires

Symptom	Possible Cause	Remedy
Flickering	Fluctuation in power supply	Determine and correct the cause of power supply instability.
	Incompatible dimmer controls	Replace dimmer controls with LED compatible controls.
	Non-dimmable LED lamps	Replace non-dimmable LED lamps with dimmable lamps.
	Loose electrical connection	Troubleshoot and repair branch circuit wiring.
	Excessive voltage drop	Reduce load on branch circuit; install larger diameter conductors.
	Mismatched lamps, drivers	Install compatible lamps and drivers
Audible humming or buzzing sound	Incompatible dimmer controls	Replace dimmer controls with LED compatible controls; remove dimmer and install snap switch control.
	Non-dimmable LED lamps	Replace non-dimmable LED lamps with dimmable lamps.
	Loose electrical connection	Troubleshoot and repair branch circuit wiring.
	Mismatched lamps, drivers	Install compatible lamps and drivers.

Inconsistent color temperature	Mismatched LED lamps from different manufacturers and/or different color temperature ratings	Install lamps from one manufacturer and/or lamps with identical color temperature ratings.
	Lamps incompatible with control system	Reset control system; install lamps and luminaires that are compatible with the control system.
Inadequate brightness	Lamps with lower lumen output	Install lamps with higher lumen output.
	Insufficient quantity of luminaires to light the space	Install additional luminaires.
	Lamps incompatible with control system	Reset control system; install lamps and luminaires that are compatible with the control system.
	Loose electrical connection	Troubleshoot and repair branch circuit wiring.
	Mismatched lamps, drivers	Install compatible lamps and drivers.
	Excessive voltage drop	Reduce load on branch circuit; install larger diameter conductors.
Overheating	Inadequate ventilation	Increase ventilation; remove insulation or other materials in direct contact with luminaires preventing heat dissipation or install compatible luminaires.
	Dust, dirt, or debris buildup	Clean lamps and luminaires.
	Lamps installed in incompatible luminaires	Install lamps compatible with the luminaires.
	Incompatible lamps installed in enclosed luminaires	Install lamps rated for installation in enclosed luminaires.
	Faulty driver/inadequate heat sink	Install driver with correct wattage rating; correct heat sink issue (mechanical connections, contact).
	Excessive voltage drop	Reduce load on branch circuit; install larger diameter conductors.
Premature failure	Manufacturing defects, poor quality components	Check warranty terms and contact original manufacturer for a replacement; install higher quality lamps.
	Mismatched lamps, drivers	Install compatible lamps and drivers.
	Overheating	See “Overheating,” above.
Ghosting (lamps continue to glow faintly when off)	Branch circuit wiring issues (residual current, improper grounding)	Troubleshoot and repair branch circuit wiring and grounding.

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(This annex is not part of the Standard)

Annex A: Lighting Troffer Compatibility Considerations

Troffers are manufactured in different types for installation in different ceiling constructions. Some are also air handling fixtures integrated into the mechanical (HVAC) system. This annex provides guidance in ordering the appropriate troffer types for different applications.

A.1 Standard Suspended Ceilings

The following chart lists the most common ceiling systems. Some luminaires can be adjusted in the field to match the ceiling, but most must be ordered for the matching ceiling type. For unusual ceilings not listed in the chart, it is very important to order fixtures to exactly match the ceiling system. Most ceiling manufacturers of unusual ceiling suspension systems are capable of coordinating with lighting manufacturers on a special-order basis.

<i>NEMA Type</i>	<i>Ceiling System Description</i>
G	1" wide exposed grid inverted tee bar
NFG	9/16" wide exposed inverted grid tee bar
Z	Concealed grid Z-spline
M	Metal pan ceiling
GR	Concealed grid inverted tee bar
SS	Screw slot inverted grid tee bar
NFSG	Narrow faced slot inverted grid tee bar
F	Flanged

The following illustrations show typical installation relationships between NEMA standard ceiling types and troffer luminaires designed for them.

Exposed "TEE" Grid Ceiling Systems

G The most common ceiling type has a nominal 25 cm (1 inch) wide tee face (usually 23 cm (15/16 inch)). Some ceiling tile types, such as "tegular," are designed to help hide the grid. While in most cases these are compatible with NEMA type G luminaires, the installer should check the specific light fixture recommendations for the ceiling system actually being used.

NFG This variation has a narrow 14 cm (9/16 inch) tee face. Because this weight-bearing flange is so narrow, additional clips are generally required to secure NEMA type NFG luminaires.

Concealed Grid Ceiling Systems

Z Concealed grid systems are intended to provide a more finished appearance by hiding the ceiling support grid within the tiles.

M This luminaire type uses a trim fitting for metal pan and similar ceiling types.

GR This luminaire, which is similar to NEMA type G, has a fixture support flange above the bottom

of the adjacent tile. It can be furnished with a shroud or trim to finish off the regress.

Screw Slot Grid Ceiling Systems

SS In luminaires for screw slot or “fine line” ceiling systems, the fixture support flange is above the bottom of the adjacent tile.

NSFG The less-costly narrow faced slot grid appears similar to NEMA type SS, but uses a lay-in luminaire and securing clips.

Wallboard and Other Ceiling Systems

F The most popular used general-purpose luminaire is NEMA type F, which can be used with many types of ceiling construction including drywall.

A.2 Mechanical System Connections

Lighting troffers can also be furnished in following configurations:

- STATIC, in which the luminaire has no provisions for specific interaction with HVAC systems.
- HEAT EXTRACTION, in which the luminaire is designed to serve as a return air path for plenum return HVAC systems by pulling air into the luminaire (usually through the ends) and past the lamps before exiting through the luminaire top. Troffers can be ordered with adjustable dampers.
- AIR HANDLING, in which the luminaire has slots along the side which can be connected to supply air ducts, return air ducts, or serve as a grille for plenum return air. Troffers can be ordered with adjustable dampers and air control blades.

Troffers can generally be purchased in a “universal” configuration in which the heat extraction openings can be activated using a simple damper, and the air handling slots are activated by knocking out or removing material that blocks the air slots.

(This annex is not part of the Standard)

Annex B: Standard Downlight Ratings

Downlights are rated and labeled for specific applications. The most common ones are shown below. Additional ratings may be required in some jurisdictions. All fluorescent luminaires (such as downlights that use compact fluorescent lamps) are required to have ballasts rated Class P.

<i>Rating</i>	<i>Application</i>
T or none	<i>Thermally Protected.</i> All luminaires installed in ceiling or wall cavities except recessed installation
IC	<i>Insulated Ceiling.</i> Required in all applications where the luminaire is in direct contact with insulation.
Damp	Damp label for protected outdoor and certain indoor locations.
Wet	Wet label for exposed outdoor and certain indoor locations.
Feed-through	Luminaire is listed for branch-circuit feed-through wiring through a wireway integral to the fixture.
IP	<i>Insulation Protected.</i> City of Chicago rating. Required in certain applications where luminaire is being used near insulation.

1590 *(This annex is not part of the Standard)*

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1592 **Annex C: Special Mountings for Suspended Luminaires**

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1594 The following products are examples of special-purpose mounting devices useful for installing
1595 commercial lighting systems.

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(This annex is not part of the Standard)

Annex D: Reference Standards

This publication, when used in conjunction with the National Electrical Code and lighting equipment manufacturers' literature, provides sufficient information to install and maintain interior lighting systems. The following publications may also provide useful information:

National Fire Protection Association

Batterymarch Park

P.O. Box 9101

Quincy, MA 02269-9101

(617) 770-3000 tel

(617) 770-3500 fax

www.nfpa.org

NFPA 70, *National Electrical Code* (ANSI)

NFPA 70E, *Standard for Electrical Safety in the Workplace* (ANSI)

InterNational Electrical Testing Association

P.O. Box 678

106 Stone Street

Morrison, CO 80465

(303) 697-8441

(303) 697-8341 Fax

www.netaworld.org

NETA ATS, *Acceptance Testing Specifications*

Institute of Electrical and Electronics Engineers, Inc.

IEEE Operations Center

445 Hoes Lane,

Piscataway, New Jersey 08854-1331

(732) 981-0060

(732) 981-1721

www.ieee.org

IEEE Standard 802.3, *IEEE Standard for Ethernet*

National Electrical Manufacturers Association

1300 North 17th Street, Suite 900

Rosslyn, VA 22209

(703) 841-3200

www.nema.org

ANSI C137.3-2017 (R2022), *American National Standard for Lighting Systems - Minimum Requirements For Installation Of Energy Efficient Power Over Ethernet (PoE) Lighting Systems*

1646
1647 Telecommunications Industry Association
1648 Technology & Standards Department
1649 1320 N. Courthouse Road, Suite 200
1650 Arlington, VA 22201
1651 (703) 907-7700
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1659 To be added at time of publication
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