DIVISION 26 – ELECTRICAL

Includes the following sections:

GENERAL 26 00 00

Abbreviations:
The following abbreviates may be referenced in these design guides specific to division 26. Where any conflicts occur with the University of California Office of the President (UCOP) Facilities Manual or design specifications, these definitions shall take priority as they relate to this section only.

A:	Amps
BMS:	Building management system
CEC:	California Electrical Code
DCFM:	designated campus fire marshal
ETL:	A listing mark that indicates to distributors, retailers and customers that a product has been tested by Intertek and found in compliance with accepted national standards.
FRP:	fiberglass reinforced plastic

IGBT: insulated-gate bipolar transistor
kV: kilo-Volts
kVA: kilo Volt-Amps
NETA: Inter-National Electrical Testing Association
NFPA: National Fire Protection Association
NO: normally open
NC: normally closed
PPDO-ES: Physical Planning Development and Operations Engineering Services
UL: Underwriter Laboratories
V: Volts
VA: Volt-Amps

DESIGN REQUIREMENTS	**26 05 00**

Verify points of connection to existing utilities with the University's Representative. All utility services, including electric, telephone, fire alarm, data, etc. are to be underground.

Building electrical systems should be 480/277 volts, 3 phase, 4 wire and/or 208/120 volt, 3-phase, 4-wire for lighting and power.

Harmonics - Building harmonics shall be evaluated and documented by the Design Professional. Where deemed necessary by the University Representative the design professional shall submit a harmonics report to University's Representative for review. Identify corrective measures if harmonics exceed building requirements. Following are a few possible corrective measures: Separate neutrals for branch circuits, full size grounding, K-rated transformers, upsize panel board neutral conductor, reduce total harmonic distortion of electronic ballasts, etc. Discuss with University's Representative prior to establishing any of the corrective measures. Transformers installed to serve 50% or greater non-linear loads such as data closets, desktop PCs, audio- visual equipment, multimedia systems, VFDs, UPSs, etc. shall include harmonic suppression systems.

POWER SYSTEM STUDY

1. Perform Short Circuit, Protective Device Evaluation, Protective Device Coordination Studies and Arc Flash Study. Study shall be prepared and signed by a California registered Electrical Engineer. The contractor shall submit studies to the University's Representative prior to receiving final acceptance of distribution equipment shop drawings or prior to release of equipment for manufacture and prior to energizing equipment. Engineer of record (or design build contractor) shall submit a preliminary

short circuit analysis with design documents to recommend ratings of specified equipment prior to issuing for bid. Provide the above referenced studies for both normal and emergency systems.

2. Studies shall include all portions of the electrical distribution system from the point of connection to the primary side of service transformers down to, and including the 480V and 208V distribution system. They shall also include required settings for all medium voltage (12KV and/or 21KV) equipment installed as part of the project. Studies involving the connection to the campus medium voltage network shall also comply with the requirements set forth in division 33 71 00. Normal system connections and those which result in maximum fault condition shall be adequately covered in the study.
3. Device identifications referenced on power systems study printouts and associated single line diagrams shall coordinate and agree with device identifiers on contract documents.
4. The study report shall summarize results in a final report. The following sections shall be included in the report:
    a. Description, purpose, basis and scope of study and single line diagram of that portion of the power system which is included within scope of study.
    b. Tabulations of circuit breaker, fuse and other protective device ratings versus calculated short circuit duties and commentary regarding the same.
    c. Protective device time versus current coordination curves, tabulations or relay and circuit breaker trip settings, fuse selection and commentary regarding the same.
    d. Fault current calculations including a definition of terms and guide for interpretation of computer printout.
    e. Specific Arc Flash OSHA compliant self-adhesive label printouts at full scale for each piece of equipment provided and installed within the scope of the project including the code required hazard warning and recommended PPE labels.
    f. Company name performing study.
    g. Electrical Engineer responsible for study.
    h. Date study was performed.
5. Protective Device Testing, Calibration and Adjustment: Contractor shall provide the services of a NETA certified field engineer and necessary tools and equipment to test, calibrate and adjust the protective relays and circuit breaker trip devices as recommended in the power system study.
6. For projects involving existing buildings with existing electrical equipment, the full scope of the coordination study, arc flash calculation and labeling requirements shall be coordinated with PPDO Engineering Services and Electrical Engineer of Record (or Design Build Contractor) in the preliminary design stage in order to add specific requirement language defining the study scope in the construction documents.

OTHER DESIGN CALCULATIONS AND STUDIES

The following shall be performed by the Electrical Engineer of Record or his/her agent and

submitted in addition to design drawings and specification documents for review:

1. Load calculations including service equipment and generator sizing calculations: The following minimum data shall be included with these calculations:
    - Historical, 30 day measured loads per California Electrical Code Section 220 to the existing building, service and utility feeders that are intended to be used for delivery of new and/or modified buildings and projects.
    - Assumed loads (and their associated criteria) when no measured recorded load survey is available (on approval of PPDO Engineering Services).
    - Calculated proposed new load after construction is complete on each panelboard, distribution board, main switchboard, service lateral and utility feeder.
    - Voltage drop calculations on all new feeders and any existing feeders affected by load increases.
    - Conduit percent fill calculation tables for typical feeder and circuit runs.
2. When a project proposes to draw power from an existing electrical service, panel or transformer connected to the campus owned 12kV or 21kV utility network the following calculations and/or data tabulations shall be shown on the 50% construction document drawings based on the point of connection:
    - 30 day measured and recorded current and voltage load data on the existing service, transformer or electrical panel to be connected to per California Electrical Code requirements for establishing existing loads.
    - As an alternative to the 30 day load study, the engineer of record shall provide field surveys and as-built data collection as necessary to provide a California Electrical Code compliant load summary calculation of connected and demand adjusted existing loads to justify the addition of electrical load required for the project.
    - A clear tabulation of existing loads, proposed new loads and final total loads with the code required adjustments. This shall also clearly show the existing service capacity and that the final load is within that capacity.
3. Lighting photometric calculations including illuminance footcandles,—shall be performed by the designer and submitted with the design documents for review. Additional lighting photometric calculations may be required depending on the use of the space. Coordinate these requirements with PPDO Engineering Services before schematic design.
4. Other calculations as deemed required and necessary for a fully engineered installation may include, but not be limited to, battery sizing, UPS sizing, motor starting current, conduit percent-fill and wire sizing, ground resistance, power factor

correction.

LOW VOLTAGE ELECTRICAL POWER AND CONDUCTORS AND CABLES 26 05 19

PRODUCTS

Conductor – The campus standard is stranded copper for all installations. The minimum size is #12 AWG unless specified otherwise and approved by UCSC PPDO Engineering Services.

Insulation - THWN or THWN-2 for wet or underground locations and THHN for dry or damp locations.

Wire Connectors

1. For wires size #8 AWG and smaller: insulated pressure type (with live spring) rated 105 deg. C, 600V, for building wiring and 1000V in signs or fixtures.
2. For wires size #6 AWG and larger: compression type with tape insulation.
3. Outdoors and below grade: All sizes to be compression type with heat shrink style watertight splice covers.

Other insulation or connectors may be specified, depending on use and in coordination with the requirements of the California Electrical Code.

Any deviations in the above requirements on wire and connectors shall require written approval from UCSC PPDO Engineering Services prior to specification in construction documents or ordering material.

EXECUTION

Install all wiring in raceways. All cables and wires passing through manholes and handholes shall be full looped inside the manhole and handhole and supported on galvanized steel, stainless steel or FRP racks. Clarify requirements with the University Representative. Contractor to coordinate between the site and building trades for the handoff between the medium voltage and building systems.

Provide panel/circuit identifiers where the number of conductors in a box exceeds three.

Wire Color Code - Color code all conductors at every handhole, junction box, pull box, manhole and underground pull/splice box and any other location where conductors can be viewed within an enclosure, equipment disconnect or outlet. Wire sizes #6 AWG or smaller shall have integral color-coded insulation. Wire sizes #4 AWG and larger may have black insulation but identified by color coded electrical tape at all junction, splice, pull, or termination points. Color tape shall be applied 1/2 lap to at least 6 inches of conductor. Color Code wires as follows (confirm with University’s Representative)

Conductors	120/208 Volt	277/480 Volt
Phase A	Black	Brown
Phase B	Red	Orange
Phase C	Blue	Yellow
Neutral	White	Grey
Ground	Green	Green
Isolated Ground	Alternating Green/Yellow	Alternating Green/Yellow

Color coding of wires used for signal and communication systems are specified under the respective sections for these systems.

TESTING

Megger and record insulation resistance of all 600 volt insulated conductors size #4/0 AWG and larger, using a 500 volt megger for 1 minute in conformance with current IEEE standards on 600V conductor testing. Make tests with circuits isolated from source and load.

GROUNDING 26 05 26

The performing contractor shall provide code compliant equipment grounding conductors and grounding electrode conductors as required at all electrical equipment. Metallic raceways and MC cable sheaths shall not be used as equipment grounding conductors or grounding electrode conductors.

The grounding system shall provide a connection to earth for the system derived neutrals, and for the service equipment enclosures. Electrical Engineer or Contractor shall coordinate between the site and building trades to confirm grounding of the distribution system. The grounding system shall provide control of the voltage gradient on the finished surfaces adjacent to the pad mounted service equipment. The grounding system shall include all of the following elements:

GROUND ELECTRODES

1. Ground Grid - A cable loop in the earth, with driven ground rods, in a ring around the service equipment pad/vault, with connecting cable. Minimum of 1 grounding rod inside the transformer and 1 outside the pad.
2. UFER Ground - A length of copper cable embedded in the concrete foundation of the facility being served.
3. Metallic Piping - A connection to the interior metal piping system.

GROUND BUSES

Provide at each Service Distribution Panel for the joining of ground connections, and to provide

an accessible grounding system test location. From each ground bus make the following ground connections:

1. The metal enclosure of the associated Service Distribution Panel.
2. The metal tank or enclosure of the associated Service Transformer.
3. The ground bus in the facility panelboards. This bonding cable to be run in the same raceway with the facility service feeder cable.
4. Combining neutrals of multiple service transformers to the system neutral(s) is prohibited. It is prohibited to daisy-chain neutrals from transformer to transformer then having a single home run to the service entrance transformer.

GROUND CONNECTIONS

Provide a separate copper-grounding electrode conductor from each grounding electrode to the system ground bus at each of the service distribution panels. Provide the code required size of grounding conductor between the transformer secondary compartment and the building main panel ground.

GROUND RODS

Copper clad steel rods, 1 inch by the required dimension, in sectional 10 foot lengths with pointed end, driven to a depth where the rod top is not less than 6 inches below finish grade at the equipment pad and not less than two inches above the floor in the equipment vault. Adjust length of exposed rod to allow multiple clamps to be affixed to the ground rods. Protect rod top with a driving tool while driving to prevent deformation or other damage.

CABLE CONNECTIONS

1. To Ground Rods - Exothermic weld, Cadweld or equal, utilizing weld molds furnished by the weld manufacturer and the type and size recommended by the weld manufacturer.
2. Ground Cable Splices - Exothermic weld, Cadweld, or equal, utilizing molds of the type and size recommended by the weld manufacturer.
3. To Ground Buses and to Equipment - Pressure indented copper cable terminal, one hole: Burndy HYLUG, T&B Blue, or equal. Install with full size galvanized or cadmium plated steel machine bolts with beveled washer each side.

TESTING

Grounding electrode resistance testing shall be accomplished with a ground resistance direct reading single test meter utilizing the Fall-of-Potential Method and two reference electrodes. Contractor to perform test prior to interconnection of the grounding systems. Orient the concrete encased ground electrode to be tested and the two reference electrodes in a straight line spaced 50’ apart, drive two referenced electrodes five feet deep. Test results shall be in writing and shall show temperature, humidity and condition of the soil at the time of the tests. In the case where the ground resistance exceeds 25 ohms, drive an additional ground rod to reduce the resistance to less than 25 ohms. Testing shall be by an independent NETA certified testing agency.

HANGERS AND SUPPORTS 26 05 29

CONDUIT SUPPORTS

Single point beam clamps are not allowed. Conduits shall not be attached to ceiling support wires. For individual conduit runs not directly fastened to the structure, use rod hangers. For multiple conduit runs, use trapeze type structural channel conduit support designed for maximum deflection not greater than 1/8 inch. In new construction, conduits installed inside of walls must have approved clamp supports.

EQUIPMENT MOUNTING AND SUPPORT HARDWARE

Steel channels, bolts, washers, etc., used for mounting or support of electrical equipment shall be galvanized type. Where installed in a marine or corrosive environment stainless steel hardware shall be used.

RACEWAYS AND BOXES 25 06 33

Sizes for conduits, unless specifically shown otherwise, shall meet the latest California Electric Code, provide adequate space for future capacity increase, this generally means using 30 percent fill. In new construction, minimum conduit size shall be 3/4 inch except conduit up to 30 feet in length, from junction box to an individual device may be 1/2 inch upon written university approval. This approval shall be documented in the schematic design phase.

MATERIALS

Galvanized Rigid steel conduit with threaded fittings shall be used in the following locations:

1. Damp and wet locations including outdoor service yards and on roof.
2. Exposed locations below 8 feet subject to physical damage.
3. In concrete walls or block walls.
4. In concrete vaults.

PVC Coated rigid steel conduit or double wrapped galvanized rigid conduit with 3M 10-mil tape or equal shall be used in the following locations:

1. In stub ups through raised floors or slabs in kitchen equipment service areas, water reclamation equipment areas or sewage treatment equipment areas
2. In exposed areas of corrosive environments
3. Exterior locations within 1000’ of the ocean.
4. Where in direct contact with earth, sand or encased in concrete.
5. Provide double wrapped GRC elbows on runs greater than 100 feet or on runs with more than two 90-degree elbows.

EMT connectors and couplings shall be steel compression with insulated throat type indoors.

Wireways: Code gauge steel, with knockouts and hinged or screwed covers. Corrosion resistant gray baked enamel finish. Wireways smaller than Wiremold brand 700 are not acceptable. Wireway with preassembled devices installed are not acceptable, i.e. Wiremold 2000 and 2200.

Use flexible steel conduits with steel Tite-Bite type connectors in the following applications and install a code sized ground wire in flexible conduit.

1. Recessed lighting fixtures.
2. Motor connections.
3. Connection between fan plenum and structure.
4. At expansion joints.
5. At transformers and other equipment which produces vibration.
6. At damp and wet locations or where exposed to weather, flexible steel conduit shall be liquid tight rated.

Flexible steel conduits (with code size ground wire) up to 20-feet in length are permitted between receptacles and between light fixtures within a single room. All home runs to panels and conduit between rooms shall be EMT.

Metal Clad (MC) cables are generally not allowed. MC may be allowed on a case-by-case basis upon submittal of detailed exception request to UCSC for approval prior to schematic design and product data submittal. Any contractor intending to use MC cable shall submit a thorough submittal clearly designating where it shall be used on a set of floor plans if it is not clearly identified in the construction documents. This submittal shall be approved by UCSC PPDO ES prior to installation.

EXECUTION

Duct shaft - Conduits shall not cross any duct shaft or area designated as future duct shaft horizontally.

Pull Strings - Install 1/8 inch diameter yellow polyline pull line in all conduits intended for future use. Tag pull lines for item served.

Sleeves – Provide at all penetrations of footings, basement walls, or floor slabs.

LOW VOLTAGE UNDERGROUND DUCTS AND RACEWAYS 26 05 43

In addition to the requirements listed above, the following applies to underground ducts and raceways. Provide line markers per Section 33 05 26.

PRODUCTS

Direct Burial and Concrete Encased Raceway - PVC Schedule 40 Duct and end bells except for the following locations which shall be rigid steel conduit:

1. Provide one 10-foot section of rigid steel conduit at point of penetration of foundation, footing or basement wall, with equal lengths inside and outside building line.
2. Make all risers to grade, including elbows. Risers to begin 18-inches below grade and extend 16-inches above grade.
3. Exposed in vaults.

Elbows - Factory made. Use a minimum radius of six times trade size.

Flush-in-grade Handholes - precast concrete type with structurally reinforced roadway type bolt-down galvanized steel covers and required extension collars. Handholes and pull/splice boxes shall be provided with concrete bottoms and 6-inch minimum height drain rock sumps.

EXECUTION

Multiple conduits shall maintain 3-inch minimum separation between conduits. Provide plastic spacers at maximum 5-feet centers or as required to maintain 3-inch spacing between conduits. Do not install plastic conduit in rock base.

PVC conduit 1-½-inch size and smaller shall be installed on a 2-inch sand base and covered by 2-inch sand backfill. In planting areas provide 2-inch concrete cap.

Concrete encased duct banks shall contain a single system. Duct banks for different systems shall not be encased together. There shall be a separation between the concrete encasement for each separate system when combined in a “shared trench”. Concrete encased duct banks in shared trenches shall be side by side and not stacked upon one another.

Install 3-inch minimum concrete encasement on raceways larger than 1-½-inch conduit or duct banks that include two or more raceways in a single trench. Drive two reinforcing bars to anchor the conduits at 10-feet centers to prevent floating during concrete pour.

Burial Depth

1. Concrete encased: 24-inch minimum for 600V or lower systems to top of concrete encasement.
2. Concrete capped: 24-inch minimum to top of conduit.
3. Conduits without concrete encasement or cap: 24-inch minimum to top of conduit.
4. Conduits under buildings: 18-inches below bottom of floor slab.

Slope electrical ducts and conduit downward toward manholes and away from buildings a minimum of 2-percent when located within ten feet of a building foundation.

Handholes shall be left in a clean condition with all debris removed and with all cables supported on approved cable supports. All stubs for handholes shall be concrete encased and

shall extend 5-inches beyond handhole.

All electric conduit or ducts shall be at least 10-feet from steam lines unless engineered to prevent heat damage.

TESTING
All underground conduits and ducts 2-inch and larger shall be proven clear by pulling through a mandrel 0.25 inches smaller than the inside diameter.

ELECTRICAL SYSTEMS IDENTIFICATION 26 05 53

SWITCH AND RECEPTACLE LABELS

Provide clear color base Dymo labels on all lighting switches and convenience and special purpose receptacles to show panel and circuit number to which the device is connected.

PULL BOX AND VAULT COVERS
Bronze plate, machine engraved with vault, manhole, or box ID. Designation in 3/8 inch high capital letters. Marker attached with epoxy adhesive to the cover. Pull Box and vault covers to have ‘ELECTRIC’ welded onto box or vault rim.

CABLE BOX RACEWAY ENTRANCES
Apply stenciled label on the wall to identify the destination of raceways. Use building name, equipment name, manhole number, or cable box number.

NAMEPLATES
Provide rigid plastic laminated Impact Acrylic plate, 2-layer, 3/16-inch minimum thickness, machine engraved with ⅜-inch high lettering, all caps, on black background. Provide nameplates for meters, transformers, panels, motor starters, disconnect switches and all associated devices. Use black background with white letters (normal power), red background with white letters for emergency power, yellow background with white letters for standby power. For remote devices (disc. switches, etc.) and all panels indicate source of power.

WARNING SIGNS
Provide plastic laminated Impact Acrylic plate, 2-layer, 3/16-inch minimum thickness, machine engraved with red lettering, all caps, on white background. Lettering 2-inches high. Provide label on all motors: “Caution, Automatic equipment. May start at any time.” Provide warning signs for service transformers.

FEEDER TAGS
Engraved laminated Impact Acrylic Tag: Engraved with white lettering on black background, letter ⅜-inches high with one piece nylon tie.

PHASE MARKERS

Cable Phase Markers: Clear plastic over wrap-to-wrap 1 –1/4 times (minimum) around cable. Label colored per color-coding with phase letter printed 1-inch high. Apply marker to each cable.

WIRE MARKERS

Slipon Wire Markers: PVC wire marker with permanent machine printed or embossed lettering.

NAMING CONVENTION AND COLOR CODING FOR EQUIPMENT AND DEVICES

The panel designation can be up to seven (7) characters with the last characters of floor and area using sequential number and letter (if needed) separated by a hyphen.

Position One – Source
E - Emergency (Fire/Life Safety)
S - Standby
Blank - Normal

Position Two – Voltage
H – 480/277 Volt
L – 208/120 Volt

Position Three – Distribution/Equipment
DP – Distribution Panel
PP - Power Panel
LP – Lighting Panel
ATS – Automatic Transfer Switch
BD – Bus Duct
MC – Motor Control Center
MS – Motor Starter
VFD – Variable Frequency Drive

Position Four - Building Level
0 – Basement/Lower Level
1 - First
2 – Second
3 - Third
M - Mezzanine

Position Five - Sequential or Area Panels/Equipment
A - First Panel or Area A
B - Second Panel or Area B
C - Third Panel or Area C
D - Fourth Panel or Area D

Examples:
E-HDP-2A =emergency panel, 480/277V, distribution panel, second floor, Area A
S-HLP-1C

S-LPP-1
HDP-1A

Color coding of panelboards, receptacles and other distribution devices used for Standby power, Emergency power and fire alarm distribution shall be as follows:

Red for Emergency and Fire Alarm
Yellow for Standby

LIGHTING CONTROL 26 05 23

GENERAL REQUIREMENTS

The interior lighting control system shall provide programmable and operational lighting control, real-time monitoring capabilities of lighting and plug loads, and historical system data storage. The lighting control system shall be accessible and maintainable from a central control location as well as a remote location via internet protocols. Firmware updates required to maintain system functionality shall be supported by the lighting control system manufacturers via on-site local connection and remote internet connectivity.

The lighting control system shall consist of operating software, network bridges and switches, room controllers, occupancy and photo-sensors, daylighting sensors, dimming controls, and switches. All devices shall be addressable. Where required by the construction documents, lighting networks shall consist of a room controller which accepts inputs from the occupancy sensors, daylighting sensors, ethernet gateways, and switches to drive the lighting load. The local network shall provide two-way communication with the operating software. The operating software shall communicate with the local networks, providing control, monitoring, adjustment, and scheduling capabilities.

The lighting control system shall be programmable and the status readable from the central control location.

The lighting control system manufacturing company shall be regularly engaged in the manufacture of lighting control equipment and ancillary equipment, specifically of types and capacities required, whose products have been in satisfactory use in similar service for not less than five years. Systems must retain their program internally for up to one year including a loss of power. Systems must automatically restore themselves during a power outage to its condition prior to the outage. If any relay panel, control, switch or sensor shall fail, the remaining portion of the system shall continue operating with only a loss of the failing component. A loss of control input power or control operating system shall cause the lighting relays to fail in the “ON” or “Emergency” position. All relays shall have a way to place the relays in a “manual ON” bypass position in software for use during troubleshooting or operating system loss. The lighting control system must be able to operate in a simulated fully-operational condition for troubleshooting and programming purposes while the relays are

locked in the “ON” position.

The lighting control system must have remote access ability to access the system and help troubleshoot, program, or alter the system without being on-site. This factory service must be available 24 hours a day, 365 days a year. Normal factory assistance using this connection shall be available after the required warranty period. A 3/4 inch conduit shall be run between the main access point (assumed to be the central control location) and the designated telecommunication location for system internet access. A work area outlet with appropriate station cabling with faceplate shall be installed in proximity to the central control panel by division 27. This connection will be used to connect the system to the central control location and for remote access to the system.

All lighting controls shall be pre-assembled, wired, commissioned and tested to operate as a complete integral system and shall provide the lighting control features specified in this document.

CAMPUS APPLICATION TYPES

The lighting control system shall be capable of addressing a new facility, major retrofits and minor renovation campus applications, as defined below. Installation, commissioning and acceptance testing shall follow Title 24 and basis of design requirements.

New Facility and Major Retrofit Applications: The installation, commissioning and acceptance testing of all lighting control system components and features as defined in the General Requirements section are required. Building space types shall be controlled as defined in the Lighting Control by Space Type section of this document.

Minor Renovations: Installation, commissioning and acceptance testing of lighting control system components capable of stand-alone room/space level lighting control strategies as defined in the ‘Lighting Control by Space Type’ section of this document are required. Lighting control system components which allow for integration of building-wide lighting control system with the central control location, as defined in General Requirements, are required at time of system installation per space type.

OCCUPANCY SENSORS

Addressable-type, digital occupancy sensors with programmable pushbuttons, appropriate for the area usages and room constructions, shall be utilized in all spaces with the exception of special areas assigned in the project building program, electrical rooms, mechanical equipment rooms, elevator rooms, and telecommunication rooms. Occupancy sensors in smaller offices and rooms shall incorporate manual-on, automatic-off functions.

Follow the general rules below for occupancy sensor applications:

PASSIVE INFRARED

Passive-infrared sensors require a direct line of sight to function properly. This means any obstructions such as walls, partitions, etc. between the sensor and the intended target will keep the sensor from triggering occupancy. Passive-infrared sensors have varied coverage ranges and patterns. An appropriate range and coverage pattern shall be determined based

on application, traffic patterns, and fixture compatibility. Operating mode shall be based on Title 24 requirements and basis of design for each space type.

ULTRASONIC

Ultrasonic sensors utilize the Doppler principle to detect occupancy by emitting a high frequency signal and sensing the frequency change of the reflected signal caused by the introduction of an occupant in the space. Ultrasonic sensors do not require direct line-of-sight to function properly, however they shall not be installed within six feet of HVAC ducts or registers to avoid false triggering. Ultrasonic sensors have varied coverage ranges. An appropriate range shall be determined based on application, traffic patterns, and fixture compliance. Operating mode shall be based on Title 24 requirements and basis of design for each space type.

PHOTOCELLS OR DAYLIGHT SENSORS

Photocells shall integrate with the lighting control system. All settings shall be remotely accessible and adjustable. Photocells shall be able to be used as inputs for lighting control systems. Systems providing local adjustment only are not acceptable.

Daylight sensors, appropriate for the area usages and room constructions, shall be utilized in all side lit and top lit spaces. Larger rooms with multiple zones shall utilize ceiling mounted sensor in an open loop configuration to measure the daylight only and not incorporate the electric lighting in its reading. The daylighting system shall provide continuous dimming of the light fixtures to maintain minimum light levels.

LIGHTING CONTROLS CERTIFICATION REQUIREMENTS

Lighting controls shall be UL Listed. Lighting control panels controlling emergency circuits shall be ETL listed to UL 924. Emergency source circuits controlled in normal operation by a relay panel shall fully comply with CEC Chapter 7.

DIMMING SYSTEM

Light dimming equipment shall have the following features:

1. Continuous dimming curve.
2. Field programmable.
3. Published “in-rush” current information.

DIMMERS

1. All devices shall be UL listed specifically for the required loads (i.e., LED, incandescent, fluorescent, magnetic low voltage transformer, and electronic low voltage).
2. All dimmers and switches shall provide power-failure memory. Should power be interrupted and subsequently returned, the lights shall come back on to the same level set prior to the power interruption. Restoration to some other default level is not acceptable.
3. Dimmers shall allow integration of occupancy sensors, daylighting controls, and switches.

LOW VOLTAGE TRANSFORMERS 26 22 00

Dry type transformers shall be copper-wound, meeting US Department of Energy's (DOE) energy conservation standards for distribution transformers. Transformers shall be designed to exceed the latest requirements of the California Code of Regulations Title 20 and Title 24 and NEMA TP-1 efficiency standards.

All sizes of transformers shall have a 115 degree centigrade temperature rise rating, K-rated and naturally ventilated (fan-assisted cooling is not acceptable). Housekeeping pads are required for floor mounted transformers. Provide external vibration isolators.

TESTING

Perform inspection and test procedures per Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems, of Inter-National Electrical Testing Association (NETA) Standard latest edition.

SWITCHBOARDS AND PANELBOARDS 26 24 00

Service to distribution equipment must be sized to their rated capacity and not the calculated load. Main circuit breaker shall have a local open and closed buttons with adjustable trip settings. All large frame circuit breakers shall be equipped with lock-out and tag-out devices. Provide 25 percent spare capacity for the system, verify requirements with the University Representative.

Each panelboard shall have a dedicated feeder and a hinged door-in-door cover. Provide copper bussing for switchboards and panelboards. Aluminum bus duct shall not be used on campus. AIC rating must conform to power system study results. Housekeeping pads are required for the main switchboard and other electrical equipment in mechanical and electrical rooms.

In cases where there is not adequate room, or in retrofit situations where it is not practical to modify a switchboard or panelboard, provide a Service Instrumentation Panel as described in 26 27 13 with instruments as described in 33 05 33.

TELECOMMUNICATIONS SPACE (TS) ELECTRICAL REQUIREMENTS

1. A sub-panel or at a minimum, ALL TS’s shall be provided a dedicated electrical service in all ADF/BDF/IDF (ER/TR) rooms. The estimated electrical load for the telecommunications space shall not exceed 80 percent of the panel.
2. Dedicated power circuits from shared panel boards shall be provided with both transient voltage surge suppression and electrical high frequency noise filtering.
3. If a low number of telecommunications spaces are planned, one electrical panel may serve multiple telecommunications spaces as a design alternative.

4. Sub-panels shall be located near the room entrance door, whenever possible, to conserve wall space and should be connected to an emergency power source if available to the building. Emergency power is especially important in the TS's that house Digital Loop Carrier systems to ensure voice and emergency systems remain operational during power outages that may extend past the systems battery backup capability.
5. HVAC systems shall not use the same electrical panel that is used to support telecommunications spaces.

ELECTRICITY METERING 26 27 13

The discussion below is for general reference only. Refer to Division 33 05 33 for additional information and more current clarification. Where the two sections are in conflict, Division 33 05 33 shall be considered more current and correct information.

Provide each new building, or portion thereof with a separate electrical meter for whole building monitoring, comply with requirements for disaggregation of loads and metering for enhanced commissioning where required. Major renovations shall provide new meters similar to a new building. Verify with the University's Representative.

POWER MONITORS

Provide one Power Monitor at each of the service transformers as part of the service instrumentation along with Current Transformers (CT's) and Voltage/Potential Transformers (PT'S), and necessary terminal and shorting blocks, coordinate with 26 24 00 and 33 05 33 to order main switchboards with the required components fabricated as part of the assembly. Isolate the service instrumentation panel and power monitor from the distribution bussing in the switchgear with a physical barrier.

INTEGRATION WITH CAMPUS SYSTEM

The instrumentation shall integrate into and shall be capable of communication with the Campus Distribution SCADA System which is based on an ION Enterprise system, and the Campus Tridium-Niagra BMS system, verify current versions and firmware upgrades with the University Representative to enable communications with the head ends. The Power Monitor shall be capable of communicating with the Campus Distribution Central SCADA Unit by means of an Ethernet connection and with the Tridium BMS system through an RS485 serial port to Ethernet connection via a media converter.

Provide pre-shipment testing of the Power Monitor and Service Instrumentation Panel with written certification that the communications system is set to interface with the University of California, Santa Cruz SCADA System.

The Service Instrumentation Panel shall be a minimum 20 x 16 x 10 NEMA 4/12 (IEC IP 66)

rated enclosure. It should be located in a clean, dry, low vibration area with easy access. The panel will be built with panel mounted Ion power systems monitor. The panel will be supplied with 120VAC and provide fused protection. PT and CT connections, to the ION monitor, will utilize fused and shorting block terminations, coordinate location of shorting blocks and meter fuses with 26 24 00, its best if fuses and shorting blocks are located in the Service Instrumentation Panel when provided. Install the protocol translator gateway and required I/O loads in the Service Instrumentation Panel. A bulkhead RJ45 connector will provide easy connection to the building's work area outlets.

PRODUCTS
Refer to Division 33 05 33 for additional information.

Communications interface: All power meters must have Ethernet and RS485.

For primary meters, each instrumentation set shall consist of a single solid-state digital monitoring unit with front of panel display and display control. Parameters to be monitored and displayable shall include the following: Volts, Amps, kVA, kVAR, kWD, PF, kWh, and kVarh. In addition, with the Campus Central SCADA Unit, the Monitor shall be capable of voltage/current wave form analysis. Verify the current meter to be specified with the University Representative.

EXECUTION
Power monitors and associated components shall be mounted between 3 feet and 6 feet from the finished floor.

Conduits

1. Install a 2 inch conduit from the power monitor to the telecommunication building distribution frame (BDF) or intermediate distribution frame (IDF), and install a work area outlet adjacent to the Power Monitoring Panel, or switchboard/panel board. Verify location with University Representative.
2. Install a 3/4 inch conduit between the power monitor and the closest building management Tridium JACE panel.
3. The BMS contractor shall run wiring and interface the power monitor to the building management system for remote monitoring.

Sub-Metering
Provide sub-metering for building lighting system, plug loads, process, MCCs and HVAC as specified in the project requirement documents. Consult University's Representative for additional sub-metering to meet project goals.

Programming

1. Programming shall be verified by the University's Representative upon energizing the service.
2. Programming of the monitoring units shall be done from the front panel.

3. The unit shall also be capable of downloading programming from the Campus Distribution SCADA System.
4. Key programming information (Phase Current Transformers ratio, Phase Voltage Input values, phase rotation, volts mode (wye or delta) etc.) to be clearly documented and accessible for site verification of programming during initial testing of the devices.

WIRING DEVICES	**26 27 26**

UL or ETL listing is required.

Wall (Local) Switches - Totally enclosed, AC rated, specification grade, white, or match existing finish. 120/277V, 20 amps or low voltage if appropriate for lighting control system integration. Heavy gauge plated steel strap.

Duplex convenience receptacles – General Use grade, 3 wire grounded, nylon face, rated 20 amps, 125V. Receptacles connected to emergency circuits shall be red in color, receptacles connected to optional standby circuits shall be yellow in color, all other devices shall be white or match existing face.

Ground fault circuit interrupter (GFCI) receptacles: 3 wire grounded, white, or match existing finish, rated 20 amps, 125V. Provide waterproof lift cover for outdoor installation. Provide weatherproof-while-in-use cover for outdoor installation that could be exposed to direct rain or water spray while in use, per code.

Unless otherwise noted on drawings, mounting heights of devices shall be as follows:

Switches:	42 inches
Receptacles:	18 inches

CORRIDOR RECEPTACLES

Provide dedicated 20-amp, 120-volt circuits to feed corridor 20-amp duplex receptacles only (4 maximum per circuit). Spacing shall be no more than 50 feet. Maximum distance from any end wall shall be 25 feet.

Install all receptacles uniformly with U-ground slot down. Twist lock and power receptacles, ground up.

OFFICE RECEPTACLES

Single occupant offices shall be circuited with a 1 circuit per office. 2 circuits per office shall be allowed for special equipment requiring it. Each receptacle shall be clearly marked with its respective circuit number.

TELECOMMUNICATIONS SPACE (TS) ELECTRICAL REQUIREMENTS

Convenience duplex receptacles shall be:

1. Mounted in each room at +18 inches AFF and horizontally spaced not to exceed

6-feet around the perimeter of the room.

2. Non-switched, 120VAC 20 Amp, duplex and divided equally on branch circuits, (i.e. all receptacles in the same room (other than single occupant offices) shall not all be on the same circuit). Minimum of 2 circuits shall be provided per room alternating duplexes around room with no more than four (6) receptacles on the same circuit.
3. Each receptacle shall be clearly marked with its respective circuit number.

Equipment Rack and Cabinet Electrical Requirements

1. Equipment racks identified for electronic equipment shall have the following installed:
   a. One (1) quad device box containing two (2) duplex 20 Amp, 120V AC NEMA 5-20R- spade receptacles located on separate dedicated circuits in the room sub-power panel.
   b. Device box shall be mounted on the backside of each rack 15 inches Above the Finished Floor (AFF). The placement of this device box and its EMT conduit shall not block or interfere with the equipment mounting area (rails) on either side of the rack.
   c. A minimum of 24-iches of flexible conduit shall be used to attach electrical service to the equipment rack. Flexible conduit is required to prevent the shearing of the conduit during a seismic event.
   d. Reference Division 27, Communications
2. Enclosed cabinets identified for electronic equipment shall have the following installed:
   a. Two (2) quad device boxes containing two (2) duplex 20 Amp, 120V AC NEMA 5-20R-spade receptacles powered from two separate dedicated circuits located in the room sub-power panel.
   b. One (1) device box shall be mounted toward the back of the cabinet near the top inside area of the cabinet to provide electrical power to the cooling fan(s). The second device box shall be located 15 inches above the floor toward the back of the cabinet.
   c. The device boxes and EMT conduit shall not block or interfere with the equipment mounting area (inside and outside mounting rails) within the cabinet.
   e. Reference Division 27 Communications.
3. Special considerations:
   a. ADF equipment racks and cabinets shall have 30 Amp, 120V AC NEMA 5-30R-spade receptacles in place of the 20 Amp, 120V AC NEMA 5-20R-spade receptacles.
   b. Provide a duplex 20 Amp, 240V NEMA 6-15R receptacle.

Verify all requirements with the University Representative.

LOW VOLTAGE CIRCUIT PROTECTION DEVICES **26 28 00**

CIRCUIT BREAKERS

Provide molded case circuit breakers conforming to Underwriters' Laboratories, Inc. (UL) 489:

1. Breaker shall be thermal-magnetic type common trip with one operating handle and solid state 7 or 9 function trip unit.
2. Adjacent poles shall be connected to phases A, B, C, respectively.
3. Minimum symmetrical interrupting current rating shall be as indicated.
4. Connectors shall be designed for use with copper or copper clad conductors.
5. Mounting shall be “bolt-on” type, removable without disturbing any other breaker.

SAFETY DISCONNECT SWITCHES

Heavy duty type, 600v, HP rated for motors. All disconnect switches shall be National Electrical Manufacturers Association (NEMA) Type HD; lockable in the “Off” position. Provide defeater mechanism to bypass this mechanism.

ENCLOSED CONTROLLERS 26 29 13

MOTOR CONTROL

Motor starter overloads in different environments require different types of devices such as thermal magnetic, induction, temperature probe and electronic. Select the overload to meet the environmental and performance requirements and starting characteristics of the installation. On high value motors and on starters mounted in high ambient temperature environments provide solid-state type overload relay with loss of phase protection built in. Provide manual thermal protection for all motors not integrally equipped with thermal protection. Provide motor starter schematics for all motors. A typical schematic for similar types of motor control is acceptable.

PRODUCTS

Overload Relay - Electronic Solid State type, (no heaters), with Phase Loss protection, short circuit protection, FLA adjustable trip over 2:1 range. All other types provide institutional grade products by easily sourced manufacturers selected for the application.

Control Voltage - 120vac unless otherwise specified. Individual mounted starters may have control transformer within enclosure. Starters mounted in Motor Control Centers to have control circuit from separate source, common to all starters. Control circuits to be disconnected when the disconnecting means is in the open position (Ref. CEC 430-71), a minimum of 2 control circuit disconnect contacts to be provided, one for the starter and one for other circuits fed through the starter auxiliary contact.

Auxiliary Contacts - Each starter to have a minimum of two NO auxiliary contacts with provision to add a minimum of two more.

Selector Switch -To have HOA (Hand-Off-Auto) selector switch mounted in cover.

Pilot Light – Red LED pilot light mounted in cover to be activated through a starter auxiliary contact, (not across the coil, or parallel with the coil).

Starters for fractional horsepower 120V motors shall be manual type unless shown otherwise, equipped with built-in overload protection and pilot light.

Refer to Division 33 for additional information.

VARIABLE FREQUENCY DRIVE MOTOR CONTROLS 26 29 23

The Variable Frequency Drive (VFD) assemblies for use on a standard NEMA Design B induction motors shall be UL listed, as one entire assembly, and bear the UL label. Insure compatible motor is specified. Motor torque characteristics and controls interface will be coordinated between electrical and mechanical. All circuit boards shall be completely tested and burned-in prior to assembly into the completed VFD. Factory test complete VFD to ANSI/UL Standard 508. Functionally test all options, perform dynamometer test at full load, cycle load and speed during factory tests. VFD manufacturer shall have a failure analysis laboratory to evaluate the failure of any component. Provide power factor correction. VFD will be located under cover in a dry location. Provide adequate ventilation for the required drive ambient operating condition. Locate drive as close as feasible to the motor being controlled, but in no case more than 200 feet without designing additional line reactors into the system.

A site-specific harmonic analysis, evaluating total voltage harmonic distortion (THD) and total current harmonic distortion without additional external devices or external filters must be submitted as part of the design process. Consider non-standard output reactors and 12 and 18 pulse rectification in the analysis and recommendations, verify requirements with the University Representative. On installations where more than 3 VFD’s are serving loads over 25 HP and supplied off a single bus compliance shall be empirically verified by the VFD manufacturer with onsite field measurements of the harmonic distortion at the point of common coupling with and without VFD’s operating. The distribution transformer(s) serving the bus shall be the point of common coupling for the measurements, submit results to the University’s Representative. In the event that field measurements demonstrate that harmonic distortion exceeds the levels claimed by VFD manufacturer, coordinate with manufacturer and propose mitigation strategies to the project electrical engineer and PPDO Engineering Services.

Warranty – verify extended warranty requirements on projects with VFD’s greater than 75 HP and voltages greater than 480 V.

PRODUCTS

The VFD shall be of an advanced Pulse Width Modulation (PWM) type using IGBT transistors and capable of achieving full motor performance with no de-rating of motor output due to current waveform distortion. The VFD must be capable of operating multiple motors in

parallel with the ability to switch motors on and off independently via external contactors. VFDs shall be manufactured by Asea Brown Boveri (ABB), or equal.

1. The VFD shall include the following ratings, adjustments, and parameters:
   a. Power unit rating: 100 percent continuous, 110 percent intermittent for one minute when previously operating at full load.
   b. Minimum efficiency: 98 percent at max. output; 92 percent at 50 percent output.
   c. Power Factor
      1) Displacement > 0.98
      2) True (Including Harmonic Distortion) > 0.85
   d. Rated input voltage: 480V, 3 phase, 60Hz and 230V 60Hz available.
   e. Short Circuit Current Rating: 65 KAIC
   f. Output voltage: 0-480V or 0-230V 60Hz.
   g. Allowable wire length to motor: 200 ft. (unless VFD schedule shows greater wire length).
   h. Automatic motor tuning.
2. The VFD must be capable of operating in the following service conditions:
   a. Ambient Temperature: 0 to 40 degrees C (32 to 104 degrees F).
   b. Relative Humidity: 0 to 95 percent, noncondensing.
   c. Elevation: 0 to 3300 ft. (100 meters) above MSL.
   d. AC line voltage variation.
      1) 480 V: 440-10 percent to 500+10 percent; 45-65 Hz
      2) 230 V: 200-10 percent to 230+10 percent; 45-65 Hz
3. Singularly, each VFD shall produce a maximum of 3 percent harmonic voltage distortion (THD) without additional external devices or external filters, and simultaneous operation of multiple VFD’s shall not add more than 5 percent total harmonic voltage distortion back to the bus when measured at the point of common coupling without additional external devices or external filters. The building distribution transformer(s) shall be the point of common coupling.
4. Each VFD shall consist of a converter, inductor, and inverter section. The input of the VFD shall be ground fault protected and require no isolation transformer. In addition, the input of the VFD shall be able to withstand switching of the input line power up to 20 times per hour without damage.
5. The power section shall allow the following faults to occur without damage to the VFD:
   a. Single-phase fault or three phase short circuit.
   b. Phase to ground short circuits.
   c. Severe overloads.
6. The VFD must withstand unlimited switching of the output under full load without damage to the VFD. Operation of code required disconnect switch on load side of drive, whether motor is operating or not, shall not have any adverse effect on the drive. Control conductors from the disconnect to the drive shall not be required for safe and reliable operation of the drive. To ensure safety of the equipment, the VFD shall include these protection features:

   a. Over current protection.
   b. Over speed protection.
   c. Power unit over temperature protection.
   d. Electronic Thermal motor protection.
   e. Responsive reaction to motor winding temperature detectors.
7. The VFD shall be a NEMA enclosure as specified in the VFD schedule, designed for wall mounting. All standard and optional features shall be included within the VFD enclosure, unless otherwise specified.
8. A stand-alone PID controller shall be standard in the drive, allowing a pressure or flow signal to be connected to the VFD, using the microprocessor in the VFD for closed loop control.
9. Minimum of 500 milliseconds power loss ride through without drive trip or loss of programming.
10. The VFD shall operate satisfactorily when connected to a bus supplying other solid-state power conversion equipment which may be causing up to 10 percent total harmonic voltage distortion and commutation notches up to 36,500 volt-microseconds.
11. VFD start-up will be provided by a factory trained technician and include start-up documentation provided to the University Representative.

Adjustments

1. VFD adjustments shall be set digitally via menu driven selections accessible from the front panel of the VFD and include the following:
   a. Max. Speed: 0-200 percent base speed (0 to 120Hz).
   b. Min. Speed: 0-200 percent base speed (0 to 120Hz).
   c. Jog Speed: 0-200 percent base speed (0 to 120Hz).
   d. Independent accel/decel time: 0.1 to 1,800 seconds.
   e. Current Limit: 0 to 100 percent cont., 160 percent for up to 1 minute.
   f. Torque Characteristics: Variable.
   g. Start Voltage (Voltage Boost).
   h. Start Compensation (Volts per Amps Boost) 0 to 20V/A.
   i. Dynamic Slip Compensation: 0 to 200percent. Speed regulation: 0.5percent with up to 90 percent load change.
   j. Starting Torque at motor shaft: 160 percent.
   k. Four Independent Parameter sets.
   l. RS-485 Serial Communications.
   m. Programmable Carrier Frequency 2-14 kHz.
   n. Flying Start into motor rotating in either direction without creating fault.
   o. Four bypass frequencies w/ adjustable bandwidth.
2. The VFD shall operate in the AUTO or MANUAL modes and, as a minimum, shall include the following front panel mounted switches and indicators:
   a. 2 line by 14-character alphanumeric English language display with ability to exhibit

any two parameters simultaneously. (Code numbers are not acceptable.) LCD displays shall be backlit.

b. Local/Remote switch.
c. Digital indicator of freq., current, volts, torque, Hp, kW, kWhrs, Motor or VFD Electronic Thermal Relay (ETR), Run Hours.
d. Manual speed control.
e. Run / Stop Switch.
f. Fwd / Rev Switch.
g. Power on and run indicator.
h. Fault indication including: current limit, over voltage, under voltage, overload, or thermal motor protection.

3. The VFD shall have provisions to lock out unauthorized access to alter or reprogram the VFD's set points.

Control Requirements

1. The VFD shall be capable of operation with either a two-wire maintained contact motor control circuit or a three-wire start/stop momentary contact motor control circuit. The VFD shall have an automatic restart circuit to automatically return the drive to full operation after a protective trip. The number of restart attempts, attempt duration and time between reset attempts shall be programmable. In addition, the VFD must accept the inputs and provide the outputs listed below:
   a. Analog input: 0-10Vdc, 0-20mA, 4-20mA, 20-0mA or 20-4mA. Linearity deviation between control signal and motor speed: +or-1 percent of rated motor speed.
   b. Digital Inputs: 8 each programmable for reset, start, stop, quick stop, reversing, change to preset speed (up to 8 preset speeds), change parameter set, increase speed, decrease speed, current limit override.
   c. Analog outputs: 2 each programmable to provide 0-20mA or 4-20mA proportional to frequency, torque, current or power (Kw).
   d. Digital outputs: 2 each programmable to indicate ready, run, trip, current above preset, frequency above preset, or electronic thermal overload.
   e. Input for motor thermocouple.
2. The drive control card shall be fully interchangeable between all drive sizes fractional through 300 HP to provide a consistent user interface, including display, keypad and terminal connections.
3. All control input and output terminals are isolated from power and ground with isolation capable of withstanding 2,500 volts RMS for one minute.
4. The VFD will be interlocked with the local motor disconnect switch when provided to shut down the drive in the event that someone opens the disconnect without first shutting down the drive.
5. VFD will have its own internal PID control capabilities.

BYPASS

Review VFD Bypass requirements with University's Representative.

Manual Bypass

1. Manual transfer to line power shall be via 3 contactors sized for applicable voltage and motor current. One contactor shall be between the VFD output and the motor. The second shall be between the bypass power line and the motor, providing across-the-line starting. The third contactor shall be between the line voltage and VFD input. Transferring load via contactors shall disconnect VFD inputs from line voltage and outputs from the motor, thus providing the ability to safely trouble shoot and test the VFD while operating in the bypass mode. A fused disconnect switch is required. Bypass and VFD output contactors to be electrically and mechanically interlocked to prevent both being closed at the same time. Include motor thermal overload protection in bypass and VFD modes. If the drive can provide the bypass feature as an integral part of its construction, this shall be acceptable.
2. Provide two 3-position selector switches to control the bypass contactor and the VFD input and output contactors: 1) Normal-Off-Test and 2) Drive-Off-Bypass. Selector switches to have pad-lockable switch covers.
3. Door mounted status lights shall include power on, drive, bypass, and safety.
4. Provide terminal strip for connection of fire, smoke contacts, external start command and VFD control signal. All external interlocks shall function in hand, auto, or bypass. External start/stop signal to be functional in auto and bypass modes.
5. 120 vac control power to be supplied by fused transformer.
6. Provide NEMA 1 enclosure for bypass components. NEMA 4 enclosure required for outdoor applications. Bypass and VFD enclosures to be factory wired and assembled on a common back-plate.
7. Manual Bypass and Accessories to be furnished and mounted by the VFD manufacturer.
8. Two contactor bypasses and knife switches are not acceptable.

Automatic Bypass with Magnetic Contactors

In rare applications, such as critical service pumps with no secondary pump for backup, the VFD shall be specified with automatic bypass. The automatic bypass shall include all of the features specified in the manual bypass plus the following additional feature: Output from the VFD run contact shall control the contactors so that a VFD failure shall automatically transfer the motor to across-the-line starting.

EXECUTION

Install VFD in dry, clean and accessible area. Provide appropriate environmental conditions for VFDs to allow them to dissipate heat effectively. Provide filtering as required.

SHAFT GROUNDING

For more information, refer to Division 23, Section 23 05 13, Common Motor Requirements.

PACKAGED GENERATOR ASSEMBLIES 26 32 00

GENERAL

Generators on the Santa Cruz campus are fueled by natural gas only, if a generator is used as an emergency power source the generator shall be dual fuel with liquid propane as the back-up to the primary fuel, no diesel generator packages are allowed per agreements with the Monterey Bay Air Resources District (MBARD) and the campus.

Generators must comply with MBARD rules and regulations. Generators must meet the Best Available Control Technology (BACT) requirements and the State "Air Toxic Control Measures" (ATCM) for stationary compression ignition engines. The particulate matter (PM) emission rate shall be less than or equal to 0.15 g/BHP-hr. Authority to Construct (ATC) permits must be obtained by the University from the air district prior to installation and operation of generators.

Once the generator is constructed a Permit to Operate (PTO) must be obtained by the University, after the system has been installed and tested, and prior to placing the unit in service. The installing Contractor shall work with the University providing all required submittal documentation to the University for submittal to the MBARD. The installing contractor shall coordinate the scheduling of all regulatory inspections on site, including coordination between the IOR, the MBARD representative, the Cal OSHA (Title 8 pressure vessel inspections) inspector, and DCFM.

The Engine Generator assembly and the Transfer Switch are to be furnished as one complete operating system and factory built, tested and shipped by a single manufacturer.

Back-up fuel tanks shall be above grade propane tanks sized to meet the rated load of the generator and shall operate for the required operating time. The Pressure Vessel Unit of Cal OSHA is the Authority Having Jurisdiction over the design, installation and permitting of LP-Gas systems. As part of the design process the University will consult with a Pressure Vessel Safety Engineer to review any design of propane tank installations on campus, the design professional shall coordinate this review and include requirements in the design.

The minimum distance between the tank and an ignition source shall be in accordance with NFPA 58 requirements and in no case less than 10’. To be conservative an interpretation of this distance has been determined to be from the closest edge of the tank, to the edge of the generator enclosure as opposed to between an appurtenance on the tank, and the actual ignition source on the engine generator. It is acknowledged NFPA 58 Appendix I stipulates the minimum distance is noted to be from the fill connection, or fixed liquid gauge to an external source of ignition. The campus is taking a more conservative approach than potentially allowed by code due to differences in interpretations in the field.

For applications where there is not adequate storage capacity to supply propane gas to the generator, the University prefers liquid lines piped to engine mounted direct fired vaporizers

(IMPCO or equal) with a heat source derived from the engine jacket water or block heater. The University recognizes not all generator packagers guarantee this option is reliable, and not all sites are suitable for placement of fuel tanks in proximity to the generator thus necessitating liquid propane piping installations with the limitations stipulated herein.

If the generator is small enough and the tank is large enough to draw "regulated gas" off the tank, the gas pipe can be buried, in this case comply with NFPA 58 and Title 8 (http://www.dir.ca.gov/Title8/sub1.html).

The basis of not allowing buried liquid propane piping is the liquid propane piping is unregulated and is effectively an extension of the tank that is fabricated on site where Quality Control (QC) activities are limited and inspection is not continuous. Additionally, catholic protection systems required by Title 8 add complexity to the maintenance of these systems.

If liquid piping is used then the liquid pipe shall be run exposed in an exterior, well ventilated location. The pipe shall be routed so as to not be exposed to vehicular or physical damage and in no case shall the developed length of a liquid propane pipe exceed 50’.

The liquid piping materials shall comply with the CCR Title 8 Subchapter 1, Article 5 section 480 and shall only be run above grade on a fully designed and detailed support system. Design professional shall coordinate between division 23 and 26 for piping and electrical requirements within the standards, respectively.

In lieu of liquid propane piping, external vaporizers may be used if internal vaporizers are not compatible. External vaporizers shall be located to minimize the length of liquid propane piping. External vaporizers shall be supplied with power from an emergency power source using appropriate explosion proof fittings according to the hazard classifications in CEC Article 500. Pilot operated vaporizers that burn propane gas shall not be allowed on campus.

External vaporizers shall not be mounted on the tank and shall be mounted on an independent support structure.

Technical support & service - The Manufacturer shall provide through a single source supplier who shall be the Manufacturer’s authorized local representative, initial start-up services and be responsible for conducting field acceptance testing. The Manufacturer shall provide factory trained service technicians to provide 24-hour service availability who are qualified to isolate and correct any typical malfunction of the Engine, Generator, Voltage Regulator system control, Automatic Transfer Switch, and implement repair. The Supplier shall have service facilities within 150 miles of the Santa Cruz Campus.

Furnished Documentation - Provide hand held service tool for engine and generator adjustments and maintenance diagnostics with correct dongle for interfacing and adjusting engine, generator and automatic transfer switch parameters.

Warranties shall start per the Contract Documents.

Submittals – Submit completed engineered submittals including all materials and layouts provided with the package.

FACILITY EMERGENCY AND STANDBY POWER SYSTEMS

The official language for emergency and standby power systems is in the code books: NFPA 110, NFPA 70, IBC, Life Safety Code, Fire Code, IFC, etc. Requirements vary based on building occupancy, facility use and critical function.
For general awareness:
Emergency is essential for safety to human life only (Fire/Life Safety). It is generally what it takes to get people safely out of a building within 90 minutes, i.e. fire alarm, emergency egress lighting, exit signs, chemical detection, smoke evacuation, sometimes elevators, etc.
Standby is for equipment and system operations that require continuous operation and if interrupted would disrupt public health, safety, national security, emergency management or business/government continuity.
By code, **emergency** power systems must transfer power within 10 seconds, have a dedicated automatic transfer switch with dedicated emergency power distribution and have an on-site local fuel source. We install dual fuel (natural gas and propane) to meet the on-site fuel requirement. The campus has many "grandfathered" systems that do not meet all of these requirements. When any modifications to existing systems are requested, we require the new installation to meet current code.
Standby power systems do not require a 10 second transfer of power, may include UPSs in the distribution system, must have an automatic transfer switch and power distribution separate from the emergency system and can have a single fuel source such as natural gas that originates off site. The campus has many "grandfathered" systems that do not meet all of these requirements. When any modifications to existing systems are requested, we require the new installation to meet current code.
Reference 2007 Campus Standard Detail 16.4-00.
A single generator can serve as both an emergency and standby power source provided that it starts and transfers power within 10 seconds, has two separate automatic transfer switches with separate distribution (one for emergency, one for standby) and has an on-site local fuel source. There are also other ways to provide emergency and standby power per code without using generators, but they are usually more expensive, more maintenance and operations effort and require more testing and permitting.

Specific campus equipment allowed by the AHJ to be connected to Emergency generator power include ITS network routers that provide fire alarm communication to dispatch, cellular phone DAS equipment, C-Cure security access equipment and BMS Jace controllers serving fume hoods. Other BMS JACE panels have an integral UPS and are connected to Standby generator power.

PRODUCTS

The Electric Engine Generator System shall be rated by the manufacturer for “standby” or “emergency” operation per Title 24 building codes and design requirements for 3 phase, 4 wire, 60 HZ at 1800 RPM (KW, KVA, and Volts, as specified at 0.8 PF). The engine and generator housings to be mechanically connected together mounted on a heavy-duty steel base with vibration isolators. Base shall be high enough to easily drain the engine oil. The engine oil filter shall be spin-on type. Provide rodent protection for the entire generator package unit including at conduit entry points to prevent mice and rats entering the unit.

Provide outside security light on both emergency and normal power and inside light and a convenience receptacle on both emergency and normal power.

Where work platforms around generators are needed, platforms are to be located at all generator access doors. Platforms are to include guardrails and access ladders. Access panels must have ability to fully open with platform in place.

The system shall have the following electrical characteristics:

1. Voltage regulation shall be within 2 percent of rated voltage.
2. Frequency regulation shall be within 5 percent from steady state no load to steady state full load.
3. Harmonic distortion - The sum of AC voltage waveform harmonics, from no load to full linear load shall not exceed 5 percent of rated voltage. No single harmonic shall exceed 3 percent of rated load.
4. Telephone Influence Factor (TIF) shall be less than 50 per NEMA MGI-22.43.

Engine - Four-cycle, 1800 RPM. Water-cooled, rated to operate at 10 percent overload for one hour at specified elevation and ambient limits.

Engine Emissions - MBARD certified catalytic converters may be required to comply with the ATCM emission standards. Engines equipped with a certified catalytic converter shall be provided with an exhaust stack thermometer and pressure gauge installed on upstream side of the catalytic converter.

Provide a permanent load bank for generators sized at 300KW or larger. The load bank shall be a complete system with all necessary controls, wiring, and devices to provide a functional system. The load bank shall have field configurable capability to provide automatic loading, automatic exercise, regenerative control, base loading and manual loading capability. Sizing of load banks may be reduced to 70 percent of the total generator capacity. The load bank shall be forced air cooled. The cooling fan(s) shall be an airfoil profile with direct drive by a three (3) phase, TEFC, 1800 RPM induction motor. The motor shall be rated at the maximum brake horsepower of the fan propeller for the applied static pressure load, temperature and altitude parameters. For generators sized at less than 300 KW, provide a circuit breaker for connection of a portable load bank.

Fuel - natural gas and propane with automatic changeover dual fuel system (to meet requirements of "On-site Reserve Fuel Supply).

Engine Jacket Heater - Thermal circulation type with internal thermostat and heavy-duty relay type contactor sufficient to handle the current requirements of the heater. (Thermostat normally furnished with unit does not have contact rating for long life). Provide shut off valves for block heater.

Generator

1. Shall be single bearing, self-aligning, four pole brushless synchronous type, revolving field, with amortisseur windings, and direct drive centrifugal blower for proper cooling and minimum noise. No brushes shall be allowed. Generator shall be direct connected to the engine flywheel housing, generator shaft to be connected to the engine flywheel by a flexible stainless-steel plate to insure permanent alignment. Gear driven generators are not acceptable. Generator design shall prevent potentially damaging shaft currents.
2. Insulation shall meet NEMA class F. The maximum temperature shall not exceed 105 degrees C at 40 degrees C ambient.
3. The 3-phase broad range reconnectable generator shall have 12 leads brought out to allow connection by user to obtain any of the available voltages of the unit.
4. Voltage Regulator shall be temperature compensated, solid-state design, and shall function by controlling the exciter magnetic field between stator and rotor. Shall be of an asynchronous pulse width modulated design that is insensitive to severe load induced wave-shape distortion from SCR or Thyristor circuits such as those used in battery charging (UPS) and motor speed control equipment (VFD). Regulator design shall include a torque-matching characteristic to allow the engine to use its fullest power producing capacity (without exceeding it or over compensating) at speeds lower than rated, to optimize motor starting capability and provide the fastest possible recovery from transient speed dips. Regulators that use a fixed volts per Hertz characteristic are not acceptable.
5. Exciter shall be three phase, full wave, rectified, with heavy-duty silicon diodes mounted on the common rotor shaft and sized for maximum motor starting loads. Systems using three wire solid-state control elements (such as transistors or SCR’s) on the rotor shall not be acceptable.
6. Provide an exciter field automatic circuit breaker, mounted on the control panel, of the manual reset only type (cannot be used as a manual disconnect) for protection of exciter field and regulator.
7. Provide fixed service ladder to roof enclosure for all combination type 500 kW and larger generators and tank packages.

Control Panel

1. The control shall have automatic remote start capability. A panel mounted selector switch shall stop the engine in the STOP position, start and run the engine in the RUN position, and allow the engine to start and run by closing a remote contact when in the REMOTE position.
2. Provide a generator mounted control panel for complete control and monitoring of the engine and generator set functions. Panel shall include automatic start/stop operation; adjustable cycle cranking, digital AC metering (0.5 percent true rms accuracy) with phase selector switch, digital engine monitoring, shutdown sensors and alarms with horn and reset, adjustable cool-down timer and emergency stop push-button. Panel shall incorporate self-diagnostics capabilities and fault logging. Critical components shall be environmentally sealed to protect against failure from moisture and dirt. Components shall be housed in a NEMA 1/IP22 enclosure.
3. Provide the following digital readouts:
    a. Engine Oil Pressure
    b. Coolant Temperature
    c. Engine RPM
    d. System DC Volts
    e. Generator AC Volts
    f. Generator AC Amps
    g. Generator Frequency
    h. KW Meter
    i. Percentage of Rated Power
    j. KVA Meter
    k. KVAr Meter
    l. Power Factor Meter
    m. KWHR Meter
4. Provide a 12 light engine monitor on the control panel; 1 red light for each of the 4 shutdowns (except the remote manual stop), and 1 yellow light each for the high engine temperature and low oil pressure pre-alarms, and 1 green run light, a flashing red light to indicate the generator is not in the automatic start mode, a yellow light to indicate low coolant temperature, a yellow light to indicate low fuel, and 2 red lights for auxiliary use (for a total of twelve lights). A panel-mounted switch shall reset the engine monitor and test the lamps. The engine generator starting batteries shall power the monitor. Operation of shut down circuits shall be independent of indication and pre-alarm circuits. Individual relay signals shall be provided for each indication for external circuit connections (not to exceed 1/2-amp draw) for a remote annunciator. A common contact for external connection to audible alarm shall be provided. Auxiliary contacts: Supply auxiliary output contacts to monitor engine alarm panel remotely.
5. The NEMA 1 enclosed control panel shall be mounted on the generator set with vibration isolators. The control shall include surge suppression for protection of solid-state components. A front control panel illumination light with ON/OFF switch shall be provided. Control panel mounted meters and devices shall include; Engine oil pressure Gauge,

Coolant Temperature Gauge, DC Voltmeter and Running Time Meter (hours); Voltage adjusting rheostat, locking screwdriver type to adjust voltage +/- 5 percent from rated value; Analog AC Voltmeter, dual range, 2 percent accuracy, Ammeter, 2 percent accuracy, Analog Frequency Meter 45-65 Hz. +/- 0.6 Hz accuracy; 7 position selector switch.

Accessories - The following are to be furnished by the manufacturer/supplier as part of the complete engine generator system; starting batteries, sized as recommended by the manufacturer with battery cables and connectors, battery tray, battery charger powered by 120 VAC (this is in addition to the alternator mounted on the engine).

Emergency and standby generator monitoring and control points shall be interfaced with the campus Building Management System (BMS) Inputs/Outputs (I/O) as follows.

Emergency (Standby) Generator BMS (Tridium) I/O
DI-01 Emergency (Standby) Power Source Available
DI-02 Normal Power Source Available
DI-03 ATS Status in Emergency (Standby) Position
DI-04 ATS Status in Normal Position
DI-05 Generator Summary Alarm
Generator DO-02 Remote ATS Transfer Normal/Emergency (Standby)

TRANSFER SWITCHES	26 36 00

Transfer switch to have a full rated neutral with lugs for NORMAL, EMERGENCY and LOAD neutral conductors inside cabinet (4 pole with a switched neutral). Equipped with direct acting linear operators for simple, reliable and fast action during automatic operation.

Switch - Factory equipped with the programmed transition delay feature. This feature shall provide a field adjustable time delay during switching in both directions, during which time the load is isolated from both power sources, to allow residual voltage of motors or other inductive loads (such as transformers) to decay before completing the switching cycle. The programmed transition feature shall have an adjustable time of 0 to 7.5 seconds minimum.

Signal - Provide a signal before transfer contacts, adjustable from 0.1 to 10 seconds, to send to elevators or other controls prior to transfer.

Front Panel Devices - Provide devices mounted on front of main cabinet door consisting of switch position indicator lights, white NORMAL, amber EMERGENCY, normal source available green, emergency source available red, and key operated switch to provide the following positions and functions. TEST; simulated normal power loss to control unit for testing of generator set, including transfer of load.

Provide analog AMMETER, VOLTMETER and FREQUENCY METER.

INTERIOR LIGHTING **26 51 10**

Lighting levels shall conform to Illuminating Engineering Society of North America (IESNA) standards (see the IESNA Lighting Handbook: Reference & application or the IESNA Lighting Reference). Zone lighting or task lighting shall be utilized whenever energy efficiency can be improved by these measures. Refer to the "How to Comply with the Latest Lighting Standards" published by the California Lighting Technology Center (CLTC) for lighting guidelines.

USER CONTROLLABILITY OF LIGHTING

Provide individual lighting controls for the building occupants, enabling adjustments to suit individual task needs and preferences. Provide lighting system controllability for all shared multi-occupant spaces enabling adjustment to meet group needs and preferences.

For large open spaces such as open plan offices, consider the size of the space and the potential for additional zones of lighting control. Observe the space and determine how the area may be divided and where the additional lighting controls would be in relation to the location of the occupants in each area. Use 1,000 square feet as a general rule of thumb for the size of the area. Review the plan with the University's Representative.

LIGHTING CONTROLS

See Section 26 09 23 for additional lighting control requirements.

GLARE REDUCTION

Exterior Effect

Design interior lighting so that the angle of maximum candela from each interior luminaire as located in the building shall intersect opaque building interior surfaces and not exit out through the windows OR maintain all non-emergency lighting on a programmable timer that turns lighting off during non-business hours. Provide manual override capability for afterhours use.

Interior

Minimize glare from exposed lamps and avoid fixtures with high brightness.

FIXTURES

For new construction and major renovations, provide light emitting diode (LED) luminaires. LED luminaires shall have a color temperature of 2700k or 3000k within a 4-step MacAdam ellipse; CRI $\geq$ 90; dimming performance from 10 – 100 percent without flicker or noise; power factor $\geq$ 0.9; 5-year replacement warranty.

Incandescent, Fluorescent and halogen fixtures are not acceptable for general purpose lighting.

Interior fixtures shall be standard manufacturer models with standard colors and finishes or match existing.

DRIVERS

1. Key qualifications for electronic dimming driver performance and reliability; contractor shall take sole responsibility for electronic dimming drivers and dimming controls.
2. Dimming range of electronic dimming drivers shall be from 100 percent to 1 percent luminance level.
3. Electronic dimming drivers shall not be damaged by miswiring line voltage and control wire inputs.
4. Electronic dimming drivers shall internally limit in-rush current to not exceed three amps at 277 volts or seven amps at 120 volts to avoid computer problems, nuisance circuit breaker trips, and control contact malfunctions.

Suggested Minimum Driver Product Quality Requirements

1. Drivers shall have a 3-year manufacturer's warranty and shall have been on the commercial market for a minimum of two years. Ballast shall be UL listed Class P and sound rated A.
2. Drivers shall maintain light regulation of +/- 10 percent with +/- 10 percent input voltage variation.
3. Current total harmonic distortion shall be less than 10 percent.
4. Flicker shall be 15 percent
5. Drivers shall be designed to withstand line transients per IEEE 587, Category A.
6. Drivers shall meet FCC Rules and Regulations, Part 18.
7. Drivers shall operate at 20 kHz or greater.
8. Drivers shall have a power factor greater than 0.90.

SPECIALTY APPLICATIONS

Use Integrated Classroom Lighting Systems (ICLS) in classrooms. ICLS is a design approach developed by the California Energy Commission though the PIER program. An ICLS integrates suspended fixtures with occupancy sensors, entry switches, and teacher control keypad into one package that provides reduced connected load, improved lighting quality, and improved occupant satisfaction.

Use task/ambient lighting in offices, laboratories, and other task/ambient oriented spaces. Task/ambient lighting approach involves using tasking and ambient lighting to get the appropriate light level needed to perform a task.

Ensure the CCT of general and task lighting match.

Laboratories should incorporate best practices as applicable from the "Labs for the 21st Century: Best Practice Guide – Efficient Electric Lighting in Laboratories":

1. Use indirect/direct lighting fixtures with at least 70 percent up light and at least 5 percent down light.
2. Make all light measurements 12 inch in from edge of work surfaces at 24-inch increments along the length of the work surface.
3. Evenly distribute the illumination over the full length of the bench.
4. Pay attention to reflective surfaces and glare.
5. Where a large amount of daylighting is available, the use of a higher CCT rated fixture may be appropriate.
6. Provide a locally controlled task light level not to exceed 100 fc at 12 inch in from edge of work surface at all locations where critical task work may be performed. Tailor the light level to the specific task, closer to 100 fc for critical work, closer to 50 fc for non-critical work.
7. Match task lamp color temperature to general illumination color temperature.

TELECOMMUNICATIONS SPACE (TS) LIGHTING REQUIREMENTS

Room Lighting shall be mounted a minimum of 8-feet, 6 inches above the finished floor. Provide a minimum equivalent of 50 foot-candles when measured three feet AFF. Locate the lights parallel to the front and back of the equipment racks on both sides and in the middle of all aisles between racks or cabinets. Recommend at least one light fixture be on an emergency power circuit, if available in the building. Lighting shall not receive power from the same electrical distribution panel breaker as the telecommunications equipment in the TS.

EMERGENCY LIGHTING 26 52 00

Emergency egress lighting shall be provided by generator power, when possible. If no emergency generator is to be provided, either an inverter system or individual battery pack lighting shall be provided. The engineer of record or his lighting design agent shall provide photometrics calculations proving that the minimum required light levels along the architects defined path of egress are maintained during a power outage for egress purposes per current code.

For renovation applications, provide LED emergency lighting with NiCad, Sodium-ion or lithium battery pack or units connected to a power distribution and control unit able to provide emergency power. Units with battery packs shall not require factory replacement of batteries to preserve UL listing.

EXIT SIGNS 26 53 00

Emergency EXIT signs are to be the LED type. Maximum wattage per sign shall be less than 7 watts and the minimum warranty shall be 5 years. For new construction, signs are to be painted white and use green LED’s. For renovations where existing signs are not green, consult the University’s Representative for appropriate color selection of new exit signs. Tritium exit signs are specifically prohibited for use on the UCSC Campus.

EXTERIOR LIGHTING	26 56 00

New installations shall comply with the latest edition of the (IESNA) Lighting Handbook and California Building Code Title 24. Light areas where exterior lighting is specifically required for safety and security. A photometric study is required to ensure the minimum lighting levels are met for each application category.

New installations shall be controlled by the BMS and lighting control system using photocells, occupancy sensors and astronomical time switches per California current Title 24 standards. Verify the individual installation requirements with PPDO ES.

Light Pole Foundations: The hole for the foundation shall be augured or hand dug, any exception shall be pre-approved by the University's Representative. Anchor bolts installed in foundations shall be provided with double nuts and washers. Anchor bolts shall be set in place and supported by the use of a template to maintain the true bolt circle before the concrete is poured. The University's Representative shall inspect the work before the concrete is poured and must be contacted 48 hours before the scheduled pouring. The top of the foundation shall be at least three (3) inches above finished grade, trowel finished and sloped slightly for drainage Surplus excavation shall be disposed of by the contractor.
Provide emergency exterior egress lighting to adjacent public right-of-way. APPLICATION

CATEGORIES

Table-1 presents the six major lighting categories deployed on the Campus. The physical attributes and performance criteria described for each category are based on commercially available technologies at time of this specification's release. The lamps used in these fixtures include LED technology. Examples of source technologies currently in service on the Campus are provided as a reference in Table 1 and the specific fixtures in service establish the minimum acceptable performance criteria. Contact the University's Representative for information on these fixtures (performance and style).

The fixture style attribute is included only as a generic label for the acceptable luminaire in each category. All new fixtures must adhere closely to the aesthetic form factors noted in Table -1.
Bollard fixtures shall not be used on any applications without approval of PPDO ES.

Unless otherwise noted, the following criteria shall apply to all fixtures:

1. All sources shall have an efficacy of 70 Lumens/Watt.
2. All fixtures shall be designed to minimize light pollution and glare, while meeting the light distribution requirements for a given category. A designation of full cutoff shall be considered one measure of compliance, but not the sole criteria in evaluating a fixture's ability to minimize light pollution and glare.

EXECUTION

1. A 13 inch wide by 17 inch wide by 12 inch deep pull box shall be located within 5 feet of any street, path or parking lot light foundation. All conduits leaving the control panel to the pull boxes adjacent to each street, path, or parking lot fixture shall be 2-inch P.V.C. Conduits from pull boxes to individual street, path, or parking lot fixture shall be 1-inch P.V.C. unless otherwise specified.
2. All vehicular street lighting electrical circuits shall be multi-staggered circuits. Street lighting systems shall be effectively grounded at the source. All conduit runs to contain a grounding conductor. Grounding electrodes shall not be installed at individual streetlights.
3. Parking lot, bicycle/pedestrian pathway, and bicycle parking lights shall have a concrete pull box installed adjacent to each fixture with conduits and wiring termination in pull box.
4. All bicycle/pedestrian pathway and bicycle parking lighting circuits shall be multi-staggered circuits. Lighting controllers shall be on a separate dedicated circuit from lighting branch circuits to minimize disruption.
5. If a raised standard is used, the pole shall be shortened to compensate for standard height.
6. Hinged pole bases shall be used on parking structure decks for servicing without the use for a lift.
7. All lighting fixtures in all categories shall include In-Line fuse holders. Fuse holders shall have a current rating of 30 amps, 600 volts, and accept a 5-amp 13/32 inch diameter by 1-1/2 inch length fuse. Fuse holders shall be located in the hand hole of the pole.

TABLE 1: EXTERIOR LIGHTING

Exterior Lighting Categories [Note 1]	**Fixture Style**	**Mfg. & Model #** [Note 2]	**Lamp Type**	**Pole / Mounting**	**Height (feet)** [Note 3]	**Finish: Pole or Fixture**	**Controls** [Note 4]	**Uniformity Ratio, Maximum to Minimum**	**Color (CRI)**
Vehicular Streets (Non-Restricted)	Box	Phillips/ Gardco	LED		20-30	Aluminum or Light Gray	Notes 9, 10, 11	6:1 (avg:min)	4000K (>70)
Parking Lot	Box	Phillips/ Gardco	LED	Square	18	Dark Bronze	Notes 9, 10, 11, 13	20:1 (max:min)	4000K (>70)
Bike & Pedestrian Pathways, Restricted Vehicular Streets	Box	Phillips/ Gardco	LED	Square Arm Mount	16	Dark Bronze	Notes 9, 10, 11, 13	2:1 (avg:min)	4000K (>70)
Bike Parking & Plaza	Box	Phillips/ Gardco	LED	Square	16	Dark Bronze	Notes 9, 10, 11, 13	2:1 (avg:min)	4000K (>70)
Parking Structure	Deck Mounted	--	LED	Deck	Garage height	Dark Bronze	Notes 8, 9, 10, 12, 13, 14	10:1 (max:min)	>70

Building Mounted & Loading Dock [Note 4]	Wallpack (Cut-off)	--	LED	Building	14	Dark Bronze	Notes 9, 10, 12, 13, 14	N/A [Note 5]	>70
Wall Mounted Decorative & Architectural Lighting	As appropriate	As appropriate	LED	As appropriate	As appropriate	As appropriate	Notes 7, 11	N/A [Note 1]	>70
Bollards		Phillips/ Gardco	LED	Bollard Dome Top	42”	Dark Bronze	Notes 9, 10, 11, 13	2:1 (max:min)	4000K (>70)
PV Canopy	Deck Mounted	--	LED	Deck	Canopy Height	Dark Bronze	Notes 8, 9, 10, 12, 13, 14	10:1 (max:min)	>70

NOTES:
1. Minimum light levels and uniformity ratios for all categories shall comply with the latest edition of Illuminating Engineering Society of North America (IESNA).
2. Or Equal.
3. Mounting and pole heights (in feet) to match with adjacent fixtures, where applicable.
4. In addition to listed controls, provide an Astronomical Time Clock.
5. Wall-pack fixture to be down type (full-cut-off).
6. If fixture is located near walkway, apply Bike & Pedestrian Pathways minimum light levels.
7. Connect to the building lighting control system.
8. Adaptive lighting controls shall be used for parking lots and under PV canopies.
9. All exterior lighting controls shall integrate into existing Campus Central Lighting Control System. Consult University’s Representative for details.
10. Lumewave RF controller, provide one per fixture.
11. 0-10V dimming power supply
12. Stepped dimming
13. Occupancy Sensor, provide one per fixture.
14. Photosensor, provide one per fixture.

REFERENCES

CONTROLS:

There are four types of occupancy sensor technologies; passive-infrared, ultrasonic, microwave, and audio based. Audio and ultrasonic technologies are inappropriate for exterior use because they can be triggered unintentionally by small animals, wind, rain, etc. This outline will assist in making an appropriate occupancy sensor selection based on the application and the type of fixture being controlled.

On/Off vs. Stepped-dimming Occupancy Controls

1. On/off occupancy controls consist of a lighting system that operates at full power and light output when occupied, and operates at zero power and light output when unoccupied. This functionality is appropriate for secondary use areas where occupant

traffic is not required to enter at night.

2. Stepped-dimming occupancy controls consist of a lighting system that operates at full power and light output when occupied and operates at a reduced power level and light output (this level can be design or product specific) when unoccupied. This design method balances energy savings and safety. This functionality is appropriate for primary use areas.

Zonal vs. Individual Occupancy Controls

A zonal occupancy control design involves occupancy sensors controlling light fixtures that they are not directly associated with (e.g. – a parking lot with occupancy sensors at the entrance controlling all of the fixtures). Zonal occupancy controls can be cost effective and provide desired performance features but they are prone to “blind” spots (i.e., it is possible to occupy the controlled zone without being detected) and unreliable communication between sensors and fixtures.

1. Individual occupancy control design involves each controlled fixture having an integral occupancy sensor. This increases reliability and minimizes “blind” spots but can increase incremental cost.

Passive-infrared Occupancy Sensor

1. Passive-infrared sensors require a direct line of sight to function properly. This means any obstructions such as buildings, trees, etc. between the sensor and the intended target will keep the sensor from triggering occupancy.
2. Passive-infrared sensors have varied coverage ranges and patterns. An appropriate range and coverage pattern should be determined based on application, traffic patterns, and fixture compliance.

Microwave Occupancy Sensor

Microwave occupancy sensors can detect motion through some (but not all) mediums. These sensors can be useful when fixture penetration is not an option (e.g., wet location listing required). If the sensor is exposed to open air or through a thin acrylic sheet it can reduce blind spots due to unforeseen obstructions. However, it is not typical for a microwave sensor to detect reliably through fixture housings. Unless a fixture is offered with an integral microwave sensor and a detailed coverage pattern, beware of specifying a sensor to be integrated into a housing.