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		Author: Office of Facilities
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Change History

Date	Description of Change	Pages / Sections Modified	Change Approver Initials
6/22/21	Removed section L (Network Lighting Controls) and created new standard. Updates for LED fixtures.	All	MG, JR, JP
6/15/16	Updated division section from 16511 to 26 51 00, removed references to other section	-	mgl44
10/17/14	Add section L (Network Lighting Controls)	16> - 16511, L (Interior Lighting; Network Lighting Controls)	SO


A. Summary

This section contains design criteria for interior lighting systems.

B. System Design and Performance Requirements


1. General

- a. LED fixtures must be Energy Star or DLC listed to be eligible for utility incentives. This requirement also applies to retrofit kits and replacement lamps.
- b. Design lighting systems to achieve required levels of illumination while minimizing energy consumption. Select lamps and luminaires for high efficiency. Interior lighting systems must operate at the highest practical voltage level available. Specify high reflectivity interior finishes to achieve the following minimum reflectances:
 - Ceilings: 80 percent
 - Walls: 50 percent
 - Floors: 20 percent
- c. Incorporate natural day lighting in the design to greatest extent possible to replace or supplement artificial lighting.
 - (1) Use windows, clerestories, and skylights to admit light into interior spaces. Use control devices, such as blinds, diffusers, and light shelves to control distribution, brightness, and glare.
 - (2) Arrange interior lighting systems so appropriate areas can be switched off or dimmed when adequate natural light is present. Where applicable,

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provide control by the following means:

- Wall switches placed for occupant convenience
 - Occupancy sensors
 - Dimming controls, which may include multi-level stepping or switching
 - Photo sensors
 - Programmable central control systems
- d. Design interior lighting systems to achieve the following levels of illumination, measured in maintained horizontal foot-candles on a working surface located 30 inches above floor level, within a tolerance of plus or minus 20 percent:
- Auditoriums.....30
 - Bedrooms20
 - Classrooms50
 - Conference rooms.....40
 - Corridors.....20
 - Dining halls15
 - Elevators.....15
 - Gymnasiums (general).....30
 - Gymnasiums (varsity)50
 - Kitchens.....75
 - Laboratories.....75
 - Lecture halls30
 - Libraries (reading areas).....50
 - Libraries (stacks).....30
 - Lobbies15
 - Locker rooms.....15
 - Lounges15
 - Mechanical rooms.....20
 - Music rooms40
 - Offices50

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- Stairways 15
- Storage areas..... 15
- Toilets 15
- Waiting areas 15
- Workshops 75

- e. In occupancies where specialized tasks are performed (for example, at serving areas in dining halls and at mirrors in toilet rooms), the illumination levels listed in paragraph 3 might not be sufficient for adequate illumination. At such locations, increase the ambient lighting levels as necessary. Ambient lighting may also be supplemented by task lighting with the approval of the Yale University Project Manager (the ambient level should not be less than one-third the level at the task).
- f. Arrange lighting throughout all critical areas (including egress areas, assembly occupancies, health care facilities, and public safety operations) so that failure of any single element of the system, such as a lamp, ballast, switch, circuit breaker, or conductor, does not leave any portion of a critical area in darkness or illuminated at less than the levels required by code.
 - (1) Where only the normal distribution system is available, provide self-contained emergency lighting units connected to an unswitched lighting branch circuit conductor.
 - (2) Where both normal and alternate distribution systems are available, lighting fixtures must alternate between each source along the entire length of the critical area.
 - (3) Systems that use a central battery are acceptable only if wired as described in paragraph 6. b.
- g. In lighting calculations, maintenance factors (LLD x LDD) must not exceed 0.65. For high-intensity discharge fixtures, ballast factors must not exceed 0.9
- h. Interior light sources should be LED to the extent feasible , except as follows:
 - (1) When installed in YARC animal holding rooms.
- i. In areas where variable levels of illumination might be required by multiple users of the space, or for energy conservation purposes, provide multi-level

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switching or dimming capabilities. Such areas can include auditoriums and lecture halls, classrooms, gymnasiums, laboratories, offices, and workshops.

- j. Use motion sensors to control lighting in areas subject to extended unoccupied periods during normal hours of occupancy. Such areas include the following:
 - Classrooms
 - Conference rooms
 - Private offices
 - Bathrooms in residential colleges (locate sensors so that the interiors of toilet stalls are within the field of view)
 - Electrical, mechanical, T/D communication rooms. Adequate coverage is essential to ensure lighting doesn't go off while personnel are in the space. Consider hi/low dimming for these spaces.
 - Storage areas
 - Laundry rooms
- k. Coordinate luminaire locations with architectural features of space and with adjacent structural and mechanical elements.
- l. Avoid quartz-restrike capability with HID luminaires.
- m. Areas in which lighting is critical, such as means of egress, places of assembly, etc., should be provided with multiple lighting circuits fed from both normal and alternate systems so that failure of either source does not require transferring of the load.
- n. Because they are subject to accumulations of dirt and debris, avoid indirect systems. In all cases, luminaire design and placement must make it difficult for combustible debris to contact hot portions of luminaires, such as lamps and ballasts. Where the control of glare is a consideration, parabolic louvers are preferred. In rooms where two or more video display terminals are used, fixtures must have a minimum 0.7 visual comfort probability (VCP) value.
- o. Avoid custom fixtures, but minor modifications to stock fixtures are acceptable. Custom fixtures are acceptable only when necessary to preserve the architectural character of prominent spaces (for example, dining halls and common rooms in residential colleges).
- p. Avoid inefficient luminaires. Coefficients of utilization should exceed 0.7 for a room cavity ratio of 1.0.
- q. Luminaires recessed in fire-rated construction must be specifically listed for

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such use.

- r. Unless required to suit specific design conditions, such as wet locations, do not specify luminaires for interior spaces that are designed for exterior use.
- s. Wire four-lamp fluorescent luminaires for dual-level switching so that one ballast serves the inner pair of lamps and the other ballast serves the outer pair, whether or not such switching is called for in the project. Wire three-lamp fluorescent luminaires for multi-level switching so that the single-lamp ballast serves the middle lamp and the two-lamp ballast serves the outer lamps, whether or not such switching is called for in project. Where three-lamp fixtures are installed in continuous rows, wire them so that the middle lamps in each pair of adjacent fixtures are served by one two-lamp ballast located in either fixture.
- t. Ensure that the lighting fixture schedules shown on construction documents are in accordance with Section 01064: Electrical Regulatory and Directive Standards, Standard Detail 16500-1.

2. Lamps

- a. Avoid unusual lamps. Unless justified by specific design conditions, restrict lamp types to those commonly stocked by Physical Plant, which are identified in paragraph 2 under Equipment. Lamps should be LED unless not feasible due to a specific design requirement.
- b. Do not use energy-saving lamps in cold temperature applications (below 50°F) or where fluorescent emergency lighting or dimming systems are used.
- c. Use incandescent lamps only where other sources are not available or unsuitable.
- d. Where incandescent lamps rated at 130 volts are used on nominal 120 volt systems, base lighting calculations on the assumption that actual lumen output is 75 percent of the output at rated voltage.
- e. Low-pressure sodium and mercury vapor lamps are not acceptable.
- f. Avoid luminaires that use unusual lamps. Unless justified by specific design conditions, restrict lamp types to those described in this section. The use of 2-foot by 2-foot fluorescent fixtures is discouraged. Such fixtures may be used only with the approval of the Yale University Project Manager. Where such fixtures are permitted, use F17T8 lamps. U-shaped lamps are not acceptable.

3. Ballasts

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- a. All ballasts must be high power factor, energy-efficient, multiple-input types, where such products are commercially available.
- b. All fluorescent ballasts must be electronic-type used in conjunction with T-8 lamps. However, energy-saving magnetic ballasts may be used for small renovation projects where adjoining areas use fluorescent fixtures equipped with magnetic ballasts.
- c. In small areas, such as toilets or portions of egress areas, where multiple fixtures are not provided, specify two-lamp fixtures with two, single-lamp ballasts so that the failure of one ballast will not leave the area in darkness.
- d. Ballasts must be remote-mounted only when considerations such as noise, temperature, radio-frequency interference, and electromagnetic fields are critical.

4. LED Drivers

- a. LED drivers must be compatible with associated fixture/lamps.

5. Emergency Lighting


- a. Self-contained battery-type emergency lighting systems are acceptable only where alternate distribution systems are not available.
- b. LED fixtures supplied with alternate power and controlled with wireless sensors (i.e. Spacewise) may require a bypass relay in certain locations. Emergency Fixtures located common areas that can be programmed to a minimum egress level and never fully shutoff do not require a bypass relay.
- c. Locate emergency lighting units so that the lamps do not create excessive glare for persons traveling along egress areas to the nearest exit.
- d. Where power packs are to be added to standard fluorescent fixtures to achieve the required emergency lighting, calculations must indicate the actual lumen output of standard lamps in the emergency mode.

6. Exit Signs

Exit signs that incorporate emergency lighting heads in one unit are not acceptable because glare from the lights obscure the exit sign during emergencies.

C. Designer Submittals

Submit the following design and construction documents.

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1. Designer Submittals

- Lighting calculations or isofootcandle layouts demonstrating that required illumination footcandle levels and watts per square foot will be achieved throughout all spaces, including means of egress described in Section 00706: General Electrical Design Conditions.
- Catalog cuts


2. Construction Documents

- Shop drawings and product data
- Exit signs must be furnished with a minimum, 20-year manufacturer's warranty (exclusive of the battery)
- Operation and maintenance instructions, with parts lists

D. Product Standards

Ensure that all products conform to the following standards:

- ANSI C78.1 (with supplements), Dimensional and Electrical Characteristics of Fluorescent Lamps, Rapid Start Types
- ANSI C78.2 (with supplements), Dimensional and Electrical Characteristics of Fluorescent Lamps, Preheat Start Types
- ANSI C78.20, Characteristics of Incandescent Lamps of A, G, PS, and Similar Shapes with E26 Medium Screw Bases
- ANSI C78.21, Characteristics of Incandescent Lamps of PAR and R Shapes
- ANSI C78.1350 through C78.1359, High-Pressure Sodium Lamps
- ANSI C78.1375 through C78.1381, Metal Halide Lamps
- ANSI C82.1, Specifications for Fluorescent Lamp Ballasts
- ANSI C82.2, Methods of Measurement of Fluorescent Lamp Ballasts
- ANSI C82.3, Specifications for Fluorescent Lamp Reference Ballasts
- ANSI C82.4 (with supplement), Specifications for High-Intensity-Discharge and Low-Pressure Sodium Lamp Ballasts (Multiple-Supply Type)
- ANSI C82.5 (with supplement), Specification for High-Intensity Discharge Lamp Reference Ballasts
- ANSI C82.6 (with supplement), Methods of Measurement of High-Intensity Discharge Lamp Ballasts


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- UL 935, Fluorescent-Lamp Ballasts
- UL 1029, High-Intensity-Discharge-Lamp Ballasts
- NEMA LE1, Fluorescent Luminaires
- UL 1570, Fluorescent Lighting Fixtures
- UL 1571, Incandescent Lighting Fixtures
- UL 1572, High Intensity Discharge Lighting Fixtures
- UL 924, Emergency Lighting and Power Equipment


E. Manufacturers

Select luminaires that contribute to the aesthetic appeal of Yale University facilities while maintaining high standards of quality, energy efficiency, maintainability, and cost-effectiveness. The following manufacturers offer such features. However, this list does not exclude other manufacturers who, based on the experience of design professionals, might also produce acceptable luminaires.

1. Compact fluorescent downlights:
 - Edison-Price
 - Halo
 - Lightolier
 - Prescolite
2. Decorative compact fluorescent lighting:
 - Kamro-Champion
 - Lightolier
 - Seagull
 - Shaper
3. General fluorescent lighting, including troffers, wraparounds, and industrial fixtures:
 - Columbia
 - Day-Brite
 - Lithonia
 - Metalux
4. LED recessed troffers:
 - Philips (Evogrid) or equivalent

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5. LED Retrofit kits for recessed troffers:
 - Philips (Evokit) or equivalent
6. Decorative fluorescent lighting:
 - Alkco
 - Architectural Lighting Systems
 - Litecontrol
7. Track lighting:
 - Juno, Prescolite, or Ruud (interchangeable on the same track)
 - Lightolier
 - Staff
8. Industrial lighting:
 - Holophane
 - Hubbell
 - Lumark
 - Sportlite
9. Fluorescent Lamps:
 - General Electric
 - Phillips
 - Sylvania/Osram
 - Link
10. LED retrofit lamps for CFL fixtures:
 - Philips
11. LED retrofit tubes for T8/T5 fluorescent lamps
 - Philips (instantfit) or equivalent
 - GE
 - Green Creative
12. Emergency Lights:
 - Dual-Lite
 - Emergi-Lite
 - Lithonia

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13. Exit Signs:


- Exitronix
- Hubbell
- Self-Powered Lighting (SPL)

F. Materials

1. Use prismatic acrylic (pattern 12) lenses for fluorescent fixtures, but specify polycarbonate where the fixtures are subject to physical damage. Use tempered glass lenses for high-intensity discharge fixtures.
2. Where louvered fixtures are selected, specify acrylic louvers instead of polystyrene. Where parabolic louvers are selected, semi-specular finishes are preferred over specular finishes. Where miniature parabolic louvers are selected, the openings must be 1/2 inch by 1/2 inch by 1/2 inch.

G. Equipment


1. Use long-life, soft white or inside frosted, Type A incandescent lamps with an average life of 3,000 hours at 130 volts.
2. Use energy-saving, Type R incandescent lamps. Specify 130 volt models where available.
3. LED Fixtures for laboratories and support spaces should have a color temp of 4000°K. Office areas should have a color temp of 3500°K. Office spaces that are within labs or direct access to a lab should have the same color temp as the lab (4000°K).
4. Compact fluorescent lamps must have a two-pin base, with a minimum rated lamp life of 10,000 hours. Chromaticity must be between 2700°K and 3000°K; however, 3500°K lamps may be used where necessary to match the color of T-8 fluorescent lamps. The following lamp types are preferred:
 - Twin tube, 7 watts: NEMA CFT7W/G23
 - Twin tube, 9 watts: NEMA CFT9W/G23
 - Twin tube, 13 watts: NEMA CFT13W/GX23
 - Quad type, 13 watts: NEMA CFQ13W/G24d
 - Quad type, 18 watts: NEMA CFQ18W/G24d
 - Quad type, 26 watts: NEMA CFQ26W/G24d

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5. Use 265 milliamp, T-8 rapid-start fluorescent lamps wherever possible. Lamp chromaticity must be 3500°K. Lamps of 3000°K may be used with the Yale University Project Manager's approval, but other colors are not acceptable. The minimum rated lamp life must be 20,000 hours. Only four-foot lamps are acceptable in fixtures four feet or more in length. U-shaped lamps are not acceptable. The following lamp types are preferred:
 - Four-foot, bi-pin base: F32T8/3500K/RS
 - Two-foot, bi-pin base: F17T8/3500K/RS

6. Metal halide lamps must be clear-, medium-, or mogul-base only with a minimum rated lamp life of 10,000 hours. Use self-extinguishing lamps in applications, such as sports lighting or open-bottom downlighting, where damage due to impact may be anticipated. Where color uniformity within groups of lamps is important, such as walkway lighting applications, use General Electric "Halarc" series lamps. The following lamp types are preferred:
 - 50 watt, medium base, for M110 ballast
 - 70 watt, medium base, for M98 ballast
 - 100 watt, medium base, for M90 ballast
 - 175 watt, mogul base, for M57 ballast
 - 250 watt, mogul base, for M58 ballast
 - 400 watt, mogul base, for M59 ballast
 - 1000 watt, mogul base, for M47 ballast
 - 1500 watt, mogul base, for M48 ballast


7. Use clear, high-pressure sodium lamps with a minimum rated lamp life of 24,000 hours. However, deluxe coated lamps with a minimum rated lamp life of 10,000 hours may be used where color rendition is important (minimum CRI 65 at 2200°K). The following lamp types are preferred:
 - 35 watt, medium base, for S76 ballast
 - 50 watt, medium base, for S68 ballast
 - 70 watt, medium base, for S62 ballast
 - 100 watt, medium base, for S54 ballast
 - 150 watt, mogul base, for S55 ballast
 - 250 watt, mogul base, for S50 ballast
 - 400 watt, mogul base, for S51 ballast

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- 1000 watt, mogul base, for S52 ballast

8. Ballasts:

- a. Fluorescent ballasts must be ETL/CBM certified.
 - b. Fluorescent ballasts, other than reactance type, used with interior fixtures must be labelled UL Class P.
 - c. Fluorescent ballasts that are not used for dimming or cold weather applications must meet or exceed Federal Ballast Efficacy Factor requirements for fixtures intended for use in commercial buildings.
 - d. Fluorescent ballasts must carry an "A" rating in the manufacturer's sound classifications; however, ballasts for 800 milliamp lamps may carry "B" rating.
 - e. Use integrated circuit fluorescent electronic ballasts.
 - f. Fluorescent ballasts used where ambient temperatures fall below 50°F must be labelled for cold weather operation.
 - g. Fluorescent ballasts used in dimming applications must be listed for use with the specific dimming controls provided, unless labeled for connection to Class 2 limited energy circuits.
 - h. Where fluorescent ballast operation will interfere with radio reception, specify ballasts with radio interference filters.
 - i. Use weatherproof ballasts only where directly exposed to weather. Use UL Type 2 outdoor ballasts for installation in exterior lighting fixtures.
- 9.** Use regulating, high-intensity discharge lamp ballasts with a minimum starting temperature of -20°F. For interior use, use enclosed, potted-type HID ballasts with the lowest available sound rating.
- 10.** Do not provide luminaries with fuses.
- 11.** Do not provide luminaries with receptacle outlets.
- 12.** Fixtures must be hard-wired. Cord-and-plug connected luminaires are not acceptable, except in high-ceiling HID applications.
- 13.** Self-contained emergency lighting units must operate from a maintenance-free, lead-calcium battery with an automatic charger. The units must be 6 VDC, except where high capacity is required to illuminate long distances or large areas, in which case 12 VDC units are acceptable. Use the following standard PAR 36, sealed-

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beam lamps:

- Halogen: 6 watts minimum
- Tungsten: 9 watts minimum


14. Battery power pack emergency lighting units must be hard-wired. Cord-and-plug connected units are not acceptable.
15. Power packs for standard fluorescent fixtures must be compatible with lamps and ballasts furnished with the fixture. Power packs must contain a battery, a charger, and control circuitry in one housing and be suitable for high-temperature operation. Power packs must be capable of being wired to switched fixtures without unnecessary emergency operation. Power packs must have LED indications to show the condition of their control circuit and batteries and have an audible alarm for component failure.
16. For energy conservation and low maintenance requirements, use Light-Emitting Diode (LED) exit signs with a maximum consumption of two watts per face. To permit visibility within a 170° field of view, furnish exit signs that have red letters with prismatic diffusers for even illumination across all parts of all letters.
17. Exit signs must operate on 120 VAC or 277 VAC power. If not connected to an emergency distribution system, specify exit signs with battery backups that include a charger and control circuitry. Specify batteries as described paragraphs 12 and 14.

H. Preparation

Protect luminaires from wall and ceiling finishing operations. Do not install the exposed portions of luminaires until the finishes have been applied to the surrounding areas and allowed to dry.

I. Installation Guidelines

1. Install lamps only in positions indicated in the lamp designation code.
2. Do not install high-intensity discharge lamps with scratched bulbs.
3. Do not energize high-intensity discharge lamps until they are enclosed within fixtures.
4. Bond all ballast cases to the equipment grounding conductor.
5. Luminaires installed in occupancies, such as laboratories and workshops, must be oriented parallel to benches and centered over the edge of the working surface.

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Space luminaires to maintain a maximum uniformity ratio of 2:1.

6. Use a maximum six-foot length of flexible metal conduit to connect luminaires located in suspended ceilings to branch circuit wiring.
7. Where dual-level or multi-level switching is provided, wire luminaires so that each switch controls corresponding lamps in all luminaires controlled by the switch.
8. Connect emergency lighting and exit sign units to unswitched conductors fed from the same branch circuit serving normal lighting in the protected area.
9. Do not mount emergency lighting and exit sign units higher than 10 feet above the finished floor unless provisions are made for the maintenance of such units.
10. Center exit signs on building elements, such as corridors and doorways.
11. Luminaires must be fitted with swivels or otherwise adjusted so they hang plumb and true. Pendant Luminaires must not be chain hung.

J. Quality Control

1. After the lamps have been in service for 100 hours, obtain footcandle measurements during periods of darkness at a sufficient number of locations to demonstrate that the design criteria have been met. Submit the results to Yale University.
2. Where ballast noise is audible above the normal ambient noise, use sound level meter capable of measuring as low as 35 dBA to test the ballast noise level in accordance with the ballast manufacturer's specifications. Provide replacement ballasts where ballast noise is excessive. Where heat dissipation is not a concern, a resilient pad may be installed between the ballast and fixture.
3. Test emergency lighting units by opening the circuit breakers that serve normal lighting in the areas protected by the emergency lighting units.
4. Test exit signs by opening the circuit breakers that serve normal lighting in the areas served by the exit signs.

K. Cleaning and Adjusting

Clean and adjust luminaires at the end of the construction period.