



26 0510 – Electrical Commissioning

1. Electrical Commissioning

- a. The Design Team shall provide fully integrated design documents to ensure all required Contractors are fully responsible for supporting the Commissioning activities for the proposed systems to be commissioned. All required labor hours and materials shall be included for, at a minimum but not limited to, meetings, supporting documentation, field testing activities, ancillary testing equipment, off-season testing, data storage, support for 10 month warranty verification (if required), etc.
- b. The Design Team shall work with the project Commissioning Agent to incorporate all of their testing requirements into the contract specifications.
- c. Lighting Controls

- i. Specifications shall include requirements to test lighting control components as follows:

1. Occupancy Sensors

- a. Each occupancy sensor shall be tested to ensure lights turn on and stay on while space is occupied, and turn lights off following 15 minutes of vacancy.
- b. Each occupancy sensor shall be tested to ensure HVAC systems are properly interfaced with the occupancy sensor to turn on HVAC systems when the room is occupied, and turn off/turn back HVAC systems following 45 minutes of vacancy.

2. Vacancy Sensors

- a. Each vacancy sensor shall be tested to ensure lights turn on via manual intervention only, stay on while space is occupied, and turn lights off following 15 minutes of vacancy.
- b. Each vacancy sensor shall be tested to ensure HVAC systems are properly interfaced with the occupancy sensor to turn on HVAC systems when the space lighting switch is activated, stay on while the space is occupied, and turn off/turn back HVAC systems following 45 minutes of vacancy.

3. Daylight Harvesting



- a. Daylight harvesting systems shall be tested to ensure lighting levels are reduced to the appropriate level, as determined by the HMS Project Manager, when the maximum amount of daylighting is available in the space.
- b. Daylight harvesting systems shall be tested to ensure lighting levels are brought up to 100% when the amount of daylighting available in the space is insufficient to properly illuminate the space, as determined by the HMS Project Manager.

4. System Programming

- a. All systems that require programming shall be programmed to control devices as indicated in this section. Programming shall also be tested for:
 - i. Astronomic control
 - ii. Daylighting control
 - iii. Time-of-day control
 - iv. Etc.

d. Low Voltage Distribution Equipment (120-600 VAC)

- i. Ensure that all circuit breaker trip settings have been adjusted to the values indicated in the Power System Study performed for the project.
- ii. Perform system function tests upon completion of equipment tests. It is the purpose of system function tests to prove the correct interaction of all sensing, processing, and action devices.

1. Implementation

- a. Verify the correct operation of all interlock safety devices for fail-safe functions in addition to design function.
- b. Verify the correct operation of all sensing devices, alarms, and indicating devices.

e. Infrared Scanning

- i. Provide a thermographic survey of all busway and other equipment as requested by the HMS Project Manager one year after the building is turned over to the Owner.

ii. Visual and Mechanical Inspection

- 1. Inspect physical, electrical, and mechanical condition.



2. Remove all necessary covers prior to thermographic inspection.
- iii. Provide report including the following:
 1. Discrepancies.
 2. Temperature difference between the area of concern and the reference area.
 3. Cause of temperature difference.
 4. Areas inspected. Identify inaccessible and/or unobservable areas and/or equipment.
 5. Identify load conditions at time of inspection.
 6. Provide photographs and/or thermograms of the deficient area.
- iv. Test Parameters
 1. Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1°C at 30°C.
 2. Equipment shall detect emitted radiation and convert detected radiation to visual signal.
 3. Thermographic surveys should be performed during periods of maximum possible loading but not less than 40 percent of rated load of the electrical equipment being inspected. Refer to NFPA 70B-1994, Section 18-16 (Infrared Inspection).
- v. Test Results
 1. Temperature differences of 1°C to 3°C indicate possible deficiency and warrant investigation.
 2. Temperature differences of 4°C to 15°C indicate deficiency; repair as time permits.
 3. Temperature differences of 16°C and above indicate major deficiency; repair immediately.]

26 0520 – Electrical Design Criteria

1. Design Statement

- a. During the various design phases of this project, the Engineer will develop options and schemes for selection of the appropriate electrical system. This approach will enable the entire Design Team (Owner, Architect and Engineer) to partake in the decision making process concerning the selection of the electrical system and major equipment.



- b. Discuss the following system characteristics with the Project Manager, and incorporate each into the design as required for the project:
 - i. Flexibility for future changes.
 - ii. Durability; ease of maintenance.
 - iii. Reliability
 - iv. Future expansion
 - v. Cost effectiveness
 - c. Every effort will be made to design, layout and install equipment in locations which will tend to encourage routine preventive maintenance by providing easy access for maintenance personnel.
2. Codes, Standards and References
- a. The electrical systems will be designed to comply with the latest volume or publication of following codes and standards:
 - i. Massachusetts State Building Code
 - ii. Massachusetts Electrical Code
 - iii. National Fire Protection Association (NFPA)
 - 1. NFPA 70 National Electrical Code
 - 2. NFPA 72 National Fire Alarm Code
 - 3. NFPA 101 Life Safety Code
 - iv. NFPA 110 Emergency and Standby Power Systems
 - v. Underwriters Laboratories (UL)
 - vi. Factory Mutual (FM)
 - vii. Occupational Safety and Health Administration (OSHA)
 - viii. Environmental Protection Agency (EPA)
 - ix. Massachusetts Department of Environmental Protection (DEP)
 - x. American National Standards Institute (ANSI)



- xi. American Society of Testing Materials (ASTM)
- xii. American Wire Gauge (AWG)
- xiii. National Electrical Manufacturers Association (NEMA)
- xiv. Institute of Electrical and Electronic Engineers (IEEE)
- xv. National Electrical Testing Association (NETA)

3. Utilization Voltages

- a. Receptacles: 120V, 1-phase.
- b. Fluorescent Lighting: 277V, 1-phase, if available, otherwise, 120V, 1-phase.
- c. LED Lighting 277V, 1-phase, if available, otherwise, 120V, 1-phase.
- d. Incandescent Lighting: 120V, 1-phase.
- e. Motors 1/3 HP and smaller: 120V, 1-phase.
- f. Motors 1/2 HP and larger: 480V, 3-phase, if available, otherwise, 208V, 3-phase..

4. Normal Power

- a. The electrical system loads will be designed as follows:
 - i. 0.1 to 1.0 volt-amperes (VA)/sq.ft. for lighting or as allowed by the Energy Code.
 - ii. 3.0 VA/sq.ft. for power-Office Areas.
 - iii. 10 VA/sf for laboratory power
 - iv. 2.0 VA/sq.ft. for power-All Other Areas
 - v. 8.0 to 10.0 VA/sq.ft. for Plumbing and HVAC air handling equipment or as required by the project.

5. Stand-by Power

- a. The emergency and legally required stand-by electrical system will be designed as follows:
 - i. 0.25 VA/sq.ft. for emergency life safety lighting
 - ii. 0.25 VA/sq.ft. for miscellaneous life safety power including fire alarm system, plumbing equipment, etc.



- b. The optional stand-by electrical system will be designed as follows:
 - i. 0.25 VA/sq.ft. for lighting in selected areas.
 - ii. 5.0 to 7.5 VA/q. Ft. For selected laboratory optional standby power
 - iii. 2.5 VA/sq.ft. for minimal fume hood exhaust system, if required by the Project.
 - iv. The following systems shall be provided with optional standby power as required for the project:
 - 1. Central building/laboratory equipment, including domestic water booster pumps, minimal laboratory exhaust systems, etc.
 - 2. Animal facility power.
 - 3. Animal facility air handling systems.

6. Lighting

- a. All lighting levels will conform with the Illuminating Engineering Society's recommendations and, in general, average maintained lighting levels shall be as follows:
 - i. Laboratories – general illumination: 40 to 50 FC
 - ii. Laboratories – task illumination 100 FC
 - iii. Laboratory support: 30 to 40 FC
 - iv. Offices: 30 to 40 FC
 - v. Working Corridors: 20 to 30 FC
 - vi. Conference Rooms/Classrooms : 40 to 50 FC
 - vii. Toilets: 20 to 30 FC
 - viii. Lobbies and Foyers: 20 to 30 FC
 - ix. Animal Holding Rooms (Day/Night Cycle): discuss with User
 - x. Animal Holding Rooms (Working): discuss with User
 - xi. Utility and MEP/FP/IT Equipment Rooms: 30 to 50 FC
 - xii. Utility Corridors: 5 to 15 FC

7. Receptacles

- a. Normal Power
 - i. Laboratories
 - 1. Two (2) circuit surface mounted raceway at laboratory bench with duplex receptacles on 18" centers.
 - ii. Laboratory Support



1. Two (2) circuit surface mounted raceway along equipment wall with duplex receptacles on 24" centers.
2. Wall mounted special purpose, 208V receptacles for larger equipment 5'-0" on center.
- iii. Offices
 1. One (1) duplex receptacle per wall and (1) double duplex receptacle at desk location.
- iv. Animal Holding Rooms
 1. One (1) duplex receptacles per animal holding room mounted 48" AFF. with ground fault protection and weatherproof cover plate.
- b. Optional Stand-By Power
 - i. Laboratories
 1. One (1) duplex receptacle at each laboratory bench (mounted on utility column).
 - ii. Laboratory Support
 1. Selected receptacles and equipment at equipment areas, including selected special purpose receptacles.
 2. Provide a minimum of 25% normal power receptacles in areas with high concentration of Optional Stand-by power.
 - iii. Animal Holding Rooms
 1. Duplex receptacles mounted 48" AFF. with ground fault protection and weatherproof cover plate.
- c. Plug Load Control
 - i. Provide plug load control via room lighting motion sensor if required by ASHRAE 90.1 Energy Code.
8. Circuiting Criteria
 - a. General Lighting
 - i. 277 volt lighting shall be limited to 3200 VA per 20A, 1 pole circuit.



ii. 120V lighting shall be limited to 1200 VA per 20A, 1-pole circuit.

iii. All dimmer switches shall be rated for 2000 VA minimum.

b. Receptacles

i. All laboratory receptacle circuits shall have a maximum of (4) duplex outlets on a 20A, 1-pole circuit, 120V.

ii. Convenience receptacle circuits shall have a maximum of (6) duplex outlets on a 20A, 1-pole circuit, 120V.

iii. All duplex and special purpose receptacles indicated for specific equipment shall be on a separate dedicated circuit.

c. Motors

i. All motors 1/8 HP and under shall be wired not more than (3) per 20A, 1-pole circuit, 120V.

ii. All motors above 1/8 HP shall have individual circuit breakers.

iii. All motors 1/2 HP and above shall be 3-phase and on individual circuits, 480V, if available, otherwise 208V.

iv. Motors shall have efficiency levels of ASHRAE 90.1 or IECC Energy Codes.

9. Grounding

a. A complete equipment grounding system shall be provided such that all metallic structures, enclosures, raceways, junction boxes, outlet boxes, cabinets, machine frames, metal fences, and all other conductive items operate continuously at ground potential and provide a low impedance path to ground for possible fault currents.

b. The main equipment electric room shall be provided with continuous copper ground bus around the perimeter of the room for properly bonding and grounding all main switchgear. The ground bus shall be bonded to the exterior ground grid system and ground rods.

c. A grounding network for the main service equipment and lightning protection system shall be provided consisting of a buried ground loop around the perimeter of the building, bonding to building steel, copper ground rods, etc.

d. A separate insulated green grounding conductor shall be provided for each single and 3-phase feeder and branch circuit. Grounding conductor shall be run with the related phase and neutral conductors. Panel feeders installed in more than (1) raceway shall



have individual, full sized, green grounding conductor in each raceway. The equipment grounding system shall not rely on the metallic raceways for grounding continuity.

- i. A separate, isolated ground system riser shall be provided originating at the main building service grounding point. Ground busses shall be provided on each floor for systems and equipment requiring isolated ground.

26 0530 – Wiring and Wiring Devices

1. Medium Voltage Conductors

- a. The medium voltage cable shall be single conductor, ethylene-propylene rubber (EPR) insulated, shielded and jacketed power cable for medium voltage applications, and shall be in accordance with NEC Article 328. Cables shall be UL listed and designated as MV-105. Cable shall be able to withstand a fault at the magnitude indicated in the short circuit study for at least 5 seconds.

2. 600 Volt Conductors

- a. Wire and cable for feeders, lighting, power, branch circuits and control circuits for systems operating between 50 and 600 volts shall be soft drawn, 98% conductive copper with 600 volt rated insulation.
- b. The phase, neutral and ground conductors for all feeder, branch circuit and auxiliary system wiring passing through pull boxes and/or being made up in panelboards shall be properly grouped, bound and tied together in a neat and orderly manner in keeping with the highest standards of the Trade, with plastic cable ties in at least one location within the enclosure. Loose ends of the cable ties shall be properly trimmed after making up same. Cable ties shall be Ty-Raps, as manufactured by Thomas & Betts, Holub Industries, Inc., Quick-Wrap, Burndy Unirap or equal.
- c. Color coding of conductors shall match the Owners color coding standard. If no standard color coding system exists, use the following:

208/120 Volts			480/277 Volts		
A Phase	-	Black	A Phase	-	Brown
B Phase	-	Red	B Phase	-	Orange
C Phase	-	Blue	C Phase	-	Yellow
Neutral Phase A	-	White w/ Black Stripe	Neutral Phase A	-	Grey w/ Brown Stripe
Neutral Phase B	-	White w/ Red Stripe	Neutral Phase B	-	Grey w/ Orange Stripe
Neutral Phase C	-	White w/ Blue Stripe	Neutral Phase C	-	Grey w/ Yellow Stripe
Ground	-	Green	Ground	-	Green w/ Yellow Stripe
Isolated Ground	-	Green w/ Orange Stripe			



- d. Color coding shall be continuous on insulation for all conductors. For conductors larger than #6 where continuous color coding is not available, each conductor shall be marked with color tape at all connections and in all pull, junction and outlet boxes.
 - e. For large size conductors available only in black, use colored plastic tape at all ends, where connections and splices are made and in all pull boxes for the specified color code identification. Tape shall be wrapped around the conductor (3) complete turns.
 - f. For 120 volt and 277 volt single phase circuits, Electrical Subcontractor shall provide additional identification to identify each neutral conductor with its associated phase conductor in all pull, junction and outlet boxes.
3. Branch Circuits
- a. Branch circuit conductors shall be single-conductors 600V rated with THWN or THHN insulation with continuous color coding.
 - b. Branch circuit conductor shall be a minimum #12 AWG. Each branch circuit shall include a dedicated neutral conductor. No more than 7 conductors (3-phase, 3 neutral and 1 ground) shall be installed in a common conduit.
 - c. Metal Clad Cable
 - i. The use of metal clad cable, and hospital grade metal clad cable, with redundant ground, shall be discussed with the Project Manager
 - ii. MC cable, with insulated green ground conductor [**and redundant ground**], may be utilized in lieu of conduit and cable in dry, hollow partitions and accessible ceiling cavities for general purpose, 20 ampere, single phase, 120 or 277 volt, branch circuits for receptacles and lighting fixtures only.
 - iii. For lighting fixture whips; maximum length 6', maximum 4 fixtures connected to a common junction box.
 - iv. For 20 ampere, single phase, 120 volt receptacle circuits; maximum length from junction box to first receptacle 30'. Maximum length between receptacles 15'. Maximum 4 receptacles connected together.
 - v. For branch circuit homeruns to surface mounted panels, MC cable shall terminate in a junction box 5'-0" (minimum) horizontally away from the panel and conduit shall be run to the panel. If panelboards are located in rooms designated as electric rooms or closets, MC cable shall terminate in a junction box outside of the electric room and conduit shall be run to the panel.
 - vi. Uses Not Permitted
 - 1. MC cable shall not be allowed in electric rooms or closets.



2. MC cable shall not be used in mechanical or plumbing rooms, closets or shafts, including mechanical penthouse.
3. Branch circuits larger than 30 ampere.

4. Raceways

- a. Raceways for feeders and branch circuits shall be metallic, rigid metal conduit, intermediate metal conduit (IMC) or electrical metallic tubing (EMT) subject to the restrictions of the National Electrical Code, minimum size 3/4". EMT shall not be used in concrete construction or where subjected to mechanical damage.
- b. Exterior ductbanks shall be comprised of PVC Schedule 40 conduit encased in concrete. Concrete duct banks shall be formed of plywood. Where ductbanks penetrate foundation walls or manholes, rigid galvanized steel (RGS) conduit shall be used.
- c. Raceways shall not be allowed in concrete floor slabs.
- d. Conduit shall be run concealed in finished areas above suspended ceilings, in wall spaces, etc. All conduit runs shall be properly grouped and installed parallel to walls, ceilings, etc., and supported with proper hangers, clamps, etc. Door swings shall be checked before installing back boxes for switches and receptacles.
- e. Raceways in finished areas shall be Wiremold raceway with HMS project Manager and Architect's approval.
- f. Conduit bends shall be made with conduit bending machines or by an approved hickey. Lock nuts and insulated throat bushings of the compatible material shall be used to fasten conduit to outlet boxes, cabinets, etc.
- g. Separation of Wiring:
 - i. Raceways for the emergency branch, legally required and optional stand-by branch of the emergency electrical system shall be kept entirely independent of all other raceways and shall not enter the same raceways, boxes or cabinets with each other or other wiring, except in transfer switches.
 - ii. Where a branch of the emergency system contains multiple transfer switches, raceways downstream from the two (or more) transfer switched shall be kept independent of each other.
- h. Cable Management
 - i. Cable tray shall be provided in IT closets, Utility Tunnels and as directed by the HMS Project Manager.

5. Wiring Devices



- a. All wiring devices shall be the product of a single manufacturer, except where specifically stated otherwise.
- b. All devices shall be standard or “Decora” style and shall be consistent with the adjacent areas.
- c. Devices with ground fault circuit interrupter shall be feed thru type and include an indicator light that illuminates when the device is tripped and a self-test feature that conducts an automatic test a minimum of every sixty (60) seconds to ensure ground fault protection is functioning. If ground fault protection is compromised, power to the receptacle shall be discontinued and an indicator light shall flash indicating that the unit should be replaced.
- d. All devices in bathrooms/toilets, within 6’-0” of sink locations, exterior outlets, utility vault, in wet areas, etc. shall be ground fault type.
- e. The equipment grounding contacts for isolated ground devices shall be connected only to the green grounding screw terminal of the device and with inherent electrical isolation from mounting strap. Isolation shall be integral to receptacle construction and not dependent on removable parts.
- f. Surge protective devices shall be provided for A/V equipment including televisions, amplifiers, etc. and include:
 - i. Integral line to ground, line to neutral, and neutral to ground surge protection. Surge protection components shall include multiple metal-oxide varistors with a nominal clamp-level rating of 500 volts and minimum single transient pulse energy dissipation of 300 joules, according to IEEE C62.41.2 and IEEE C62.45.
 - ii. Device shall include an active visual and audible indication, with light visible in face of the device to indicate the device is "active" or "no longer in service". Green light = protected; flashing red light = no longer protected; no light = no power to unit.
- g. USB charging receptacles shall be provided in classroom spaces and include an LED indicator to show USB power available, and shall be compatible with 1.x, 2.0 and 3.0 devices, including Apple products.
- h. Color of all devices shall be white, unless directed otherwise by the Project Manager or Architect.
- i. Devices on the Emergency system shall be red.
- j. Devices on the Optional Standby system shall be red



- k. All normal power wiring device plates shall be stainless steel with a brushed finish, type 302/304:
 - l. All Emergency branch power wiring device plates shall be stainless steel with a brushed finish, type 302/304 with red filled "EMERGENCY" engraved in plate:
 - m. All Optional Stand-By branch power wiring device plates shall be stainless steel with a brushed finish, type 302/304 with red filled "Stand-By" engraved in plate: {Engraved or P Touch Labels}
 - n. Heads of device plate screws shall be of the same material/color as the device plate.
6. Outlet Boxes
- a. Outlet boxes, for wiring devices in new hollow frame partitions shall be mounted on "stud-to-stud" type mounting brackets. Brackets shall be secured using self-threading metal screws, and shall engage more than one stud for support.
 - b. Outlet boxes in existing hollow frame partitions shall be old work type boxes, with tabs. "Madison" bars will not be acceptable

26 0550 – Identification

- 1. Equipment Identification
 - a. Uniquely engraved nameplates, mounted on the face of each assembly, shall be furnished for all electrical distribution equipment specified herein.
 - b. Nameplates shall be laminated plastic and secured with screws.
 - c. Nameplates shall be a minimum of 2 inch high x 2 1/2 inch wide, laminated with **[black letters on white background] [white letters on black background]**.
 - d. Characters shall be 3/16 inch high, minimum.
 - e. New equipment shall have identification consistent with the building it is installed.
- 2. Wiring Device Identification
 - a. P Touch labels shall be provided on each wiring device cover indicating panel and circuit number. A legible handwritten tag shall also be provided in the wiring device box.
- 3. Conductor Identification
 - a. All conductors shall have panel and circuit number identified in all accessible locations, such as panel troughs, pull, junction and outlet boxes.



- b. Identification shall consist of plastic nameplates ty-wrapped to the conductors (phase, neutral and ground conductors comprising the circuit), with legible handwritten characters, using a permanent marker.

26 0570 – Power System Studies

1. The Engineers shall perform the following preliminary Power System Studies.
 - a. Short Circuit Studies
 - b. Protective Device Coordination Studies
 - c. Arc Flash Hazard Analysis
2. The studies shall include all portions of the electrical distribution system from the normal power incoming source or sources of power, the emergency standby source or sources, down to and including all panels and distribution equipment in the distribution system. Normal system connections and those which result in maximum fault conditions shall be adequately covered in the study.
3. In addition, the study shall include all existing distribution equipment directly affected by the new work. The Engineer shall obtain/verify existing characteristics, feeder sizes, nameplate data, etc. as may be required to complete the studies.
4. The power system studies shall include all new and directly affected existing electrical system components to confirm the adequacy of the interrupting ratings, proper coordination settings of all overcurrent protection devices and to determine the requirements for arc flash protection boundary and incident energy exposure labeling to the satisfaction of the Electrical Engineer.
5. Project specifications shall require the distribution equipment manufacturer or a firm engaged by the distribution equipment manufacturer to perform the final Power System Studies, determine adjustable trip settings and calculate and print Arc Flash labels.
6. Short Circuit Study
 - a. Short circuit study shall include the results for each mode of operation, as follows:
 - i. Normal power available and all transfer switches in the normal position.
 - ii. Emergency generator(s) or emergency source(s) running and all transfer switches in the emergency position
 - iii. If closed transition paralleling is provided, study shall be run for each mode of parallel operation as follows:
 1. Multiple normal sources in parallel



2. The normal and emergency source in parallel
 3. multiple emergency sources in parallel
- b. Motor Contribution
- i. Include fault contribution of all motors in the study as follows:
 1. 100% of all motors with standard starters (no VFD's)
 2. 25% of all motors provided with VFD's and bypass starters
 3. 0% of motors provided with VFD's without bypass starters
 - ii. Motor short circuit contribution shall be included at the appropriate locations in the system as indicated on the drawings, so that the computer calculated values represent the theoretical short circuit current available.
7. Coordination Study
- a. In the protective device coordination study, provide time-current plots graphically indicating the coordination proposed for the system, centered on conventional, full-size, log-log forms.
8. Arc Flash Study
- a. Calculation of incident energy exposures shall be performed on all parts of the electrical system, for the Owner's determination and implementation of details of personal protective equipment as required by NFPA 70E Standard for Electrical Safety Requirements for Employee Workplaces.
9. The final study shall be completed by the successful switchgear manufacturer.
10. The input data shall be transferred to the HMS Project Manager in a format compatible to the HMS Power System Study software.


26 0580 – Electrical Acceptance Testing

1. All medium/high voltage equipment, cable and transformers shall be high pot tested per NETA standards.
2. All low voltage 600V equipment, cable, motors, dry type transformers, etc., shall be field tested per NETA Standards.

26 0900 – Power Meters



1. Provide full function electronic meters on the following equipment:
 - a. All main circuit breakers.
 - b. All Distribution Panels, either at the panel, or the circuit breaker serving the panel.
 - c. All automatic transfer switches.
2. The meter shall be UL recognized, CSA certified and also meet ANSI Standard C37.90.
3. The meter shall provide direct reading metered or calculated values of the items listed below and shall auto range between Units, Kilo-units, and Mega-units for all metered values. Accuracy indicated below to be of read or calculated values.
 - a. AC Current (Amperes) in A, B, and C phase, 3 Phase Average and Neutral (N). Accuracy +/- 0.2% (provide phase and neutral current transformer).
 - b. AC Voltage (Volts) for A-B, B-C, and C-A, Phase Average, A-N, B-N, and C-N and Average Phase to N. Accuracy +/-0.2%.
 - c. Real Power (WATTS), Reactive Power (VARs), Apparent Power (VA), for each phase and system (system shall apply only for 3 wire applications). Accuracy +/- 0.4%. Forward/Reverse indication shall be provided.
 - d. Real Energy (WHR), Reactive Energy (VARHR), Apparent Energy (VAHR) for each phase and system (system shall apply only for 3 wire applications). Accuracy +/- 0.4%. Forward/Reverse indication shall be provided.
 - e. Frequency (HERTZ) Accuracy +/- 0.04%.
 - f. Demand values for System Current (AMPERES), System Real Power (WATTS), System Reactive Power (VARs), and System Apparent Power (VA).
 - g. Power Factor both Displacement only 60 cycle fundamental WATTS to VA and Apparent total WATTS to total VARs including harmonics for A, B, and C phase and system. Accuracy +/- 0.4%.
4. Meters shall have a trending interval of 15 minutes and shall store a minimum of 3 years of data within the meter. Should the meter lose power, data shall be retained in the meter for a minimum of one year.
5. Meter shall be BACnet (primary), Modbus and TCP/IP capable and shall interface with HMS Building Automation System.
6. Discuss with Project Manager for metering laboratory panel branch circuits.

 HARVARD MEDICAL SCHOOL	FACILITIES DESIGN STANDARD CONSTRUCTION/RENOVATION	SOP #: HMS_DS_ELECTRICAL_180701
TITLE: Division 26 - Electrical		REVISION: May 12, 2019

26 1100 – Medium Voltage Distribution Equipment

1. Medium Voltage Distribution Equipment
 - a. Medium voltage switchgear assemblies shall consist of individual vertical sections having vacuum circuit breakers, customer metering equipment, auxiliary devices and equipment, etc. The switchgear assembly shall meet Eversource and/or MATEP standards.
 - b. The switchgear shall be designed with (2) incoming main circuit breakers with a normally open tie circuit breaker. Each main shall have station class arrestors. The switchgear shall include an automatic transfer scheme including sensing devices and logic equipment such that, upon loss of voltage to the line side of a main that main shall open and then the tie shall close. The automatic transfer scheme shall also include manual-automatic selector switch, logic controller, lockout relays, automatic return to normal condition allowing momentary closed transition, time delays etc. The switchgear shall also contain (4) feeder breakers, (1) per substation transformer and provisions for future expansion. The bus bars shall be copper with 15 kV Class insulation. All bus joints shall be plated, bolted and insulated. The bus shall be braced to withstand fault currents equal to the close and latch rating of the breakers. A copper ground bus shall extend the entire length of the switchgear.
 - c. The 15 kV service shall be distributed in a primary-selective radial system. So that, if one primary feeder is out of service, the remaining feeder has sufficient capacity to carry the total load.
2. Transformers
 - a. Transformers shall be dry type, 13.8 kV to 277/480V, with Class H insulation suitable for 115°C rise.
3. Substations
 - a. The primary side of substations shall include medium voltage circuit breakers interconnected with current transformers on the secondary side main circuit breaker, to reduce arc flash incident energy between the transformer secondary terminals and the secondary main circuit breaker.

26 2000 – Low Voltage Distribution Equipment

1. Busway
 - a. Vertical busways shall be non-ventilated and supported with adjustable vertical hangers at each floor. The busway shall include phase and neutral copper bus bars with a housing ground. On designated floors busway shall be plug-in type. Maximum capacity

 HARVARD MEDICAL SCHOOL	FACILITIES DESIGN STANDARD CONSTRUCTION/RENOVATION	SOP #: HMS_DS_ELECTRICAL_180701
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of busway shall be 1600A. Busway shall be braced to withstand available short circuit currents. All bus shall be copper.

- b. Busway plug-in circuit breakers for the normal system shall be current limiting type with integral ground fault protection.

2. Circuit Breakers

- a. The following circuit breakers shall contain an energy reducing maintenance switch or an equivalent means of reducing arc flash energy:
 - i. Circuit breakers with no instantaneous trip function or breakers with an instantaneous trip set to a value intentionally set to "0" or "off".
 - ii. All circuit breakers 1,200 amp frame and above, regardless of trip setting.
 - iii. All circuit breakers with adjustable trip unit if the highest continuous current trip setting can be set to 1,200 amps or above.
- b. Molded case circuit breakers 100 amperes and above shall be molded case and shall provide circuit overcurrent protection with inverse time and instantaneous tripping characteristics. Circuit breakers shall be bolt-on operated by a toggle-type handle and shall have a quick-make, quick-break over-center switching mechanism that is mechanically trip-free. Automatic tripping of the breaker shall be clearly indicated by the handle position. Contacts shall be non-welding silver alloy, and arc extinction shall be accomplished by means of arc chutes. A push-to-trip button on the front of the circuit breaker shall provide a local manual means to exercise the trip mechanism.
- c. Molded case circuit breakers over 250 ampere frame, shall have be microprocessor-based with true RMS sensing trip units.
- d. Circuit breakers shall be thermal magnetic type with common type handle for all multiple pole circuit breakers. Circuit breakers shall be minimum 100 ampere frame and through 100 ampere trip sizes shall take up the same pole spacing. 20 ampere, single pole circuit breakers shall be UL listed as type SWD for lighting circuits.
 - i. Where ground fault protection is provided or required on building main circuit breaker, downstream feeder breakers shall be provided with ground fault protection and be coordinated with the upstream device.
 - ii. Where ground fault protection is provided on circuit breakers serving busway, and the busway includes a neutral conductor and serves 277 volt loads, such as lighting loads, all feeder circuit breakers on the busway shall be provided with ground fault protection and be coordinated with the upstream device.

3. Switchgear



- a. The switchgear shall consist of the required number of vertical sections bolted together to form a rigid assembly. The sides shall be covered with removable bolt-on covers. All edges of front covers or hinged front panels shall be formed. Provide ventilators located on the top of the switchgear over the breaker and bus compartments to ensure adequate ventilation within the enclosure. Hinged rear doors, complete with 3 point latch and provisions for padlocking, shall be provided.
 - b. Each vertical steel unit forming part of the switchgear line-up shall be a self-contained housing having one or more individual breaker or instrument compartments, a centralized bus compartment and a rear cabling compartment. Each individual circuit breaker compartment, or cell, shall be segregated from adjacent compartments and sections, including the bus compartment, by means of barriers. It shall be equipped with draw-out rails and primary and secondary disconnecting contacts. Removable hinge pins shall be provided on the breaker compartment door hinges. Current transformers for feeder instrumentation shall be located within the appropriate breaker cells.
4. Switchboards
- a. Switchboards shall be deadfront, completely metal enclosed, self-supporting structures. All bus bars shall be copper with bolted connections at joints and dedicated ground bus. Switchboards shall be front accessible with panel mounted molded case circuit breakers with solid-state trip units. All trims shall be door-in-door type. All bus shall be copper.
5. Distribution and Branch Circuit Panelboards
- a. Distribution, lighting, receptacle, laboratory and laboratory support panelboards shall be deadfront construction utilizing thermal magnetic circuit breakers. Panels 225A and below may be series rated, for the available short circuit current, with the upstream device. Panels over 225A shall be fully rated for the available short circuit current. All trims shall be door-in-door type. All bus shall be copper.
 - b. Distribution panels on laboratory floors and all laboratory and laboratory support panels, fed by "K" factor transformers, shall have 200% rated neutral busses.
 - c. Each distribution panel and branch circuit panel shall include a wiring trough above. The trough shall be the width and depth of the panel, and shall include a removable cover. The trough shall be mounted directly above the panel with sufficient number of 2" nipples (2 minimum), or may be mounted at a higher elevation (such as above an accessible ceiling) with sufficient number of 2" conduits (2 minimum) connecting it to the panel. All unused circuit breakers have appropriately sized phase, neutral and ground conductors wired from the breaker to the trough. Wiring associated with each breaker shall be properly grouped, supported and labeled in the trough.
6. Step Down Transformers



- a. Step down transformers, 480V delta to to 208/120V, 3-phase wye, shall be dry-type, 2-winding, self-cooled. All bus shall be copper. Transformers provided on laboratory floors shall be suitable for non-sinusoidal current loads with "K" factor not less than 4.
- b. Floor mounted transformers shall be mounted a minimum of 6" from walls with proper clearance in front. Floor mounted transformers shall be installed on non-metallic, vibration isolating pads meeting seismic requirements and selected for at least 0.2" deflection. Panelboards shall not be mounted on wall above transformers.
- c. Trapeze mounted transformers shall be supported with threaded rods and channel and shall be isolated with hanger isolators meeting seismic requirements and suitable for the weight and size of the transformer.

7. Concrete Housekeeping Pads

- a. Concrete pads shall be installed for all freestanding electrical distribution equipment.
- b. All concrete housekeeping pads shall extend beyond the equipment supported as follows:
 - i. Equipment with front and rear access, or equipment mounted freestanding with access in front and rear:
 1. 1" in front of the equipment
 2. 6" on each side of the equipment
 3. 6" in back of the equipment
 - ii. Equipment with front access only, mounted against a wall:
 1. 1" in front of the equipment
 2. 6" on each side of the equipment
 3. 0" in back of the equipment
- c. If overcurrent devices exceed 6'-6" above finished floor as a result of the housekeeping pad, the pad shall extend in front of the gear a minimum of 4'-0", and include ramps on each end.

26 3000 – Stand-by Power

1. The following equipment is proposed to be provided with stand-by power in the event of a normal power failure.
 - a. Emergency Systems Power
 - i. Egress lighting



- ii. Exit signs
 - iii. Fire alarm equipment
 - iv. One elevator per elevator bank
 - v. Fire pump/jockey pump
 - b. Legally Required Stand-by System Power
 - i. Sewage ejectors
 - ii. One elevator per elevator bank
 - iii. Minimal fume hood exhaust system
 - iv. Building automation system and accessories
 - v. Emergency Generator room lighting and receptacles
 - c. Optional Stand-by System Power
 - i. One (1) receptacle per 5'-0" of equipment wall space in laboratory support areas
 - ii. Miscellaneous special purpose (208 volt) receptacles in laboratory support areas.
 - iii. Miscellaneous central laboratory equipment (i.e., purified water system, etc.)
 - iv. Environmental rooms
 - v. -80 degrees C and lower freezers (if generator capacity allows)
 - vi. Minimal fume hood exhaust system
 - vii. Laboratory waste system
 - viii. Radioactive hood exhaust fans
 - ix. BSL-3 suites
 - x. Building heating systems to protect building from freezing
 - xi. Animal facility heating system
 - xii. Animal facility air handling equipment
 - xiii. Selected building supply and exhaust systems
 - xiv. Additional lighting in selected areas (Vivarium)
 - xv. Sump pumps
 - xvi. Water booster pumps
 - xvii. Hot water circulating pumps
 - xviii. Security system
 - xix. Telecommunication system
2. Stand-By Generators



- a. Diesel fired engine-generator sets shall be provided to supply electrical power to building emergency, legally required and optional stand-by (essential laboratory, vivarium and building power equipment) systems in the event of loss of normal power.
 - b. Generators shall be 480/277 volt, 3-phase, 4-wire, 60 Hz, 12 lead, 0.8 power factor. The generators shall be a permanent magnet generator (PMG) with brushless construction using full wave 3-phase rotating rectifier assembly.
 - c. Each unit shall be capable of picking up its rated capacity in one step and provide a transition time for the emergency system loads of (10) seconds or less from instant failure of the normal power source to the stand-by generator source. Legally required and optional stand-by loads shall transfer within (15) seconds from failure of the normal power source.
 - d. Generator "run" signal shall connect to the HMS Building Automation System.
3. Automatic Transfer Switches
- a. Each automatic transfer switch shall be provided with a bypass isolation switch. The bypass isolation switch shall provide a safe and convenient means for manually bypassing and isolating the automatic transfer switch regardless of the condition or position of the switch. Each automatic transfer switch shall be double-throw, actuated by (2) electric operators. Each transfer switch shall have an inherent "off" position for shedding the load in the event of an engine-generator failure.
 - b. Closed transition automatic transfer switches shall be used for critical loads, as determined by the Project Manager.
4. Emergency System Wiring
- a. The following emergency branch and legally required branch feeders, branch circuits and control circuits shall be 2 hour fire rated type MI mineral-insulated metal-sheathed cable where not installed in spaces fully installed within a 2 hour fire rated room, closet and/or shaft:
 - i. Feeders from the generator(s) to main emergency distribution equipment.
 - ii. Feeder from the generator or generator distribution system to the fire pump controller.
 - iii. Feeders from main emergency distribution equipment to each emergency branch and legally required branch automatic transfer switch.
 - iv. Feeders from each emergency branch and legally required branch automatic transfer switch to associated distribution equipment.



- v. Feeders from emergency branch and legally required branch distribution equipment to all downstream switchboards panelboards, transformers, enclosed circuit breakers, etc.
- vi. Feeder from the main normal distribution system to the fire pump controller.
- vii. Branch circuit wiring to all smoke evacuation, stairwell pressurization, elevator pressurization fans, and associated equipment.
- viii. Branch circuit to elevator motor(s), controller(s) and cab lighting.
- ix. Engine start circuit from each automatic transfer switch to the generator.

5. Load Bank

- a. Discuss with the Project Manager the need for a radiator mounted load bank, sized for a minimum of 30% of the full power rating of each generator.

6. Docking Station

- a. Furnish an emergency generator docking station at the loading dock of the building, or other similar location, accessible by truck. Docking station shall include the provisions necessary to connect a temporary generator during times when the main generator will be out of service for maintenance, repair or replacement. Docking station shall support a temporary generator of the same rating as the building generator.
- b. Docking station shall include the capability of connecting a load bank to the generator for testing purposes.

7. Weatherproof housing

- a. If exterior, the generator set shall be enclosed in a weatherproof, sound attenuated enclosure constructed of aluminum throughout. The housing shall be designed to accommodate heavy snow loads and shall be equipped with motorized intake and exhaust louvers, pre-wired and pre-piped prior to shipment. Housing shall be constructed per BOCA requirements. Fire suppression shall be provided in walk-in enclosures.

8. Installation


- a. All emergency, legally required and optional standby system equipment, including the generator(s) shall be mounted above the floodplain, as determined by FEMA.

26 5000 – Lighting Fixtures and Controls



1. Lighting Fixtures

- a. Lighting fixtures shall conform to the highest commercial Standards available. Fixture components shall be manufactured of materials most appropriate to their use or function, and resistant to corrosion and to thermal and mechanical stresses encountered in the normal application and function of the fixtures.
- b. Provide recessed fixtures that are constructed to be suitable for, and compatible with, the ceiling, wall or pavement materials and construction in which they shall be installed.
- c. Each and every lighting fixture driver or ballast shall be complete with accessible, individual fuse holder such as Bussman NLR fuse holder or approved equal.
- d. Lighting fixtures shall be UL Listed and Labeled and DesignLights Consortium® (DLC) Listed
- e. Lay-in recessed fixtures in grid type ceilings shall be supported from the underside of roof or floor slab, and utilize hangers with attachments to building construction, independent of other systems. All fixtures shall have a minimum of (2) hangers supports. Hanger wire will not be acceptable.
- f. All lighting fixtures shall be supported from the slab above and shall not be suspended from ducts, piping, equipment, ceiling support system, etc.
- g. Where continuous rows of lighting fixtures are installed (pendant mounted), appropriate mounting channels shall be provided to properly align fixtures.es
- h. Lighting fixtures in vivarium's or wet/damp areas shall be rated for the environment their installed in. Vivarium's require fixtures with gaskets to ensure proper sealing.
- i. Incandescent lamps and Fluorescent lamps will not be acceptable.
- j. Lighting fixtures shall primarily utilize Light Emitting Diode (LED) lamps and drivers.
- k. LED diode arrays shall conform to the following:
 - i. Color temperature of 4,000° Kelvin and minimum Color Rendition Index (CRI) of 82, unless noted by the HMS Project Manager for special circumstances, such as rooms with A/V equipment or specialty color schemes.
 - ii. Lamp life \geq 50,000 hours, and maintain \geq 70% of initial lamp lumen output throughout this period.
 - iii. Have a minimum efficacy of 50 lumens per watt.
 - iv. LED arrays shall meet all applicable IESNA and ANSI standards relating to measurement and construction in effect at their time of purchase.

 HARVARD MEDICAL SCHOOL	FACILITIES DESIGN STANDARD CONSTRUCTION/RENOVATION	SOP #: HMS_DS_ELECTRICAL_180701
TITLE: Division 26 - Electrical		REVISION: May 12, 2019

- v. All LED assemblies shall be covered by a (5) year full manufacturer’s warranty covering the assembly and its replacement in case of failure, provided that operating conditions (thermal and electrical) are maintained within the manufacturer’s stated limits.

I. Fluorescent Lamps

- i. Existing fluorescent fixtures in areas of renovation shall be replaced with LED.

2. LED Drivers

- a. Drivers for LED lamps shall be suitable for the electrical characteristics of the supply circuits to which they are to be connected, and which are suitable for operating the specified lamps. Drivers shall have the following characteristics:
 - i. Constant Current/Voltage.
 - ii. Power factor $\geq .90$
 - iii. Total harmonic distortion $\leq 20\%$
 - iv. Lamp current crest factor ≤ 1.7
 - v. UL Class 2
 - vi. Sound Rating A
- b. Where required by the program, or the Project Manager, LED drivers shall be dimmable with 0-10 volt control.
- c. Drivers shall conform to UL, and ANSI specifications and display labels or symbols of approval by UL, and of certification by the CBM. Mark drivers “Class 2” indicating approved integral driver protection. This driver protection is provided by a built-in self-resetting thermally actuated device that will remove the driver from the line when excessive driver temperature is reached.
- d. Rigidly mount drivers, unless specifically indicated otherwise, to the inside of the top of the fixture housing, with driver surfaces and housing in complete contact for efficient conduction of driver heat. Permanently affix driver mounting screws to the fixture housing. Provide only fixtures whose design, fabrication, and assembly prevent overheating or cycling of lamps and drivers under any condition of use.
- e. Drivers for fixtures that are inaccessible shall be remote mounted in an accessible location and labeled indicating fixture controlled.
- f. Dimming drivers shall be compatible with 3-wire (Line Voltage), Electronic Low Voltage (ELV) or Digital Addressing as required by lighting control system and fixture manufacturer. Provide identical drivers within each fixture type.
- g. Drivers shall have the lowest sound-rating available for the lamps specified and clearly show their respective sound ratings.



- h. For outdoor use and wherever drivers are used outside a heated environment provide drivers capable of lamp-starting at any temperature down to 0 degrees F.
- i. Drivers shall have a 5-year warranty from date of acceptance of the completed installation.

3. Controls

- a. Lighting fixtures in individual rooms, such as offices and conference rooms shall be provided with wall or ceiling mounted vacancy sensors. Vacancy sensors shall require manual intervention to turn fixtures on, and will automatically turn fixtures off after the space has been vacant for an adjustable amount of time, not to exceed 30 minutes, initially set at 15 minutes.
- b. Lighting fixtures in open areas such as large laboratories and open office areas shall be provided with ceiling mounted occupancy sensors with manual on/off control near the entrances to these areas. When the manual switches are in the on position, occupancy sensors shall automatically turn fixtures on when they sense occupants, and automatically turn fixtures off after the space has been vacant for an adjustable amount of time, not to exceed 30 minutes, initially set at 15 minutes. When the manual switch is in the off position, the lights shall remain off
- c. Vacancy and occupancy sensors shall include additional contacts for the building automation system, to set back temperatures when the space is unoccupied.
- d. Vacancy and motion sensors shall be passive infrared.
- e. Vacancy sensors in bathrooms shall be dual technology passive infrared and ultrasonic.
- f. Daylight harvesting shall be utilized in all spaces where an appropriate level of natural lighting is available.
- g. Lighting controls shall be coordinated with, but not integrated into, A/V controls in classrooms.
- h. Animal holding spaces shall have day/night control, with positive feedback monitoring via a separate photocell on the building automation system. Discuss dawn/dusk dimming requirements with the Users.
- i. All occupancy and vacancy switches shall be Wattstopper or Lutron. Wireless sensors are acceptable in renovations, wired sensors are required in new construction.

 HARVARD MEDICAL SCHOOL	FACILITIES DESIGN STANDARD CONSTRUCTION/RENOVATION	SOP #: HMS_DS_ELECTRICAL_180701
TITLE: Division 26 - Electrical		REVISION: May 12, 2019

26 General installation requirements for sealing penetrations of electrical equipment

Penetrations: Whether pre-existing or created for new mechanical, electrical, plumbing or ventilation purposes, each penetration – **whether or not required by code** - should be sealed by an appropriate method that not only preserves the fire / smoke rating of the penetrated structure but also sustainably prevents the entry and passage of insect and rodent pests. Escutcheon plates are acceptable only if the penetration behind is first sealed. Weep holes in the building’s exterior façade shall be protected by an insect- and rodent-resistant device or product that will permit flow of air and water. To exclude rodent and insect pests, penetrations in masonry may be packed with cement or grout. If firestopping compounds are used in masonry, wall board or other partitions, the openings might first be tightly packed, as practical, with non-oxidizing metal meshes such as stainless steel mesh pads (e.g. ‘Xcluder’ brand blocks or fabric) or copper mesh (e.g. ‘Stuf-Fit’ brand). Guidance on such product application is available from the Harvard University EH&S Senior Environmental Public Health Officer and from the pest control vendor.