

PRINCETON PLASMA PHYSICS LABORATORY	<b>ENGINEERING STANDARD</b> <b>ES-ELEC-004</b>		<b>No. Page</b> <b>Rev. 1</b> i of v
<b>Subject</b>  ELECTRICAL CONSTRUCTION SPECIFICATION FOR INSTALLATIONS OPERATED AT 600 VOLTS AND BELOW	<b>Effective Date</b>  December 17, 2004	<b>Initiated</b>  Electrical Safety	
	<b>Supersedes</b>  Revision 0, dated: 2/19/93	<b>Approved</b>  Head, Engineering & Technical Infrastructure	

**Applicability**

This construction standard applies to all 600 volts and below de-energized electrical work performed by employees and subcontractors in the electrical trade at the Princeton Plasma Physics Lab and to apparatus designated for installation at the Princeton Plasma Physics Lab.

**Scope**

Electrical work as specified herein refers to the design, construction, installation, remodeling, maintenance, or repair of equipment, systems, or similar activities. Only de-energized work is allowed and included in this standard. All energized work must have approval of cognizant division head (s) and the Head of Engineering and Technical Infrastructure approval of all work procedures and Job Hazard Analysis.

Install grounding, raceways, boxes, distribution equipment, motor controls, wire, cable, wiring, and control devices as specified herein and as shown on the DRAWINGS with all appurtenances necessary for a complete project.

Radiological effects on electrical equipment and materials are not included in this standard and shall be reviewed by the COGNIZANT ENGINEER.

**Reference Documents**

- ANSI C2 ..... National Electrical Safety Code (NESC).
- ANSI C80.1 ..... Rigid Steel Conduit - Zinc Coated.
- ICEA Publication No. S61-402 - Appendix A - NEC Color coding of Multi-conductor Control Cables.
- NEMA ICS 1 ..... General Standards for Industrial Control and Systems.
- NEMA PB 2 ..... Dead front Distribution Switchboards.
- NEMA ST 20..... Dry-Type Transformers for General Applications.
- NEMA TC 2 ..... Electrical Plastic Tubing and Conduit.
- NETA ATS-1999 ..... International Electrical Testing Association - Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems.
- NETA MTS-2001..... International Electrical Testing Association - Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems.
- NFPA 70E.....Standard for Electrical Safety Requirements for Employee Safety
- NFPA 70..... National Electrical Code (NEC).
- NFPA 79..... Electrical Standard for Industrial Machinery.
- PPPL ES&HD 5008, Section 2.0 - Electrical Safety.
- PPPL ESH-016..... Control of Hazardous Energy Sources via Lockout/Tagout of Energy Isolation Devices.
- \*PPPL ENG-024.....Digging Permits
- \*PPPL ENG-028.....Core Boring, Cutting and Drilling of walls, floors & ceilings
- \* Denotes items provided with contract if applicable
- Product Directories of Underwriters Laboratories (UL), Inc.
  - Electrical Construction Materials Directory.
  - Electrical Appliance and Utilization Equipment Directory.
  - Recognized Component Directory.

- UL 1 Flexible Metal Electrical Conduit.
- UL 6 Rigid Metal Electrical Conduit.
- UL 67 ..... Electric Panel boards.
- UL 360 ..... Liquidtite Flexible Steel Conduit Electrical.
- UL 467 ..... Electrical Grounding and Bonding Equipment.
- UL 651 ..... Schedule 40 and 80 Rigid PVC Conduit.
- UL 797 ..... Electrical Metallic Tubing.
- UL 1063 ..... Machine Tool Wires and Cables.
- UL 1660 ..... Liquid-tite Nonmetallic Conduit.

**Upper Tier Documents**

This standard Includes PPPL requirements that are intended to supplement, but do not conflict with the following documents:

29 CFR 1910 and 1926..... Occupational Safety and Health Standards (OSHA).

DOE

DOE 440.1A..... Worker Protection Management for DOE Federal and Contractor Employees

ICEA Publication No. P32-382 - Short-Circuit Characteristics of Insulated Cables.

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## 1 GENERAL

### 1.1 SOURCE QUALITY CONTROL

Equipment and materials shall be furnished from the current issues (latest) of the Product Directories of Underwriters Laboratories (UL), Inc., or other nationally recognized approval agency directories, having a date prior to the issue date of these specifications. An approval stamp from a nationally recognized approval agency shall be present whenever standards have been established and label service is regularly furnished. Supply equipment and materials conforming to the requirements of the National Electrical Code (NEC), and the requirements of the CONTRACT DOCUMENTS. Particular attention shall be directed to NEC Articles 110-2 and 110-3 regarding equipment acceptability.

### 1.2 FIELD QUALITY CONTROL

Equipment and material shall be installed in accordance with Local, State, and Government laws and regulations governing electrical installations, the latest edition of the NEC, the National Electrical Safety Code (NESC), and the requirements of the CONTRACT DOCUMENTS. Energization of constructed electrical systems shall be contingent on final inspection and approval by the COGNIZANT ENGINEER along with AC Power, Quality Control, and Environmental Safety and Health (ES&H) Electrical Safety representatives. As-built single line diagrams and panel board circuit directories or red-lined marked up as-built prints shall be furnished prior to final inspection.

### 1.3 ELECTRICAL SAFETY

All work specified herein shall be performed within the requirements and guidelines of ES&HD-5008, Section 2.0 - Electrical Safety, and PPPL Policies and Interpretations regarding electrical equipment. The subcontractor's Safety Representative shall submit the subcontractor's safety procedure for the control of hazardous energy (Lockout / Tagout procedure) to the Manager of Environmental, Safety, and Health Division or his/her designee for review before the subcontractor connects to any PPPL-furnished temporary or permanent electric power. **PPPL policy, NFPA 70E and OSHA 29CFR1910.333(a)(1) requires ...Live parts to which an employee may be exposed shall be de-energized, verified safe and Locked / Tagout before an employee works on or near them. All circuits that require de-energizing shall be approved for de-energizing by the cognizant person for that work. All de-energization of major distribution equipment shall be coordinated through the PPPL AC Power Section.**

## 1.4 SUBSTITUTIONS

Substitute materials and methods meeting the stated specifications shall be submitted to the COGNIZANT ENGINEER for review and approval prior to their procurement or implementation. All materials must have been approved by a recognized approval agency (see 1.1 above).

## 1.5 ACCEPTANCE AND MAINTENANCE TESTING

Acceptance and/or maintenance tests designated by the COGNIZANT ENGINEER shall be performed by the subcontractor and the results documented prior to energization of the electrical work. International Electrical Testing Association publication NETA ATS-1992 outlines acceptance tests, and publication NETA MTS-2001 outlines maintenance tests.

## 2 GROUNDING

### 2.1 GENERAL

Ground electrical system neutrals and non-current-carrying parts of electrical equipment, mechanical equipment, and piping in conformance with the minimum requirements of Article 250 of the NEC, except where additional requirements are indicated on the DRAWINGS, or are specified in this SECTION.

### 2.2 MATERIAL USAGE

#### 2.2.1 Grounding Conductors

- A. General: Number of strands as specified on the DRAWINGS.
- B. Grounding Conductors for General Use Above and Below Grade: Bare.
- C. Grounding Conductors in Duct Banks: Bare.
- D. Grounding Conductors in Conduit with Circuit Phase Conductors: Bare or Insulated.
- E. Specialty Grounding Systems: If required, they will be specified in this SECTION.

#### 2.2.2 Grounding Connections

- A. Ground Connections in Earth or Inaccessible Locations: Exothermic welded or compression type.
- B. Grounding Connections to Structural Steel used for Main Building Framing and Connections to Building Perimeter Ground Bus Bars: Exothermic welded type or UL listed mechanical grounding system, except where indicated on the DRAWINGS. Designated ground system test points shall be bolted lugs.

- C. Grounding Connections to Fixed Equipment and Ground Plates: Lugs bolted to the equipment or plate. If unbolted, ground connections must be tagged per PPPL ESH-016 (Lockout/Tagout).

## 2.3 MATERIALS

### 2.3.1 Grounding Conductors

- A. Bare Grounding Conductors: Stranded annealed copper. Aluminum is not acceptable.
- B. Insulated Grounding Conductors: Stranded annealed copper, rated 75° C, 600 volts, and color coded green. Insulation shall be a heat- and moisture-resistant, cross-linked, synthetic polymer compound meeting UL requirements for Type XHHW, or a heat- and moisture-resistant thermoplastic insulating component meeting UL requirements for type THW. Conductors sized No. 6 AWG and smaller may be solid in lieu of stranded. The use of 600 volt welding cable as a grounding conductor is acceptable only when approved by the COGNIZANT ENGINEER.

### 2.3.2 Grounding Connections

- A. General: Grounding conductors shall be manufacturer listed and certified for the application.
- B. Exothermic Welding Connection Materials: As specified in Attachment 1, MANUFACTURERS or UL listed compression connections as specified in Attachment 1, MANUFACTURERS.
- C. Grounding Fittings for Connecting to Piping Systems: Conforming to UL 467 "Electrical Grounding and Bonding Equipment"
- D. Grounding Fittings for Bonding a Ground Conductor to the Metallic Conduit Enclosing It: As specified in Attachment 1, MANUFACTURERS.
- E. Liquid-tite Flexible Metal Conduit: As specified in Attachment 1, MANUFACTURERS.
- F. Grounding Fittings for Connection of Ground Conductor to Fencing: As specified in Attachment 1, MANUFACTURERS.
- G. Other Grounding Connectors and Lugs: Compression type as specified in SECTION 6.3.2.

## 2.4 INSTALLATION

- A. Install conductors of size required by Article 250 of the NEC, except where specified by the DRAWINGS. Conflicts between the NEC and DRAWINGS shall be brought to the immediate attention of the COGNIZANT ENGINEER. Ground structural steel building framing between the gage lines in the web of the column.

- B. Thoroughly clean all bonding surfaces of conducting materials. Where bolted connections are used for aluminum bus bars, treat surfaces immediately after cleaning with a corrosion-inhibiting compound before making a connection.
- C. Where grounding conductors are insulated for isolation purposes, thoroughly tape all exposed splices and connections.
- D. Where metallic conduit is used for mechanical protection of a ground conductor (required for conductors smaller than #6 AWG), **the grounding conductor shall be bonded to the conduit at both ends.** PVC rigid nonmetallic conduit may be substituted, and bonding omitted with the approval of the COGNIZANT ENGINEER.
- E. For electrical system service neutral grounding, do not use conductors smaller than No. 8 AWG.
- F. **Install insulated green color coded, or bare grounding conductors in each raceway containing power, lighting, or Class 1 non-power limited control circuits. Bond all metallic enclosures and raceways with grounding conductors and ground bushings.** The grounding conductors are to be sized in accordance with largest ampacity conductor in the raceway.
- G. Bonding of interior metal piping systems shall be performed in accordance with NEC Article 250-104, and the tables referenced therein.
- H. Grounding connections designed for attachment to portable temporary grounds shall be labeled for the purpose.

### 3 RACEWAYS AND BOXES

#### 3.1 MATERIAL USAGE

Temperature restrictions for metallic and nonmetallic raceways may reduce the allowable ampacities of the conductors inside. Refer to Table 3.1 for guidelines. For temperature restrictions applicable to plastic insulated bushings, refer to 3.2.2 G.

**TABLE 3.1 MAXIMUM AMPACITY OF CONDUCTORS IN CONDUIT**

Liquid-tite Flexible Conduit (Metallic & Nonmetallic)	UL Product Category DWWY	Limited to 60° C
Flexible, Intermediate, and Rigid Metal Conduit	UL Product Category DXUZ, DYBY, & DYIX	Limited by ambient conditions & number of current-carrying conductors
Rigid Nonmetallic Conduit	UL Product Category DZKT	Limited to 75° C indoors & 90° C outdoors or underground

#### 3.2 MATERIALS

##### 3.2.1 Conduit

- A. Rigid Steel Conduit, Elbows and Couplings: Conforming to ANSI C80.1, "Specification for Rigid Steel Conduit - Zinc Coated," and UL 6, "Rigid Metal Electrical Conduit." Galvanized, threaded steel.
- B. Rigid Aluminum Conduit, Elbows and Couplings: Conforming to UL 6, "Rigid Metal Electrical Conduit".
- C. Rigid Nonmetallic Conduit: Conforming to NEMA TC 2, "Electrical Plastic Tubing and Conduit," and UL 651 "Schedule 40 and 80 Rigid PVC Conduit." Rigid polyvinyl chloride, heavy wall, Schedule 40. PVC conduit shall be used only as indicated on the drawings when approved by the COGNIZANT ENGINEER.
- D. Flexible Steel Conduit: Conforming to UL 1, "Flexible Metal Electrical Conduit".
- E. Flexible Aluminum Conduit: Conforming to UL 1, "Flexible Metal Electrical Conduit".
- F. Liquid-tite Flexible Steel Conduit: Conforming to UL 360, "Liquid-Tight Flexible Steel Conduit," with a PVC jacket.
- G. Liquid-tite Flexible Aluminum Conduit: As specified in Attachment 1, MANUFACTURERS.
- H. Liquid-tite Flexible Nonmetallic Conduit: Conforming to UL 1660, "Liquid-Tight Flexible

Nonmetallic Conduit".

- I. Electrical Metallic Tubing (EMT): Conforming to UL 797, "Electrical Metallic Tubing," plated steel.

### 3.2.2 Conduit Fittings

- A. Fittings for Rigid Steel and Aluminum Conduit: Cast or malleable bodies, with taper threads, screw attached cover plates, and gaskets when located in areas requiring gaskets as specified in 3.3, INSTALLATION.
- B. Expansion Fittings for Rigid Steel and Aluminum Conduit: Cast or malleable bodies, with threaded end caps for receiving fixed and movable conduits, metallic pressure packing and copper bonding jumper assembly, and providing for a minimum of 2 inches movement of the conduit in either direction.
- C. Fittings for Rigid Nonmetallic Conduit: PVC conduit, Schedule 40 fitting, UL listed.
- D. Fittings for Flexible Steel and Aluminum Conduit: Secured to the conduit by clamping action around the periphery of the conduit. **Do not furnish fittings that anchor the conduit by means of set screws, use compression fittings only.** Fittings must be listed for use as a grounding means.
- E. Fittings for Terminating Liquid-tite Flexible Steel, Aluminum, and Nonmetallic Conduit: Designed to maintain the liquid-tight feature of the installation. If metallic, fittings must be listed for use as a grounding means.
- F. Fittings for EMT: Steel body, steel nut, with rust resistant coating. **Fittings to be the compression type** in outdoor and underground installations. **Do not use set screw couplings to connect lengths of EMT. Do not furnish fittings that anchor the conduit by means of set screws.**
- G. Bushings for 1 inch and Smaller Conduits: Insulating type of non-combustible thermosetting phenolic, conforming to UL Product Category DWTT for Conduit Fittings. Do not furnish non-rigid plastic bushings. Listed temperature ratings for inserts in bushings shall be equal to or exceed that of the conductors installed within. Insulation colored black or brown are rated for 150° C. All other color insulation are rated for 90° C, unless specifically marked.
- H. Bushings for 1-1/4 inch and Larger Conduits: With insulating insert of thermosetting plastic as specified for smaller conduit bushings, molded and locked into the bushing ring.
- I. Conduit Channel Systems and Straps: As specified in Attachment 1, MANUFACTURERS.

### 3.2.3 Outlet Boxes

- A. Sheet Metal Boxes: Aluminum or galvanized steel stock, not less than the thickness specified in NEC Article 314-40(b), with knockout openings, single or multiple gang, with extensions, adapters, plaster rings, tile covers, fixture studs, and cover plates. Furnish accessories with same gage and finish as specified for the boxes, except where special finishes are specified for covers and device plates in 7.1.6, Wiring Device Plates. Provide sizes conforming to NEC requirements for wiring space, except where minimum sizes are specified under 3.3, INSTALLATION.
- B. Cast or Malleable Boxes: Aluminum or galvanized steel, single or multiple gang, with taper threaded hubs, adapters and cover plates. Furnish accessories of the same material as specified for the boxes, except where special device plates or covers are specified in 7.1.6, Wiring Device Plates. Furnish gaskets when located in areas requiring gaskets as specified in 3.3, INSTALLATION. Provide sizes conforming to NEC requirements for wiring space, except where minimum sizes are specified under 3.3, INSTALLATION.

### 3.2.4 Pull and Junction Boxes

- A. Boxes Less Than 5 Inches by 5 Inches: Conform to 3.2.3, Outlet Boxes.
- B. Sheet Metal Boxes: Code gage, full seam welded with bent-in flanges, seam welded at corner joints, screw fastened cover of the same gage as the box. Provide sizes conforming to NEC requirements in Article 314 for wiring space, except where boxes of larger size are indicated on the DRAWINGS. Furnish gaskets when located in areas requiring gaskets as specified in 3.3, INSTALLATION. All sheet steel boxes are to be galvanized steel.
- C. Cast or Malleable Boxes: With threaded hubs or conduit bosses for field drilling and tapping, screw fastened cover. Provide sizes conforming to NEC requirements for wiring space, except where boxes of larger size are indicated on the DRAWINGS. Furnish gaskets when located in areas requiring gaskets as specified in 3.3, INSTALLATION.
- D. Fiber glass and polycarbonate boxes when specified on drawings. All boxes are to be constructed to comply with NEC article 314.
- E. PVC boxes may be used in special cases when listed on drawings for indoor use. PPPL Fire Protection Engineer must approve the location and quantity.

### 3.2.5 Wireways

- A. General: Metallic enclosures with hinged or screw fastened cover, bends, elbows, tees, crosses, adapters, and accessories as required, easily assembled into a complete system. Provide sizes conforming to NEC requirements for wiring space, except where larger sizes are indicated on the DRAWINGS. Furnish gaskets when located in areas requiring gaskets as specified in 3.3, INSTALLATION. Supports shall be provided at flanges only in accordance with manufacturer's recommendation.

## 3.3 INSTALLATION

### 3.3.1 Conduit Systems

- A. Install rigid metal conduit in general for all applications, except as otherwise specified or indicated on the DRAWINGS.
- B. Install 1/2 inch minimum size flexible conduit (3/8 inch with permission of the COGNIZANT ENGINEER), in lieu of rigid conduit for service to individual recessed fixtures, and other equipment subject to vibration or movement. Use liquid-tite, 60° C rated flexible conduit in lieu of non-jacketed flexible conduit in damp or wet locations, and for final connections to all motors in lengths not exceeding six feet. All flexible conduit must be supported at intervals of 4.5 feet and within 12 inches of boxes, cabinets, and conduit bodies.
- C. Install conduit systems as indicated on the DRAWINGS, as required by the NEC, and as specified. Install conduit sizes as indicated on the DRAWINGS. Where conduit sizes are not indicated, install sizes in conformance with NEC requirements. Do not use conduit sizes smaller than 1/2 inch unless otherwise specified.
- D. Install exposed conduit runs parallel or perpendicular to walls, structural members, or intersections of vertical planes and ceilings. Keep conduit at least six inches away from parallel runs of high temperature surfaces, such as steam or hot water pipes. Do not run conduit directly under cold water lines.
- E. Group conduit for common support where indicated and elsewhere as directed by the COGNIZANT ENGINEER. Provide 50% additional space for future conduits.
- F. Do not install crushed or deformed conduits. Avoid trapped runs in damp or wet locations. Prevent the entrance of water and the lodging of concrete, plaster, dirt, or trash in conduit, boxes, fittings, and equipment during construction. Conduit which is not free from obstructions must be replaced. Where conduit joints occur in concrete slabs, or in damp or wet locations, make joints watertight by applying an engineer-approved compound on the entire thread area before assembling. Draw up all conduit joints as tightly as possible. Cap exposed empty conduits that do not terminate in outlets, panels, cabinets, etc. with standard

galvanized plumber's pipe caps. Plug empty conduits that terminate flush with floors or walls with a flush coupling and slotted brass plug. **Direct burial of rigid steel conduit shall be coated with bituminous material when not encased in concrete.** Prior to drilling or digging a permit must be issued in accordance with ENG-024.

- G. Voids left where conduits and cables pass through walls, ceilings, or floors shall be filled with a fire seal listed by a nationally recognized approval agency. Raceways entering experimental areas require approval of a PPPL Fire/Penetration engineer. ENG-028 specifies the requirements for core drilling, boring and cutting of walls, floors and ceilings. Wall board shall only be drilled or cut to the thickness of the wall board.
- H. Conduits stubbing up at freestanding floor mounted equipment shall be terminated with a flush coupling and plug. After equipment has been placed, remove the plug and extend the rigid conduit to the equipment. Where approved for the purpose, flexible conduit may be substituted.
- I. Make changes in direction of runs with symmetrical bends, fittings or pull boxes. Use fittings, not bends around outside comers. Install elbows, bends and offsets having a minimum radius of curvature of 24 inches for 2 and 2-1/2 inch conduit, and 30 inches for 3 inch and larger conduit. Except where conduit runs are shown in exact detail on the DRAWINGS, install pull points at not greater than 200 foot intervals in straight runs. Do not use "C" conduits as pull points for power wiring; use wire ways or pull boxes. Control wiring may use "C" conduits. Where bends are included between pull points, reduce the 200 foot maximum separation between pull points by 50 feet for each 90 degree bend and 25 feet for each 45 degree bend. Calculate deductions for all other angle bends on a similar basis. When bends are made in the field, use an approved hickey or conduit bending machine. Except for concentric bends in conduit banks to maintain parallel runs, make bends in 1-1/4 inch and larger conduits with manufactured conduit elbows. Do not compromise the cable bending radii or maximum sidewall pressure.
- J. Provide conduit nipples with two independent sets of threads. Do not use running threads on any part of the conduit system. Nipples between adjacent sides of electrical enclosures shall be permitted to have running threads, providing double locknuts and bushings are installed at each enclosure. Where conditions require joining two fixed conduits into a continuous run, use a conduit union or Erickson coupling in place of running threads and coupling.
- K. Install expansion fittings where indicated on the DRAWINGS, and in exposed conduit runs crossing building expansion joints.

- L. Install double locknuts and bushings on all rigid conduit terminations onto threadless enclosure openings. Increase the length of conduit threads at terminations sufficiently to permit the bushing to be fully seated against the end of the conduit. Bonding required by NEC Article 250-97, shall be provided in raceways at box knockouts with bonding type locknuts or bushings.
- M. Use either clevis type hangers, or one hole pipe straps made of material similar to that of the conduit for support of single runs. Support groups of conduit on trapeze hangers allowing 50% spare space for future runs. Use threaded rod or an approved structural system for hanger supports. Perforated strap or wire shall not be used for conduit or hanger support. Use beam clamps of malleable iron or wrought steel with hook rods to grip the beam flange for conduit or hanger support. Do not use C-clamp type fittings. Supports for exposed conduit shall be spaced as specified in Chapter 3 of the NEC, unless otherwise noted on the DRAWINGS. All conduits (rigid and flexible) are to be supported within 3 feet of its termination.
- N. In damp and outdoor locations, breathers shall be installed at all high points in conduit runs. Drains shall be installed at all low points in conduit runs as well as in the bottoms of control enclosures .
- O. The cutting of conduits will normally be performed on the floor. All measurements and fit-ups shall be done prior to conduits being installed overhead where possible. Any conduit cuts not being made on the floor and being cut in place will require that the conduit being cut be marked and that a second person verifies that the right conduit has been identified for cutting. Safety glasses with shields shall be required at all times when working and cutting materials overhead. The proper PPE shall be identified in the JHA (Job Hazard Analysis) prior to start of work.

### 3.3.2 Outlet, Pull, and Junction Boxes

- A. Outlet Boxes for Use with Rigid Steel Conduit in Non-hazardous Areas: Sheet steel for flush or concealed work in dry locations; cast or malleable iron in exposed, damp, or wet locations.
- B. Flush Mounted Boxes: For single outlets, use boxes not less than 4 inches square and 2-1/8 inches deep. For multiple outlets, use gang type boxes not less than 2-1/4 inches deep. Furnish plaster rings not less than 1-1/8 inches deep. For ceiling outlets in concrete slabs, use boxes not less than 3 inches deep.
- C. Gaskets: Provide cover gaskets for boxes in damp or wet locations and in fabrication areas of PPPL shops.

- D. Pull and Junction Boxes for Use with each Type of Conduit: As specified for outlet boxes for each conduit type under above paragraphs.
- E. Install boxes in the wiring or raceway systems as required for pulling of wires, making connections, and mounting devices and fixtures.
- F. Install extension rings, adapters, raised covers, and plaster rings on flush-mounted boxes as required. Install flush-mounted boxes in masonry block or tile walls with tile covers.
- G. Install separate concealed boxes for semi-flush or recessed fixtures when required by the fixture terminal operating temperature. Make boxes readily accessible on removal of the fixture, or provide ceiling access panels as approved by the COGNIZANT ENGINEER.
- H. Locate outlets in offices and other areas with due regard for the finish and interior architectural treatment. Outlets are to be centered with respect to panels, joints, or moldings, and so that plaster rings, frames, and tile covers are properly located on the finished surface.
- I. Support boxes independent of the conduit, and secure them rigidly in place. Install boxes used for fixture support such that they are capable of carrying 100 pounds. Ensure that plaster rings, frames, and tile covers are properly located with respect to the finished surface.
- J. In concrete, anchor boxes securely to the reinforcing steel and forms to prevent shifting when the concrete is placed. Ensure that plaster rings, frames, and tile covers are properly located with respect to the finished surface.
- K. Above suspended ceilings, boxes shall be supported independently from the ceiling and fastened to the ceiling support system by bar hanger or other engineer approved support.
- L. In Experimental Areas, where designated on the DRAWINGS, or where specified by the COGNIZANT ENGINEER, aluminum boxes must be used.
- M. All boxes containing electrical systems operating at over 600 volts shall be labeled with a "DANGER - HIGH VOLTAGE - KEEP OUT" safety sign.

## 4 DISTRIBUTION EQUIPMENT

### 4.1 MATERIALS

#### 4.1.1 Distribution Switchboards

- A. General: Dead front, sectionalized, free standing, NEMA 1, front accessible, conforming to NEMA PB 2 "Dead front Distribution Switchboards", and UL 891 "Dead-Front Switchboards." Rated 480/277 volts, 3 phase/4 wire, 60 Hz. Consisting of an incoming line section with main breaker, feeder breakers, and spaces with arrangement and connections as indicated on the DRAWINGS.
- B. Supporting Structure: Rigid assembly of steel sheets, reinforced with structural members welded and bolted together. Arrangement to allow for front access of equipment and connections, with all sections of a common depth. Individual equipment to be enclosed in separate compartments lined with arc-resisting barriers where applicable, and sealed to prevent the flow of ionized gas into adjacent compartments. Provide hinged doors for access, and ventilation louvers where required to limit temperature rise. Mount the structure on a steel base suitable for use on a concrete floor. Galvanize, prime, and finish paint in the manufacturer's standard finish.
- C. Busses: Tin plated aluminum or copper bar, with the main bus continuous current rating equal to the current rating of the main disconnecting device. Provide a full size insulated neutral bus, arranged for connection of incoming and outgoing neutral wiring. Provide a ground bus the full length of the switchboard for grounding the equipment and structural frame. Furnish the incoming line bus arrangement for connection of wiring entering from above or below as indicated on the DRAWINGS.
- D. Main Breaker: Stationary, integrally fused, molded case circuit breaker. AC rated, 3 pole quick-make, quick-break, with a trip-free operating handle, position indication, and common trip from interchangeable thermal magnetic trip device.
- E. Feeder Devices: Circuit breaker type, panel mounted, consisting of AC rated, 3 pole quick-make, quick-break, with a trip-free operating handle, position indication, and common trip from thermal magnetic trip device. Provide sheet metal covers over the individual breakers with openings for the operating handle with means for locking it in the "OFF" position.
- F. Spaces: Equip panel boards with bus and minimum hardware when future circuit breakers designated as "SPACE" are noted on the DRAWINGS. Furnish a blank removable spacer plate to cover the opening.
- G. Circuit Directory: Heavy plastic covered metal frame card holder and card on individual breaker covers.

H. Lugs for Mains: Compression type as specified in SECTION 6.3.2.

#### 4.1.2 Panel boards for Power, Lighting, and Receptacle Distribution

- A. General: Dead front type, conforming to NEMA PB 1 "Panel boards", and UL 67 "Electric Panel boards." Consisting of a 3 phase/3 wire or 3 phase/4 wire, solid neutral main bus, with main lugs or main circuit breaker, and branch circuit breakers, in a surface or column mounted steel cabinet. Provide a ground bus drilled for the connection of incoming and branch circuit ground conductors.
- B. Ratings: As indicated on the DRAWINGS.
- C. Circuit Breakers: Bolt-in, molded plastic case type. AC rated, single or multi-pole, quick-make, quick-break, with a trip-free operating handle, position indication, and common trip from thermal magnetic trip device.
- D. Enclosures: NEMA 1, with trim covering wiring gutters only. Provide sheet metal covers over the individual breakers with openings for the operating handle with means for locking it in the "OFF" position. Galvanize, prime, and finish paint in the manufacturer's standard finish.
- E. Spaces: Equip panel boards with bus and minimum hardware when future circuit breakers designated as "SPACE" are noted on the DRAWINGS. Furnish a blank removable spacer plate to cover the opening.
- F. Circuit Directory: Heavy plastic covered metal frame card holder and card on individual breaker covers, or inside of front door as required.
- G. Lugs for Mains: Compression type as specified in SECTION 6.3.2.

#### 4.1.3 Panel boards for 125 Volt DC Service

- A. General: Dead front type, conforming to NEMA PB 1 "Panel boards", and UL 67 "Electric Panel boards." Consisting of a 2 wire main bus with main fusible switch or circuit breaker, and branch fusible switches or circuit breakers, in a surface mounted steel cabinet.
- B. Ratings: As indicated on the DRAWINGS.
- C. Fusible Switches and Circuit Breakers: DC rated, 2 pole, fuse clips to be silver or cadmium plated. Furnish an external operating handle positively interlocked so that the cover door cannot be opened unless the switch is in the "OFF" position.
- D. Enclosures: NEMA 1, trim covering wiring gutters only. Provide a hinged door with flush latch and cylinder lock. Key all locks to the existing system. Galvanize, prime, and finish paint in the manufacturer's standard finish.

- E. Spaces: Equip panel boards with bus and minimum hardware when future circuit breakers designated as "SPACE" are noted on the DRAWINGS. Furnish a blank removable spacer plate to cover the opening.
- F. Circuit Directory: Heavy plastic covered metal frame card holder and card on individual compartments.
- G. Lugs for Mains: Compression type as specified in SECTION 6.3.2.

#### 4.1.4 Distribution Transformers for Indoor Dry Locations

- A. General: Metal enclosed, ventilated, indoor, dry, single or polyphase copper winding, having average sound levels not to exceed NEMA and ANSI standards. Conforms to NEMA Standard ST 20 for Dry-type Transformers for General Applications, having voltage, KVA and connections as indicated on the DRAWINGS. Transformer leads shall be located in a terminal compartment below the core and coil assembly. The compartment shall provide provisions for connection of conduit, 90° C insulated primary and secondary terminations, and both grounding electrode conductor and grounded conductor.

## 4.2 INSTALLATION

### 4.2.1 General

- A. Assemble and anchor the switchboards.
- B. Mount panel boards at uniform heights throughout buildings as indicated on the DRAWINGS, such that the distance from the floor to the center of the top switch or circuit breaker does not exceed 72 inches. Install handle locking provisions on all breakers. Do not install under foreign systems(water pipes, steam lines, etc.)where possible. See NEC article 110.26 for clearance requirements.

### 4.2.2 Equipment Supports

- A. Mount non-self supporting electrical equipment securely with a minimum of 1/4 inch separation to walls, columns, and machine frames. Provide spacers, brackets, structural pieces, inserts, anchors, and bolts for this purpose.
- B. Provide supports for truss-mounted and wall mounted transformers.
- C. Anchor self supporting equipment to floors and to supporting steel where supports are indicated or required. Provide structural channels in concrete floors for support and leveling where indicated or required.

### 4.2.3 Transformer Grounding

- A. General: Transformer core and case shall be bonded to the primary and secondary equipment grounding conductors. This does not apply to isolation transformers.
- B. Isolation transformers must be grounded per drawings. ES-ELEC-001 specifies the minimum isolation requirements for grounding electronic racks. Transformer BIL may require special limits as specified by the cognizant engineer.

## 5 MOTOR CONTROL

### 5.1 MATERIALS

#### 5.1.1 480 Volt Motor Control Centers

- A. General: Conforming to NEMA Standard ICS 1 "General Standards for Industrial Control and Systems." Consisting of an incoming line compartment, circuit breaker type combination starters, fusible feeder switches, and circuit breakers. All equipment shall be mounted in a NEMA 1, fully sectionalized, free-standing, dead front enclosure, with all equipment and wiring accessible from the front. Designated unused spaces shall be fully equipped to receive future units. Standard NEMA ground lug connections shall be provided at opposite ends of the completed structure.

#### 5.1.2 Single Phase Manual Motor Starters - Fractional Horsepower Type

- A. General: Conforming to NEMA Standard ICS 1 "General Standards for Industrial Control and Systems." Consisting of a toggle-operated or key operated, single-pole, quick-make, quick-break type starter, with single thermal overload element and pilot light in the cover as indicated on the DRAWINGS. Mounted in a NEMA 1 surface mounted enclosure or flush mounted in an outlet box. Provide a means for padlocking the operator in the "OFF" position. Provide a total of four keys for key-operated starters.

#### 5.1.3 Control Devices

- A. Pushbuttons and Selector Switches: Heavy duty, oil-tight type, with contacts rated at 10 amperes continuous at 600 volts AC. Legend plate and operation as indicated on the DRAWINGS.
- B. Indicating Lights: Heavy duty, oil-tight type, with integral 120-6 volt transformer and 6 volt lamp, push-to-test feature. Legend plate and color cap as indicated on the DRAWINGS.
- C. Control Relays: Heavy duty, industrial-type, with convertible contacts rated 10 amperes continuous at 600 volts AC. They shall have sufficient thermal capacity to withstand continuous energization at 110% of rated voltage, and shall not malfunction if the voltage

drops to 85% for one minute. Provide 120 volt AC coils unless otherwise indicated on the DRAWINGS. Provide number and type of contacts as indicated on the DRAWINGS.

- D. Timing Relays: Electronic or pneumatically controlled, with contacts rated at 10 amperes continuous at 600 volts AC. Provide 120 volt AC coils unless otherwise indicated on the DRAWINGS.
- E. Control Enclosures: Shall meet the requirements of NFPA 79 - "Electrical Standard for Industrial Machinery." Code gage, galvanized sheet steel, with dimensions as indicated on the DRAWINGS. A grounding terminal shall be provided for field installed equipment grounding conductors.
- F. Terminal Blocks: Rail or surface mounted barrier type, complete with screw terminal, wire clamp, and white marking strip, rated a minimum of 25 amps, 600 volts. Each terminal point shall be marked with the designations indicated on the DRAWINGS. Each panel terminal board shall have not less than 12 points. Two points out of each 12 shall be spares. Wiring internal to the equipment shall be connected to one side of the terminal board, external connections to the other. Hot and neutral connections shall not be located on adjacent terminals.

#### 5.1.4 Safety Switches

- A. General: Quick-make, quick-break, heavy duty, visible blade type, NEMA 1 enclosure, fusible or non-fusible as indicated on the DRAWINGS. Furnish 3 pole, single throw switches, with silver or cadmium plated contacts and clips, and voltage and current ratings as indicated on the DRAWINGS.
- B. Interlocking: Equip switches with an external operating handle interlocked with the cover door so that the door cannot be opened unless the switch is in the "OFF" position. Provide a cover sealing mechanism, a release, and a means for padlocking the operator in the "OFF" position. Equip switches with auxiliary contacts when indicated on the DRAWINGS.
- C. Fuse Clips: Standard type for dual-element cartridge fuses unless otherwise indicated on the DRAWINGS.

#### 5.1.5 Fuses

- A. General: One-time, high-interrupting capacity, dual-element or current-limiting type as specified on the DRAWINGS.

## 5.2 INSTALLATION

### 5.2.1 Motors

- A. Motors 1/2 horsepower and larger used for process systems such as cooling water and lube oil supplies are to be 480 Volt, 3 Phase, 60 Hz. Motors less than 1/2 horsepower are to be 120 Volt, 1 Phase, 60 Hz, unless other requirements are indicated on the DRAWINGS.

### 5.2.2 Control Equipment

- A. Control equipment shall be installed at locations as indicated on the DRAWINGS. In general, install motor starters, safety switches, and control devices, with associated operating means at uniform heights as indicated on the DRAWINGS. Operating means are not to be located at heights greater than 6 1/2 feet above the operating floor or platform.

## 6 WIRE AND CABLE

### 6.1 GENERAL

- A. Wire and Cable: Listed and labeled by UL or other nationally recognized approval agencies as meeting NEC requirements. Conductors and cables should be marked in accordance with NEC Article 310-11.
- B. Furnish wire and cable on which standard factory tests established by ASTM, ANSI, ICEA and NEMA have been performed. Provide those field acceptance tests specified by the COGNIZANT ENGINEER or as recommended by the International Electrical Testing Association in their specification, "Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems," or both.

### 6.2 WIRE AND CABLE DELIVERY

Deliver wire and cable to the site on reels or in coils that are plainly marked for complete identification, including the wire or cable size; the number of conductors; the type of wire or cable; the length, weight, thickness and character of the insulation; and the name of the manufacturer.

### 6.3 MATERIALS

#### 6.3.1 Wire and Cable

- A. General: Furnish wire and cable meeting the standard specification established for both material and construction by ASTM, ANSI, ICEA, and NEMA, where applicable. The ICEA/NEMA type letters of the wire and cable shown below have not been investigated for use in ionizing radiation environments. Foot markers shall be factory hot stamped on all

multi-conductor cables. Furnish coated-copper conductors unless otherwise specified. Minimum size of No. 12 AWG, except for control conductors, which may be No. 14 AWG. Smaller gauges may be used with permission of the COGNIZANT ENGINEER for fire systems, security systems, and other special applications. Furnish conductor sizes and stranding as indicated on the DRAWINGS. Unless otherwise specified, furnish wire and cable as specified in Attachment 1, MANUFACTURERS.

- B. Wire for Final Connection in Conduit to Incandescent Fixtures, HID Fixtures with Remote Ballast, and Remote Ballasts: Stranded copper, Teflon Type E, or Silicone Type SF-2 rated 200° C, 600 volts.
- C. Wire for Use Within 3 Inches of a Ballast in Fluorescent Fixture Continuous Wiring Channels: Stranded copper, ICEA/NEMA type XHHW or THHN/THWN-2 rated 90° C minimum in dry locations, 600 volts.
- D. Wire for Exposed Cord Connection to Integrally Ballasted HID Fixtures: Three conductor portable cord consisting of three stranded annealed copper conductors, individually insulated with not less than 30 mils of heat- and moisture-resistant ethylene propylene rubber compound (EPR) rated 90° C, 600 volts, cabled round with fillers and binder tape, and covered with an overall neoprene or similar jacket not less than 60 mils thick.
- E. Wire for General Interior and Exterior Use Within Raceways: Single conductor, annealed copper, ICEA/NEMA type XHHW or THHN/THWN-2 rated minimum 90° C in dry and damp locations, and 75° C in wet locations, 600 volts.
- F. Wire for Underground Service Entrance: Single conductor, annealed copper, ICEA/NEMA type USE rated 75° C, 600 volts.
- G. Wire for Use in Underground Duct or Conduit: Single or multi-conductor, as indicated on the DRAWINGS, ICEA/NEMA type USE or UF rated 75° C, 600 volts.
- H. Wire for Direct Burial: Single or multi-conductor, as indicated on the DRAWINGS, ICEA/NEMA type USE or UF rated 75° C, 600 volts.
- I. Multi-Conductor Control Cable for Installation in Conduit and Cable Trays: Meeting NEC Article 336 requirements, UL recognized for the use, size and number of conductors as indicated on the DRAWINGS, stranded copper conductors, insulated and jacketed with thermoplastic rubber or PVC, rated 90° C dry, 600 volts, color-coded in conformance with ICEA S61-402 - Appendix A.
- J. Multi-Conductor Control, Signal, and Instrumentation Cables Installed in Under-floor Spaces of Electronic Computer/Data Processing Rooms: Meeting NEC Article 390, 374, and 372 requirements, shall be listed for the purpose.

- K. Wire for Use in Areas Indicated as High Temperature Areas on the DRAWINGS: Single conductor annealed copper, ICEA/NEMA type SA, rated 125° C, 600 volts or as specified on drawings.
- L. Multi-Conductor Fiber optic Cable for Installation in Conduit or Cable Tray: Number of fibers as specified on the DRAWINGS, 100 micron core, 140 micron cladding with fillers and binder, Polyurethane or PVC outer jacket.
- M. Power limited communications and signal cable, 300 volt rated, type CL3R and CMR. See NEC article 725 for specifications.

### 6.3.2 Lugs

- A. Lugs for Terminating Power Conductors up to and including No. 8 AWG: Where required, use pre-insulated, solderless, compression type, manufacturer's standard unless otherwise specified. Wire nuts shall be permitted on lighting and receptacle circuits, not on machines or in equipment.
- B. Lugs for Terminating Power Conductors No. 6 AWG and Larger: Where required, use solderless compression type, one hole for No. 6 AWG through No. 4/0 AWG. NEMA standard two hole for larger sizes.
- C. Connectors for Splicing Conductors up to and including No. 8 AWG: Solderless, two piece, having a metallic crimp type connector with a plastic insulating cover, rated 105° C, 600 volts.
- D. Connectors for Splicing Conductors No. 6 AWG and Larger: Solderless, compression, 2-way type.
- E. Connectors for 3-way Splicing Conductors No. 6 AWG and Larger: Solderless compression type.

### 6.3.3 Wire Labels

- A. Wire Labels for Identification of Conductors: As specified in Attachment 1, MANUFACTURERS.

### 6.3.4 Insulating Tape

- A. General Use Tape: Vinyl, 105° C: As specified in Attachment 1, MANUFACTURERS.
- B. High Temperature Area Tape: Glass cloth, 130° C: As specified in Attachment 1, MANUFACTURERS.

## 6.4 INSTALLATION

### 6.4.1 General

- A. Install wiring in raceway systems, as specified and as indicated on the DRAWINGS. Install wiring only in completed raceway systems, and when systems are protected from the weather. Install conductors without splices between equipment. Where splices are required in power, control, or instrument circuits, make the splices in junction boxes. Do not use conduit fittings for splicing, except when permitted in cable trays by NEC Article 392-8. Only lighting and receptacle branch circuits not installed on machines or within equipment may be spliced using listed connectors in conduit fittings.
- B. **The use of a single grounded conductor(Neutral) for multiple circuits is prohibited.** A separate grounded conductor(Neutral) must be run for each set of phase conductors.
- C. The use of a single grounding conductor is permitted in a single raceway having multiple phase conductors when sized per NEC Table 250-122. Install phase, grounded, and grounding conductors of each branch or feeder circuit in raceways or trays per NEC Articles 250-66 and 300-20. Install conductors in parallel per NEC Article 310-4. Emergency lighting shall be routed in dedicated raceways and installed in conformance with NEC Article 700-12.
- D. Prior to pulling cables in conduit, clean all internal surfaces until cleaning swab is pulled out clean. While pulling cable into conduit, continuously lubricate all non-armored cables. Install cable by pull-in eye or basket grip using an approved compound compatible with the conductor insulation or jacket.
- E. Install conductors in such a manner that the bending radius under tension of any single conductor wire or cable is not less than the minimum recommended by ICEA and/or the manufacturer. Do not exceed the manufacturer's recommended values for maximum pulling tension or sidewall pressure applied to any conductor or cable. When installing cables of different size in one pull, do not exceed the maximum tension or sidewall pressure of the smallest conductor in the group. Center-pulling as outlined in Paragraph G of this SECTION is the recommended method for conductor installation.
- F. Do not pull fiber optic cable with metallic conductors or cables. Center-pulling of fiber optic cable, as outlined in Paragraph G of this SECTION, is recommended unless the cable run is very short and the cable cannot be laid in a cable tray.
- G. Implement center-pulling as follows: From the midpoint of the run, pull the cable into the conduit or tray from the shipping reel in the usual fashion. When this portion of the pull is complete, the remainder of the cable must be removed from the reel and the other end made

available for pulling in the opposite direction. This is done by hand-pulling the cable from the reel and laying it in large "figure-8" loops. The purpose of the "figure-8" pattern is to avoid cable tangling and kinking. Be certain that the loops are laid carefully one upon the other to prevent subsequent tangling, and are in a protected area to prevent damage by machinery, traffic, etc. The other end of the cable is then available for installation.

This technique minimizes the amount of cable tension and reduces hardware and manpower requirements. In some cases, it necessary to setup a winch at an intermediate pull point. The required length of cable is pulled to that point out of the raceway, and coiled into a "figure 8". The "figure 8" is then flipped to gain access to the free cable end, which can then be reinserted into the duct system.

- H. Connect all power wiring to equipment so that phasing will be A-B-C three phase, left to right, top to bottom, and front to back, when facing the front of the equipment. Permanently identify phasing on the structure or housing adjacent to the bus. Phase identification A-B-C is equivalent to transformer phase identification X1-X2-X3, and H1-H2-H3. Locations to be grounded during maintenance shall be identified.
- I. Connect and identify phase wiring to all three phase receptacles to insure the same phase rotation in all receptacles with interchangeable plugs.

#### 6.4.2 Splices and Terminations

- A. Thoroughly clean wire ends before connectors or lugs are applied.
- B. Splice and terminate conductors with connectors and lugs as specified for the size and type of conductor. Do not splice armored cable except where cable lengths are limited by reel capacity.
- C. Insulate all bare surfaces of conductors with a minimum of four layers (half lap in two directions) of electrical insulating tape. On larger splices and terminals, build up connection with electrical insulating putty before applying tape, to eliminate both sharp edges and voids. Heat or cold shrink tubing may be used with prior approval of the COGNIZANT ENGINEER.
- D. Perform a final phase check verification after terminations are completed.

## 7 WIRING AND CONTROL DEVICES

### 7.1 MATERIALS

#### 7.1.1 Local Lighting Switches

- A. Switches shall be specification grade AC quiet type, 20-amperes, 120-277 volts. Switches shall be designed for side or back wiring for up to No. 10 wire, with back clamp type terminals and two back wiring holes with screw-type clamping for feed-thru wiring and screw-type terminals for side wiring. Toggles shall be nylon construction. Switches shall have rivetless one piece copper-alloy contact arm and neoprene rocker with coil compression spring. Use single pole, double pole, three-way, four-way, pilot, or keyed type, as shown on the DRAWINGS.

#### 7.1.2 Grounded Receptacles, Plugs, & Connectors - Straight Blade

- A. Straight Blade Grounded Duplex Receptacles shall be specification grade, 2-pole, 3-wire grounding, with green hex head grounding screw, ground terminals and poles internally connected to mounting yoke, 20 amperes, 125 volts, NEMA 5-20, with metal plaster ears, back- and side-wiring with screw-type clamping, eight large back wiring pockets, #10 binding head terminal screws, one piece grounding system, one piece triple-wipe line contacts and nylon face, hospital grade.
- B. Straight Blade Grounded Single Receptacles shall be as follows:
- 2-pole, 3-wire, 20-amperes, 125 volts, NEMA 5-20
  - 2-pole, 3-wire, 30-ampere, 125 volts, NEMA 5-30
  - 2-pole, 3-wire, 50-ampere, 125 volts, NEMA 5-50
- C. Straight Blade Ground Fault (GFCI) Receptacles shall be heavy duty, duplex receptacles, ground-fault circuit interrupters, feed-thru type, capable of protecting connected downstream receptacles on single circuit, grounding type UL listed Class A, with solid-state ground fault sensing and signaling; 20-amperes, 125 volts, NEMA 5-20R. All grounding receptacles shall be tested for grounding and operation with a Hubbell GFT-2G or other suitable tester.
- D. Straight Blade Grounded Plugs shall be as follows:
- 2-pole, 3-wire, 20-amperes, 125 volts, NEMA 5-20
  - 2-pole, 3-wire, 30-ampere, 125 volts, NEMA 5-30
  - 2-pole, 3-wire, 50-ampere, 125 volts, NEMA 5-50

E. Straight Blade Grounded Connectors shall be as follows:

2-pole, 3-wire, 20-ampere, 125 volts, NEMA 5-20.

### 7.1.3 Grounded Receptacles, Plugs & Connectors - Locking

A. Locking Grounded Receptacles shall be as follows:

2-pole, 3-wire, 20-amperes, 125 volts, NEMA L5-20, single flush receptacle, melamine.

2-pole, 3-wire, 30-amperes, 125 volts, NEMA L5-30, single flush receptacle, melamine.

3-pole, 4-wire, 20-amperes, 125/250 volts, NEMA L14-20, melamine.

3-pole, 4-wire, 30-amperes, 125/250 volts, NEMA L14-30, melamine.

3-pole, 4-wire, 50-amperes, 125/250 volts, California Standard.

4-pole, 4-wire, 30-amperes, 480 volts, watertight with flap cover.

4-pole, 4-wire, 60-amperes, 480 volts, watertight with flap cover.

B. Locking Grounded Plugs shall be as follows:

2-pole, 3-wire, 20-amperes, 125 volts, NEMA L5-20, nylon.

2-pole, 3-wire, 30-amperes, 125 volts, NEMA L5-30, nylon.

3-pole, 4-wire, 20-amperes, 125/250 volts, NEMA L14-20, nylon.

3-pole, 4-wire, 30-amperes, 125/250 volts, NEMA L14-30, nylon.

3-pole, 4-wire, 50-amperes, 125/250 volts, California Standard, impact resistant nylon, nonmetallic cord grip.

C. Locking Grounded Connectors shall be as follows:

2-pole, 3-wire, 20-amperes, 125 volts, NEMA L5-20, white nylon.

2-pole, 3-wire, 30-amperes, 125 volts, NEMA L5-30, white nylon.

3-pole, 4-wire, 20-amperes, 125/250 volts, NEMA L14-20, white nylon.

3-pole, 4-wire, 30-amperes, 125/250 volts, NEMA L14-30, white nylon.

3-pole, 4-wire, 50-amperes, 125/250 volts, California Standard, impact resistant nylon, nonmetallic cord grip.

#### 7.1.4 Isolated Ground Receptacles

- A: Material Usage: Isolated ground receptacles shall be used for sensitive electronic equipment such as Programmable Logic Controllers (PLC's), computers and highly sensitive diagnostic and communications equipment.
- B. Straight Blade Isolated Ground Receptacles shall be as follows:
- 2-pole, 3-wire, 20-amperes, 125 volts, NEMA 5-20R, back and side wired.
  - 2-pole, 3-wire, 30-amperes, 125 volts, NEMA 5-30R, single, flush, back-wired, urea.
  - 2-pole, 3-wire, 50-amperes, 125 volts, NEMA 5-50R, single, flush, back-wired, urea.
- C. Locking Isolated Ground Receptacles shall be as follows:
- 2-pole, 3-wire, 20-amperes, 125 volts, NEMA L5-20, back-wired, clamp type terminals, urea.
  - 2-pole, 3-wire, 30-amperes, 125 volts, NEMA L5-30.
  - 3-pole, 4-wire, 20-amperes, 125/250 volts, NEMA L14-20.
  - 3-pole, 4-wire, 30-amperes, 125/250 volts, NEMA L14-30.

#### 7.1.5 Special Wiring Devices

- A. Straight Blade, 2-Pole, 3-Wire, 20-ampere, 250 volt, Grounding Receptacles shall be NEMA 6-20, back-and side-wired, one-piece grounding system, nylon face, one-piece triple-wipe brass lined contacts.
- B. Straight Blade, 3-Pole, 4-Wire, 125/250 Volts, Grounding Angle Plugs and Receptacles shall be flush black urea with matching nylon angle plugs as follows:
- 30-Amperes, NEMA 14-30.
  - 50-Amperes, NEMA 14-50.
  - 60-Amperes, NEMA 14-60.
- C. Locking, 2-Pole, 3-Wire, 250 Volt, Grounding Plugs and Receptacles shall be black melamine, individual wire pockets, back-wired with color-coded clamp type terminals, and matching plug as follows:
- 15-Amperes, NEMA L6-15.
  - 20-Amperes, NEMA L6-20.
  - 30-Amperes, NEMA L6-30.

D. Locking, 3-Pole, 4-Wire, 250 Volt, 3 phase, Grounding Plugs and Receptacles shall be black melamine, individual wire pockets, back-wired with color-coded clamp type terminals, and matching plug as follows:

20-Amperes, NEMA L15-20.

### 7.1.6 Wiring Device Plates

Wall plates shall be stainless steel, high corrosion-resistant combination 18% chromium - 8% nickel, .032 inches thick, satin finish, anti-magnetic. Aluminum or plastic plates may be used where applicable.

## 8 MISCELLANEOUS

### 8.1 PORTABLE CORDS AND HAND LAMPS

Listed, preassembled portable hand lamps may be used while performing a task lasting less than eight calendar days if:

- it is GFCI protected.
- it is connected to a premises receptacle, either directly or through extension cord sets of any length. Daisy chaining of extension cords is not permitted. Extension cords and power cords of temporarily installed must not be run through any type of pinch points (doorways, etc.) and may not cause a trip hazard.
- the hand lamp only supplements the permanent area or task lighting.

- A. Portable 120 Volt Hand lamp Without Receptacle: As specified in Attachment 1, MANUFACTURERS.
- B. Portable 120 Volt Hand lamp With Single Polarized, Grounded Receptacle: As specified in Attachment 1, MANUFACTURERS.

### 8.2 PROTECTIVE SHIELDS FOR LAMPS

- A. General: All lamps used for general illumination that are not guarded by an elevation of 8 feet (per NEC Article 110-27), nor protected by a suitable fixture guard shall be of a shatterproof, plastic-coated design.

### 8.3 LOCKOUT / TAGOUT

Newly Installed disconnects, panel boards, and circuit breakers are to include provisions for padlocks to lock-out the devices. ES&H approved procedures for Lockout/Tagout per PPPL ESH-016 are to be followed during installation. All new installed circuits are to be locked and tagged out until inspected and approved for energization by Electrical Safety, AC Power and Quality Control representatives.

## **9 ES&H CONSIDERATIONS**

### **9.1 UNACCEPTABLE MATERIALS AND PROCESSES**

Materials and chemicals which are environmentally unacceptable are: lead, asbestos, benzene, carbon tetrachloride, polychlorinated biphenyls (PCB), carbon disulfide, and hydrofluoric acid. All chemicals must have an MSDS sheet and be approved for use at PPPL by the Industrial Hygienist (ext.2533) along with a Job Hazard Analysis (JHA).

#### **Attachments**

Attachment 1 "MANUFACTURES SUGGESTED EQUIPMENT

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<b>MANUFACTURES SUGGESTED EQUIPMENT</b>		<b>Attachment 1</b>	

## **Attachment 1**

### **Introduction**

This Attachment specifies suggested trade names, brand names, and catalog numbers used herein to establish standards of performance and quality for the ELECTRICAL CONSTRUCTION SPECIFICATION FOR INSTALLATIONS OPERATED AT 600 VOLTS AND BELOW. Substitute materials and methods meeting the stated specifications shall be either listed by an approved testing agency or submitted to the COGNIZANT ENGINEER for review and approval prior to their procurement or implementation. The intent of this attachment suggests manufacturers to establish standardization of materials used at the Princeton Plasma Physics Laboratory.

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## **2 GROUNDING**

### **2.5 MANUFACTURERS**

#### **2.5.2 Grounding Connections**

- B. Exothermic Welding Connection Materials: Erico/Cadweld.
- C. Grounding Fittings for Connecting to Piping Systems: Burndy GD or GG, Teledyne Penn-Union Type GU or GO.
- D. Grounding Fittings for Bonding a Ground Conductor to its own Rigid Conduit: O-Z/Gedney BLG series, Thomas & Betts 3870 series.
- E. Liquid-tite Flexible Metal Conduit: O-Z/Gedney 4Q series, Thomas & Betts 5331GR series, or suitable grounding fitting for the specified brand.
- F. Grounding Fittings for Connection of Ground Conductor to Fencing: Burndy GD or GG, Teledyne Penn-Union GU or GO.

## **3 RACEWAYS AND BOXES**

### **3.4 MANUFACTURERS**

#### **3.4.1 Conduit**

- A. Rigid Steel Conduit, Elbows and Couplings: Allied, Pittsburgh, Triangle.
- B. Rigid Aluminum Conduit, Elbows and Couplings: Alumax, Pittsburgh, Reynolds.
- C. Rigid Nonmetallic Conduit: Adalet, Hubbell, National.
- D. Flexible Steel Conduit: Anamet (Anaconda), Electri-Flex, Steelflex.
- E. Flexible Aluminum Conduit: Anamet (Anaconda), Electri-Flex.
- F. Liquid-tite Flexible Steel Conduit: Anamet (Anaconda) "Sealtite," Electri-Flex "Liquatite," Thomas & Betts.
- G. Liquid-tite Flexible Aluminum Conduit: Electri-Flex "Liquatite".
- H. Liquid-tite Flexible Nonmetallic Conduit: Anamet (Anaconda) "Sealtite", Electri-Flex "Liquad-tite" & "Corrllok," Hubbell (Kellems) "PolyTuff".
- I. Electrical Metallic Tubing (EMT): Allied, Pittsburgh, Triangle.

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### 3.4.2 Conduit Fittings

- A. Fittings for Rigid Steel and Aluminum Conduit: Appleton, Crouse-Hinds, Pyle-National.
- B. Expansion Fittings for Rigid Steel and Aluminum Conduit: Appleton, Crouse-Hinds, O-Z/Gedney.
- C. Fittings for Rigid Nonmetallic Conduit: Adalet, Hubbel, Pyle-National.
- D. Fittings for Flexible Steel and Aluminum Conduit: Anamet (Anaconda), Electri-Flex.
- E. Fittings for Liquid-tite Flexible Steel, Aluminum, and Nonmetallic Conduit: Anamet (Anaconda), Electri-Flex, Thomas & Betts.
- F. Fittings for EMT: Appleton, O-Z/Gedney, Steel City.(compression type only)
- G. Bushings for 1 inch and Smaller Conduits: Appleton, O-Z/Gedney, Steel City.
- H. Bushings for 1-1/4 inch and Larger Conduits: Appleton, O-Z/Gedney, Steel City.
- I. Conduit Channel Systems and Straps: B-Line, Kindorf, Unistrut.

### 3.4.3 Outlet Boxes

- A. Sheet Metal Boxes: Appleton, Raco, Steel City.
- B. Cast or Malleable Boxes: Appleton, Crouse-Hinds, Pyle-National.

### 3.4.4 Pull and Junction Boxes

- A. Boxes Less Than 5 Inches by 5 Inches: Appleton, Raco, Steel City.
- B. Sheet Metal Boxes: Appleton, Hoffman, Steel City.
- C. Cast or Malleable Boxes: Appleton, Crouse-Hinds, Pyle-National.

### 3.4.5 Wireways

- A. General: Hoffman, Square D.

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## **4 DISTRIBUTION EQUIPMENT**

### **4.3 MANUFACTURERS**

#### **4.3.1 Distribution Switchboards**

A. General: General Electric, ITE/Siemens, Square D,

#### **4.3.2 Panel boards for Power, Lighting, and Receptacle Distribution**

A. General: General Electric, ITE/Siemens, Square D,

#### **4.3.3 Panel boards for 125 Volt DC Service**

A. General: General Electric, Square D,.

#### **4.3.4 Distribution Transformers for Indoor Dry Locations**

A. General: General Electric, Hevi-Duty, .

## **5 MOTOR CONTROL**

### **5.3 MANUFACTURERS**

#### **5.3.1 480 Volt Motor Control Centers**

A. General: Allen-Bradley, General Electric,.

#### **5.3.2 Single Phase Manual Motor Starters - Fractional Horsepower Type**

A. General: Allen-Bradley, General Electric, Square D,.

#### **5.3.3 Control Devices**

A. Pushbuttons and Selector Switches: Allen-Bradley, Cutler-Hammer, General Electric.

B. Indicating Lights: Allen-Bradley, Cutler-Hammer, General Electric.

C. Control Relays: Allen-Bradley, Cutler-Hammer, General Electric.

D. Timing Relays: Allen-Bradley, Cutler-Hammer, General Electric.

E. Enclosures: Hoffman, Hammond.

F. Terminal Blocks: Allen-Bradley, Cutler-Hammer, General Electric.

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### 5.3.4 Safety Switches

- A. General: General Electric, ITE/Siemens, Square D.

### 5.3.5 Fuses

- A. General: Bussman, Gould Shawmut.

## 6 WIRE AND CABLE

### 6.5 MANUFACTURERS

#### 6.5.1 Wire and Cable

- A. General: Alpha, Anamet (Anaconda), Belden, Manhattan, Royal, Triangle.
- B. Wire for Final Connection in Conduit to Incandescent Fixtures, HID Fixtures with Remote Ballast, and Remote Ballasts: Alpha, Belden, Manhattan, Royal.
- D. Wire for Exposed Cord Connection to Integrally Ballasted HID Fixtures: Okonite-Firex Type SO, Royal SOW-A/SO, Triangle "Elasto-prene" SOW-A/SO.
- I. Multi-Conductor Control Cable for Installation in Conduit and Cable Trays: Alpha, Belden, Manhattan, Royal, Triangle.
- L. Multi-Conductor Fiberoptic Cable for Installation in Conduit or Cable Tray: Belden, Siecor.

#### 6.5.2 Lugs

- B. Lugs for Terminating Power Conductors No. 6 AWG and Larger: Burndy Type YA-L, or Thomas & Betts Series 54000.
- C. Connectors for Splicing Conductors up to and including No. 8 AWG: Burndy "Insulink", Thomas & Betts "Sta-kon".
- D. Connectors for Splicing Conductors No. 6 AWG and Larger: Thomas & Betts 60500 Series, Burndy Type YS-L.
- E. Connectors for 3-way Splicing Conductors No. 6 AWG and Larger: Burndy YST.

#### 6.5.3 Wire Labels

- A. Wire Labels for Identification of Conductors: Brady, Raychem type TMS, Ideal.

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#### 6.5.4 Insulating Tape

- A. General Use Tape: Scotch Super 33+.
- B. High Temperature Area Tape: Scotch 27.

### 7 WIRING AND CONTROL DEVICES

#### 7.2 MANUFACTURERS

##### 7.2.1 Local Lighting Switches

- A. Switches shall be Bryant TECH-SPEC 4900 series, Hubbell 1200 series.

##### 7.2.2 Grounded Receptacles, Plugs, & Connectors - Straight Blade

- A. Straight Blade Grounded Duplex Receptacles shall be Arrow-Hart 8300, Bryant 8300, Hubbell 8300.
- B. Straight Blade Grounded Single Receptacles shall be as follows:
  - 2-pole, 3-wire, 20-amperes, 125 volts, **NEMA 5-20**: Bryant 5361, Hubbell 5361.
  - 2-pole, 3-wire, 30-ampere, 125 volts, **NEMA 5-30**: Bryant 9530-FR, Hubbell 9308.
  - 2-pole, 3-wire, 50-ampere, 125 volts, **NEMA 5-50**: Bryant 9550-FR, Hubbell 9360.
- C. Straight Blade Ground Fault (GFCI) Receptacles shall be Bryant GFR53FT, Hubbell GF5352.
- D. Straight Blade Grounded Plugs shall be as follows:
  - 2-pole, 3-wire, 20-amperes, 125 volts, **NEMA 5-20**: Bryant 5366-N, Hubbell 5366C.
  - 2-pole, 3-wire, 30-ampere, 125 volts, **NEMA 5-30**: Bryant 9530ANP, Hubbell 9309.
  - 2-pole, 3-wire, 50-ampere, 125 volts, **NEMA 5-50**: Bryant 9550ANP, Hubbell 9361.
- E. Straight Blade Grounded Connectors shall be as follows:
  - 2-pole, 3-wire, 20-ampere, 125 volts, **NEMA 5-20**: Bryant 5369-N, Hubbell 5369C.

##### 7.2.3 Grounded Receptacles, Plugs & Connectors - Locking

- A. Locking Grounded Receptacles shall be as follows:
  - 2-pole, 3-wire, 20-amperes, 125 volts, **NEMA L5-20**: Bryant 70520-FR, Hubbell 2310A.
  - 2-pole, 3-wire, 30-amperes, 125 volts, **NEMA L5-30**: Bryant 70530-FR, Hubbell 2610A.

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3-pole, 4-wire, 20-amperes, 125/250 volts, **NEMA L14-20**: Bryant 71420-FR, Hubbell 2410A.

3-pole, 4-wire, 30-amperes, 125/250 volts, **NEMA L14-30**: Bryant 71430-FR, Hubbell 2710A.

3-pole, 4-wire, 50-amperes, 125/250 volts, California Standard: Bryant CS6369, Hubbell CS6369.

4-pole, 4-wire, 30-amperes, 480 volts, watertight with flap cover: Crouse-Hinds DR342, Russellstoll 3114W.

4-pole, 4-wire, 60-amperes, 480 volts, watertight with flap cover: Crouse-Hinds DR642, Russellstoll 3124W-78.

**B. Locking Grounded Plugs shall be as follows:**

2-pole, 3-wire, 20-amperes, 125 volts, **NEMA L5-20**: Bryant 70520-NP, Hubbell 2311.

2-pole, 3-wire, 30-amperes, 125 volts, **NEMA L5-30**: Bryant 70530-NP, Hubbell 2611.

3-pole, 4-wire, 20-amperes, 125/250 volts, **NEMA L14-20**: Bryant 71420-NP, Hubbell 2411.

3-pole, 4-wire, 30-amperes, 125/250 volts, **NEMA L14-30**: Bryant 71430-NP, Hubbell 2711.

3-pole, 4-wire, 50-amperes, 125/250 volts, California Standard: Bryant CS-6365N, Hubbell CS6365C.

**C. Locking Grounded Connectors shall be as follows:**

2-pole, 3-wire, 20-amperes, 125 volts, **NEMA L5-20**: Bryant 70520-NC, Hubbell 2313.

2-pole, 3-wire, 30-amperes, 125 volts, **NEMA L5-30**: Bryant 70530-NC, Hubbell 2613.

3-pole, 4-wire, 20-amperes, 125/250 volts, **NEMA L14-20**: Bryant 71420-NC, Hubbell 2413.

3-pole, 4-wire, 30-amperes, 125/250 volts, **NEMA L14-30**: Bryant 71430-NC, Hubbell 2713.

3-pole, 4-wire, 50-amperes, 125/250 volts, California Standard: Bryant CS-6364N, Hubbell CS6364C.

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## 7.2.4 Isolated Ground Receptacles

B. Straight Blade Isolated Ground Receptacles shall be as follows:

2-pole, 3-wire, 20-amperes, 125 volts, **NEMA 5-20R**: Duplex - Bryant 8300-IG, Hubbell IG8300. Single - Bryant 5361-IG, Hubbell IG5361.

2-pole, 3-wire, 30-amperes, 125 volts, **NEMA 5-30R**: Bryant 9530-IG, Hubbell IG9308.

2-pole, 3-wire, 50-amperes, 125 volts, **NEMA 5-50R**: Bryant 9550-IG, Hubbell IG9360.

C. Locking Isolated Ground Receptacles shall be as follows:

2-pole, 3-wire, 20-amperes, 125 volts, **NEMA L5-20**: Bryant 70520-IG, Hubbell IG2310A.

2-pole, 3-wire, 30-amperes, 125 volts, **NEMA L5-30**: Bryant 70530-IG, Hubbell IG2610A.

3-pole, 4-wire, 20-amperes, 125/250 volts, **NEMA L14-20**: Bryant 71420-IG, Hubbell IG2410A.

3-pole, 4-wire, 30-amperes, 125/250 volts, **NEMA L14-30**: Bryant 71430-IG, Hubbell IG2710A.

## 7.2.5 Special Wiring Devices

A. Straight Blade, 2-Pole, 3-Wire, 20-Ampere, 250 Volt, Grounding Receptacles shall be: Duplex - Bryant 5462(\*\*), Hubbell (†)5462. Single - Bryant 5461(\*\*), Hubbell (†)5461.

B. Straight Blade, 3-Pole, 4-Wire, 125/250 Volts, Grounding Angle Plugs and Receptacles shall be as follows:

30-Ampere, **NEMA 14-30**: Receptacle - Bryant 9430-FR(\*), Hubbell 9430. Plug - Bryant 9432-ANP, Hubbell 9431C.

50-Ampere, **NEMA 14-50**: Receptacle - Bryant 9450-FR(\*), Hubbell 9450A. Plug - Bryant 9452-ANP, Hubbell 9451C.

60-Ampere, **NEMA 14-60**: Receptacle: Bryant 9460-FR(\*), Hubbell 9460A. Plug - Bryant 9462-ANP, 9461C.

(\*) Replace "FR" with "IG" for isolated ground.

(†) Add prefix "IG" for isolated ground.

(\*\*) Add suffix "-IG" for isolated ground.

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C. Locking, 2-Pole, 3-Wire, 250 Volt, Grounding Plugs and Receptacles shall be as follows:

15-Amperes, **NEMA L6-15**: Duplex - Bryant 70615-DR(††), Hubbell (†)4550. Single - Bryant 70615-FR(\*), Hubbell (†)4560. Plug - Bryant 70615NP, Hubbell 4570C.

20-Amperes, **NEMA L6-20**: Receptacle - Bryant 70620-FR(\*), Hubbell (†)2320A. Plug - Bryant 70620-NP, Hubbell 2321.

30-Amperes, **NEMA L6-30**: Receptacle - Bryant 70630-FR(\*), Hubbell (†)2620A. Plug - Bryant 70630-NC, Hubbell 2621.

D. Locking, 3-Pole, 4-Wire, 250 Volt, 3 phase, Grounding Plugs and Receptacles shall be as follows:

20-Amperes, **NEMA L15-20**: Receptacle - Bryant 71520-FR(\*), Hubbell (†)2420A. Plug - Bryant 71520-NP, Hubbell 2421.

(\*) Replace "FR" with "IG" for isolated ground

(†) Add prefix "IG" for isolated ground.

(††) Add suffix "IG" for isolated ground.

### 7.2.6 Wiring Device Plates

Wall plates shall be Bryant or Hubbell stainless steel Type 302 Deluxe

## 8 MISCELLANEOUS

### 8.1 PORTABLE CORDS AND HANDLAMPS

A. Portable 120 Volt Hand lamp Without Receptacle: Rated for use with a 200 watt incandescent lamp, furnished with a maximum twenty five foot long cord, a polarized, grounded, attachment plug: McGill 5025RG, or ES&H approved equivalent.

B. Portable 120 Volt Hand lamp with Single Polarized, Grounded Receptacle: Furnished with a maximum twenty five foot long, 14/3, heavy duty cord, an attachment plug rated 15 amperes, grounded metal cage, melamine phenolic handle: McGill 5025RG, except 14/3 SJO cord, or ES&H approved equivalent.

### 8.2 PROTECTIVE SHIELDS FOR LAMPS

A. General: Lamps may be coated with DuPont® Surlyn, or Surlyn & Teflon (SHO lamps) as manufactured by Shat-r-shield of Salisbury, NC, or Lexan-coated as manufactured by McGill Manufacturing Co., Inc. of Valparaiso, IN, under the trade name of "Protect-O-Tube."