SECTION 16050 - BASIC ELECTRICAL MATERIALS AND METHODS

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1.0 SCOPE

This section covers electrical standards for BASIC ELECTRICAL MATERIALS AND METHODS that are applicable for all electrical design, construction and installation for the City of Portland (COP), Bureau of Environmental Services (BES), Wastewater Group (WG). The requirements of this section apply to the sections listed below unless specially exempted or superseded by another requirement in that section.

SECTION 16300 - HIGH VOLTAGE DISTRIBUTION
SECTION 16400 - SERVICE AND DISTRIBUTION
SECTION 16480 - MOTOR CONTROL
SECTION 16500 - LIGHTING
SECTION 16660 - POWER GENERATION
SECTION 16700 - COMMUNICATIONS
SECTION 16900 - CONTROLS
SECTION 17100 - INSTRUMENTATION

The requirements of SECTION 16010 shall be considered as part of the requirements of this section. If the requirements of section 16010 contradict the requirements of this section, the requirements of this section shall be followed when doing work on materials and equipment covered by this section.

2.0 MATERIALS PROVIDED

2.1 RACEWAYS

Exposed raceways shall be a minimum of ¾" galvanized rigid steel. EMT may be used in office areas in walls and ceilings for lighting and receptacles.

All conduits connected to electrical boxes or devices in locations subject to moisture/condensation shall be installed so ***moisture/condensation will not infiltrate the electrical box or device. The use of condulets or other approved fittings may be used to accomplish this requirement***

2.1.1 GALVANIZED RIGID STEEL CONDUIT LOCATION

Provide galvanized rigid steel conduit for raceways exposed to weather, in hazardous areas and/or in damp locations.

Paint all threads of galvanized conduits with zinc-rich paint or liquid galvanizing compound before assembling. Touch up after assembly to cover nicks or scars.

2.1.2 PVC CONDUIT

2.1.2.1 RIGID PVC NON-METALLIC CONDUIT

Run grounding conductor from the service to the ground rod(s) in PVC rigid non-metallic conduit. For utility service entrance conductors and all underground direct burial raceways. Use schedule 40 for installations not under driveways and schedule 80 for installations under driveways.

2.1.2.2 COATED RIGID STEEL CONDUIT

For underground direct earth burial that is under concrete floor slabs and in corrosive areas, provide PVC coated rigid steel conduit.

Use PVC coated outside and urethane coated inside (Robroy Plasti-Bond Red) conduit. Conduit shall consist of galvanized rigid steel conduit meeting the requirements of NEMA RN 1, UL, and the NEC, and having a factory applied PVC coating 40 mils nominal thickness bonded to the metal outside and urethane coating 2 mils nominal thickness bonded to the metal inside. The bond between steel and PVC shall be equal to or greater than the tensile strength of the PVC coating.

2.1.2.3 PVC COATED RIGID STEEL CONDUIT FITTINGS

Use PVC coated outside and urethane coated inside (Robroy Plasti-Bond Red) fittings. Fittings shall consist of galvanized rigid steel conduit fittings meeting the requirements of NEMA RN 1, UL, and the NEC, and having a factory applied PVC coating 40 mils nominal thickness bonded to the metal outside and urethane coating 2 mils nominal thickness bonded to the metal inside. The bond between steel and PVC shall be equal to or greater than the tensile strength of the PVC coating.

Provide fittings with overlapping pressure-sealing sleeves. Use PVC coated conduit suitable for conductors with 75 degrees C insulation. Use only factory coated and threaded couplings, elbows and nipples. All fittings, couplings, boxes, outlets, covers, etc., for PVC coated rigid steel conduit shall be by the same manufacturer as the conduit.

2.1.3 FLEXIBLE CONDUIT

For 3 phase motors above 50 horse power and single phase motors above 10 horse power, make the final connection to motors, wall mounted fans, dry-type transformer, local instrumentation, and other equipment with flexible conduit, when a flexible connection is required to minimize vibration or when it is required to facilitate removal or adjustment of equipment.

Use liquid tight flexible non-metallic conduit, Type B:

- For use with metallic and non-metallic fittings.
- That is rated for 105 degrees C.
- That is sunlight resistant and is rated for outdoor direct burial (do not bury).

Use fittings that are approved for use with liquid tight flexible non-metallic conduit.

2.1.4 CONDUIT IN WETWELL

Conduit mounted in a wet well area shall be PVC coated, rigid conduit as mentioned above.

2.1.5 CONDUIT FITTINGS

For rigid steel conduit, use bushings, couplings, elbows, nipples, and other fittings, galvanized hot dipping only, and meeting the requirements of ANSI-C80.4, UL, and the NEC. Use form 7 devices.

Unions shall be galvanized, Ferrous alloy types. Thread-less fittings are *not* acceptable and shall not be used. Use only threaded (do not use set screw or compression type) couplings, bushings, and other fittings.

Bushings, 2 inches and larger, shall be galvanized, malleable iron with insulating collars. Bushings smaller than 2 inches may be plastic or fiber. Grounding bushings shall be locking-type with feed-through compression lugs.

2.1.5.1 INSULATED THROAT BUSHINGS FOR RIGID STEEL CONDUIT

Use insulated throat bushings of metal with integral plastic bushings rated for 105 degrees C.
Use Thomas & Betts Nylon Insulated Metallic Bushings, or O.Z./Gedney, Type B, or equal.

2.1.5.2 HUBS FOR RIGID STEEL CONDUIT.

Use Myers Scru-Tite, Crouse Hinds, O.Z./Gedney, or equal.

2.1.6 THREADED JOINTS OF CONDUIT

Threaded hubs shall be used to terminate conduits entering boxes. Use appropriate conduit and conductor entry fittings with enclosures which maintain the specified enclosure NEMA rating after proper installation (conduit connections shall maintain the integrity of the enclosure NEMA rating).

Use only couplings for rigid steel conduit supplied by the conduit manufacturer. Use Appleton Type EYF, EYM, or ESU; Crouse-Hinds Type EYS or EZS; Killark Type EY or EYS, or equal, sealing fittings for rigid steel conduit.

Where condensate may collect on top of a seal, provide a drain by using Appleton Type SF or Crouse-Hinds Type EYD or EZD Drain Seal, or equal.

Use Appleton Type ECDB or Crouse-Hinds ECD drain fittings for rigid steel conduit, or equal.

2.1.7 UNDERGROUND CONDUITS

All underground conduit runs and duct banks that have deflections greater than 30 degrees in 10 feet, shall be in rigid galvanized conduit. The radius size of the conduits shall be no less than the following:

	conduit size	conduit radius
Conduits containing any control wiring	1"	11"
	1 1/4"	14"
	1 1/2"	16"
	2"	21"
All conduits	2 1/2"	25"
	3"	31"
	3 1/2"	36"
	4"	40"
	5"	50"
	6"	61"

2.1.8 RACEWAYS FOR INSTRUMENT AND COMMUNICATIONS WIRING[1]

Where possible (such as in buildings, tunnels, and walkways) instrument and communications wiring and fiber optics shall be run in enclosed cable tray. These conductors and fibers must be laid in, not pulled in.

Do not run instrument, fiber, or communications wiring in raceways that contain conductors carrying voltages over 30 volts.

[1] Also Section 17100 3.4.1

2.2 CONDUCTORS AND CABLES[2]

All electrical conductors shall be stranded copper wire. 25% extra control conductors shall be installed.
All spare conductor ends shall be landed on compression terminal blocks and identified as spare conductors.

2.2.1 CONDUCTOR COLOR CODING[3]

For conductors, provide all single conductors with integral insulation pigmentation using the following coloring system:

SYSTEM	GROUND	NEUTRAL	PHASE A	PHASE B	PHASE C
120/240 1 phase, 3 wire	green	white	black	red	
120/208 3 phase, 4 wire Y	green	white	black	red	blue
120/240 3 phase, 4 wire delta, hot/high leg	green	white	black	orange (hot leg)	blue
277/480 3 phase, 4 wire Y	green	white/stripe or natural gray	brown	orange	yellow
480 3 phase, 3 wire high impedance ground	green		brown	orange	yellow
All 24 VDC, or less, inside control cabinet			positive red	negative purple	
120 VAC inside control cabinet	green	white	control power-black		
Foreign Voltage inside panel[4]			pink		

Conductors larger than no. 6 AWG shall be provided with color coding by wrapping the conductor at each end, and at all accessible locations, with colored self-adhesive vinyl tape. Where this method is used, wrap at least six (6) full turns of tape around the conductor, covering an area 1.5 to 2 inches wide at a visible location at all conductor termination and pulling points. Vinyl tape shall be 3M company No. 35 or equal.

[2] Also Section 17100 3.4.2
[3] Also Section 17100 3.4.3
[4] Rev.2003

2.2.2 CONDUCTOR IDENTIFICATION[5]

Identify and tag power, control conductors (10 AWG or smaller) and control cables at each termination, consistent with associated drawings. Tags shall be legible, permanent sleeves of heat shrinkable, cross-linked, flexible polyolefin with machine printed black marking. Tags relying on adhesives or taped-on markers are not acceptable.
Tags shall be Kroy shrink tubing (P/N 2404220) used with Kroy label / printer TM650[6], Raychem, Brady, or equal. All circuit identification tags shall be readily accessible for inspection at termination points.

Excluded from the identification system are: (1) circuit breaker terminations at the distribution panel, and (2) terminations at lighting fixtures and receptacles. See section 16010 for details on how the numbers are to be derived.

2.2.3 EQUIPMENT GROUNDING CONDUCTORS

Provide conductors, as indicated on the drawings or as required by NEC, for equipment grounding. Provide conductors with green insulation. Grounding conductors shall be insulated and run in conduit.

2.2.4 CONDUCTOR TEMPERATURE RATING AND SPECIFICATIONS

Conductor applications shall conform to Federal Specification J-C-30 and to those listed in the following tables[7]:

INSULATION TYPE	TEMPERATURE RATING	SPECIFICATION
XHHW	75 & 90 C	ICEA S-66-524

Note: MTW wire may be used for cabinet interior wiring

AREA TO BE USED	75 C XHHW
Administrative and non-process areas such as Offices, Labs, Stores, etc. **Internal** Wiring.	X
Administrative and non-process areas such as Offices, Labs, Stores, etc. **External** Wiring.	X
All process areas such a primary treatment, secondary treatment, etc. **All** wiring.	X
Pump Station(s).	X
Underground installations.	X

[5] Also Section 17100 3.4.3.1
[6] Rev.2003
[7] Rev.2003

2.2.5 CONDUCTORS FOR LIGHTING & RECEPTACLE CIRCUITS

All conductors shall be type XHHW[8].

> Note: Type THWN may be used for indoor office lighting and indoor receptacles[9].

2.2.6 CONDUCTORS CARRYING FOREIGN VOLTAGES WITHIN A PANEL

If a voltage is present within a panel whose disconnecting means is **not** in the panel (foreign voltage), each foreign voltage conductor shall come into the panel and be landed on a terminal block. Pink colored wire shall be used to identify foreign voltage circuits within the panel from the terminal block on. Pink insulation shall **not** be used on wires for any other purpose.

2.2.7 WIRE CONNECTIONS AND CONNECTING DEVICES

Where a particular piece of equipment is supplied with terminals that require a ring or fork, compression-type wire lug, and it is not possible to make a sound electrical connection otherwise, the use of compression type wire lugs is acceptable provided the following requirements are met:

Connectors for stranded conductors shall be tool applied, tin plated copper, compression type of the correct size and UL approved for the application. Connectors for wire sizes No. 10 AWG and smaller shall be nylon self-insulated, non-locking spade crimp lugs where approved, or stud crimp lugs (where applicable) Panduit # PV14-P47C, PV18-P47C or approved equal.

2.2.8 FIXTURE CONNECTIONS

All electrical fixture connectors shall be compatible with stranded wire.

2.3 CABLES[10]

2.3.1 SHIELDED CABLE GROUNDING[11]

Ground the shield only at the ground nearest the power supply that provides power to the conductors (or the majority of the conductors). Insulate the shield where the possibility exists of the shield shorting to ground. Where a circuit is part of more than one shielded

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[8] Rev.2003
[9] Rev.2003
[10] Also Section 17100 3.5
[11] Also Section 17100 3.5.1

cable, continue the ground of the cable nearest the power supply to the shield of each succeeding cable.

2.3.2 INSTRUMENT CABLE[12]

- Single Pair: Cables used to connect instrument systems shall be individual 18 AWG stranded copper[13] conductors twisted into a single pair, paired assembly covered with an aluminum-polyester shield with tinned copper drain wire, with overall 35-mil PVC jacket rated 90 degrees C minimum. Provide cables with **red and black**[14] and /or black and white color coding. When connected, black shall be negative and ***white or red*** shall be positive. Outer diameter shall be 0.28 inch maximum. Install 25% extra twisted pair.

- Multiple Pair: Provide cables with individual stranded copper conductors twisted into pairs, individually covered with an aluminum-polyester shield and a tinned copper drain wire twisted along the outside of the shield. The conductor bundle shall be shielded with an overall aluminum polyester shield with a tinned copper drain wire. The outer jacket shall be 40-mil minimum PVC rated at 600V, 90 degrees C minimum. Provide Type 1, Instrumentation cable (600 Volt, Multi-Twisted Shielded Pairs with a common overall shield.)

600 V Twisted, Shield Pair, Instrument Type TC[15]

Belden Trade#	Conductor/Pair Count	Strand Count	Nominal O.D. (in.)
Pairs			
9341	1	19	0.276
1048A	2	7	0.381
1049A	4	7	0.498
1050A	8	7	0.654
1051A	12	7	0.785
1052A	16	7	0.898
1053A	24	7	1.115
1054A	36	7	1.299
1038A	50	7	1.527
600 V Shielded Triad, Instrument Type TC			
Triads			
1121A	1	7	0.292

[12] Also Section 17100 3.5.2
[13] Rev.2003 Also Section 17100 3.5.2
[14] Rev.2003 Also Section 17100 3.5.2
[15] New 2003 Also Section 17100 3.5.2

2.3.2.1 INSTRUMENT CABLE COLOR CODE[16]

SYSTEM	GROUND	NEUTRAL	PHASE A	POSITIVE	NEGATIVE
All 24 VDC **or less** inside control cabinet				red	purple
120VAC inside control cabinet	green	white	control power-black		
Foreign voltage inside control cabinet			pink		
Twisted shielded Pair				red or white	black

2.3.3 CONTROL CABLES[17]

Tray cable that is used for control of electrical circuits (discrete only) shall be a minimum of #14 AWG, stranded copper. With the individual conductors having a THWN or XHHW-2 insulation rated at 600 volts. Cable shall be UL type TC.

Any conductors used for power transmission rather than control shall be derated as required by the current adopted NFPA-70 NEC. (Such as Belden.)

2.3.3.1 INTERNAL CABINET WIRING AND WIRING TO A PLC OR ASSOCIATED CARD[18]

All wiring shall be stranded copper. Internal cabinet wiring may use MTW wire. PLC's and associated cards may use 20 gauge provided the NEC ampacity is not exceeded. Field wiring from the field device to a terminal board within the PLC cabinet shall be minimum 14 gauge. (This includes discrete instruments, not analog.)[19]

2.3.4 RF TRANSMISSION CABLE

Andrews Corporation No. LDF4-50A, 1/2-inch HELIAX cable with foam dielectric.

2.3.5 DIRECT BURIAL CABLE

Direct Burial cable shall not be used.

2.3.6 CABLE REELS

[16] Rev.2003 Also Section 17100 3.5.3
[17] Section Rev.2003 Also Section 17100 3.5.4
[18] Also Section 17100 3.5.5
[19] Rev.2003

All cable reels, unless otherwise specified, shall be weather protected with weather proof cord-caps in addition to cable grip, cable locking ratchet, and split ball cable stop for pick up, and be equipped with 30 feet of #12 three-conductor cable. Use Appleton RL100 series or approved equivalent.

2.3.7 600 V POWER CABLES

Copper conductors shall be provided unless specifically noted otherwise. Minimum wire size for any branch circuit conductor shall be No.12 AWG stranded.

2.3.8 PENDANTS & CORDS

Pendants, and/or cord sets, shall be provided with a Duty and Temperature rating suitable for the terminal compartment and area to be served. Provide Type SO, SOW, SJOW cord or better, unless otherwise specified. Where heat resistant cord is required Type HO shall be provided unless otherwise required for the application. All cords shall include a grounding conductor.

2.4 BOXES

2.4.1 TYPES OF BOXES TO BE PROVIDED IN A STEEL RACEWAY SYSTEM

Provide cast steel boxes in all locations except in raceways installed in interior dry locations or in framed walls. Cast steel boxes shall be a ferrous alloy (Appleton-type F.S./ F.D., or equal) if available, with integrally cast threaded hubs for conduit entry. In dry locations or framed walls, formed steel boxes may be used.

2.4.2 CAST STEEL BOXES

Provide boxes of cast ferrous metal with gasketed, watertight, cast ferrous metal covers and stainless steel screws. Provide boxes with threaded conduit hubs and cast mounting.

Utilize NEMA 12 industrial enclosures for indoor, dry locations.

Utilize NEMA 4X, watertight, corrosion-resistant stainless steel enclosures for outdoor or wet locations and where subscript WP is indicated at the box location on the Drawings.

Utilize NEMA 7 hazardous location enclosures for NEC Class I, Divisions 1 and 2 Hazardous Locations.

Provide watertight, cast metal boxes for above grade locations.

Where larger cast metal boxes are required, use neoprene gasketed, watertight boxes with cast metal full-access covers, stainless steel cover hardware, and drilled and tapped conduit entrances. Use Crouse-Hinds Series W, O.Z./Gedney Series Y boxes, or equal.

2.4.3 OUTLET AND DEVICE BOXES

Provide a box suitable for the conditions encountered at each outlet in the wiring or raceway system and sized in accordance with the NEC. Use the listed types unless otherwise indicated in writing by the Engineer. Provide boxes not less than 2 inches deep, unless shallower boxes are required by structural conditions and are specifically accepted by the Engineer. Do not use box extensions to provide wiring space required by the NEC.

Where larger sheet steel boxes are required, utilize boxes of code-gauge, galvanized steel with full-access screw covers mounted with corrosion-resistant machine screws

2.4.4 BOXES FOR WEATHERPROOF RECEPTACLES

For all receptacles in wet or damp locations subject to wet conditions, a receptacle cover that effectively provides protection from the effects of water while a plug is inserted in the receptacle shall be used. Use Red Dot CKMVD (vertical), CKMD (horizontal) or approved equal.

2.4.5 BOXES FOR WEATHERPROOF SWITCHES

Where weatherproof switches are designated, the switch shall be installed in the specified box with a gasketed, weatherproof, cast-metal cover plate incorporating an external operator for the internal switch and with stainless steel mounting screws. Manufacturers and types: Crouse-Hinds DS-181 or DS-185, Appleton FSK-IVTS or FSK-IVS, or equal.

2.4.6 BOX DEVICE PLATES

Securely fasten device plates to switch or receptacle boxes, or the wiring device contained therein. Install device plates plumb and level. Do not use sectional-type device plates. Provide plates fitting closely and tightly to the box on which they are to be installed.

On surface mounted boxes, provide plates that do not extend beyond the sides of the box unless the plates do not have sharp corners or edges. Use plate material compatible with the box material such that galvanic corrosion of the plate and/or box does not occur, provide cast metal device plates of malleable ferrous metal with gaskets and stainless steel screws with oval heads.

On boxes installed in walls, provide specification grade, one-piece, 0.040-inch nominal minimal thickness, No. 430 satin finish stainless steel device plates with oval-head, matching mounting screws.

2.4.7 RECEPTACLE NAMEPLATES

Provide laminated plastic nameplates attached to receptacle device plates using epoxy adhesive. Nameplate shall be engraved with 1/8 inch high letters, numbers or characters with the distribution panel name and branch circuit number(s) of the circuit(s) powering the device, e.g. "DP-13"

2.4.8 CONDULETS

Provide condulets of cast ferrous metal with gasketed watertight steel covers. All condulets with a form 7 design shall be interchangeable with other manufacturers. Provide condulets with threaded hubs and with sufficient space, clearance and distance to install the conductors within the raceway it serves.

2.5 CABINETS AND ENCLOSURES

Do not mount any devices on or near the area of panels or enclosures where a person's hand will be (the area around the door handle) when opening or closing the door. The purpose of this requirement is to prevent a person's hand from being hurt when opening or closing the door.

2.5.1 CONTROL PANEL AND ENCLOSURE RATINGS

Doors shall have full-length piano hinges with the door removable by pulling the hinge pin.

Except in damp or wet locations, provide NEMA 12 enclosures. In damp or wet locations, where exposed to weather or where weatherproof (WP) is indicated on the Drawings, provide either NEMA 4X stainless steel or reinforced non-metallic fiberglass enclosures. In hazardous locations, provide enclosures rated for the environment indicated.

Control panels in indoor non-process areas shall be heavy duty industrial units, NEMA 12. Control station boxes shall have mounting ears for exterior mounting.

Control panels in all other locations, except hazardous, shall be NEMA 4X of fiberglass reinforced, high impact plastic or stainless steel. Manufacturers: Allen-Bradley 800H series NEMA 4X rating, Square D class 9001 type SK, or approved equal.

Control panels located in areas classified as hazardous shall be rated NEMA 7, Group D unless otherwise specified. Legend plates (STOP, AUTO, etc.) shall be as provided by manufacturer.

Control panels (devices and wiring) shall be built in accordance with standard JIC EM-1.

2.5.2 CONTROL PANEL AND ENCLOSURE SPECIFICATIONS

All cabinets used for electrical equipment or circuits shall be gasketed and vented or shall be sealed and provided with a cooling unit. Panels, cabinets or junction box doors shall use handles and external quick-release latches.[20] All cabinets and control panels (large, stand-alone enclosures) shall be equipped with automatic door switches for lights (Hoffman; type cat. # ALTOB1 or equivalent) and lighting sufficient to enable personnel to work efficiently on the controls and circuits in the cabinet or panel.[21] 115-volt door switches shall have covers to protect maintenance personnel from electrical shock.

Adequate space shall be provided in each panel. Adequate space is defined as 6 inches of space from the top, bottom, or side wall of the enclosure to the edge of the plastic wireway if there is an entry point. If there is no entry point the distance may be 3 inches**.** 2.0[22] inches is required from the edge of the plastic wireway, to the edge of any termination point. If a side panel is used, 6 inches of space is required between the surface closest to the wireway and the wireway.

Din rail must be elevated off of the backplane, based on a ratio 2:1 of slotted-style raceway (example: panduit) to rigid elevated din rail. Example: 2" high raceway will require a 1" standoff. No standoff required for raceways 1" high or less.[23]

2.5.3 IDENTIFICATION - ENCLOSURES AND CABINETS

All enclosures shall be provided with phenolic labels indicating equipment number, source of the control power, the destinations of any driven equipment, and any warnings.

2.6 MISCELLANEOUS DEVICES

2.6.1 POWER RECEPTACLES

Label shall indicate equipment number and power source, circuit identification number.

2.6.1.1 120 VOLT RECEPTACLES - SINGLE AND DUPLEX

Provide UL listed, specification grade receptacles meeting NEMA WD 1 performance standards and Federal Specification W-C-596 and having a contact arrangement such that contact is made on two sides of each inserted blade without detent. Use two-pole, three wire grounding type receptacles rated 20 amps, 125 volts, NEMA Configuration 5-20R and with screw type wire terminals suitable for No. 10 AWG. Provide phenolic composition bases colored gray. Manufacturers: General Electric, Bryant, Hubbell, Sierra, Pass and Seymour, or equal.

[20] Rev.2003
[21] Rev.2003
[22] Rev.2003
[23] Rev.2003

2.6.1.2 RECEPTACLE MOUNTING

Mount receptacles with grounding slot down except where horizontal mounting is indicated, in which case mount with neutral slot down. Ground receptacles to boxes with grounding wire, not by yoke or screw contact. Mount weatherproof receptacles with the hinge for the protective cover above (not at side, or below) the receptacle opening.

2.6.1.3 GFI RECEPTACLES

Provide duplex Industrial Grade GFI receptacles tripping at 5 milliamps (mA); rated 20 amps, 120 volts, NEMA Configuration 5-20R; and capable of interrupting 1,000 amps without damage. Use units meeting NEMA WD 1, fitting standard sized outlet boxes. Use standard model where ground fault protection is needed at an individual location.

Do not use feed-through models or GFCI circuit breakers.

Acceptable Manufacturers: Pass and Seymour, Square D, General Electric, or equal.

2.6.1.4 SELECTOR SWITCHES

Selector switches shall be heavy duty, oil tight and rated at 600 volts, 10 amps continuous duty. Legend plate engravings shall be as specified or shown.

General Use Switches
Provide UL listed, totally-enclosed, AC type, quiet tumbler switches meeting NEMA WD 1 performance standards and Federal Specifications W-S-896E, and capable of control of 100 percent tungsten filament and fluorescent lamp loads. Use switches rated at 20 amps, 120/277 volts. Switches shall have screw or compression terminals as appropriate for the application.

Manufacturers
General Electric, Bryant, Hubbell, Pass and Seymour, or equal.

3.0 MATERIAL AND EQUIPMENT INSTALLATION REQUIREMENTS

3.1 RACEWAYS

3.1.1 CONDUIT INSTALLATION

No conductors shall be installed in a raceway until any thing that might cause damage to wires, conduit boxes, or fittings has been eliminated. Where conductors pass through holes or over edges in sheet metal, remove all burrs, chamfer all edges, and install bushings and protective strips of insulating material to protect the conductors.

All conduit runs shall have a ground conductor installed. Conduit connections shall maintain the integrity of the NEMA rating of the enclosure they enter.

Where indicated on the Drawings, and where necessary to terminate conductors, tap-off, or redirect multiple conduit runs, provide appropriately designed junction boxes. Provide pull-boxes to limit the number of directional changes of conduit to a total of **not more** than 270 cumulative degrees in any run between pull-boxes. Conduit runs between pull-boxes shall be limited to 400 feet maximum, less 100 feet for each 90-degree change in direction.

3.1.2 RACEWAYS NEAR OTHER UTILITY SYSTEMS

Locate raceways at least 12 inches away from parallel runs of piping for other utility systems.

3.1.3 FLEXIBLE CONDUIT

Use 18-inch minimum, 72-inch maximum lengths of liquid-tight, non-metallic flexible conduit. The flexible conduit shall be long enough to allow the item to which it is connected to be withdrawn or moved off its base. Make no bends in flexible conduit that exceed allowable bending radius of the cable to be installed or that significantly restricts the conduit's flexibility.

3.1.4 RACEWAY IDENTIFICATION

Raceway shall be permanently identified with tag numbers consistent with associated drawings. See **Section 16010 – 2.7** (EQUIPMENT AND DEVICE IDENTIFICATION) for details on equipment numbering.

3.1.5 ARRANGEMENT AND ROUTING

Arrange multiple conduit runs in accordance with any details shown on the Drawings. Locate underground direct buried conduits where indicated on the Drawings. Determine exact alignment and depth as required to avoid other utilities.

Make changes in location or cross section as necessary to avoid obstructions or conflicts. Where raceway runs cannot be installed substantially as shown because of conditions not discoverable prior to digging of trenches, refer the condition to the Engineer for instructions <u>before</u> further work is done.

3.1.6 EXPOSED RACEWAYS

Run exposed raceways parallel or perpendicular to walls, structural members, or intersections of vertical planes to provide a neat appearance. Follow surface contours as much as possible.

3.1.7 CONDUIT BENDS

Where conduit(s) requires a change in direction the following shall be done:

- All bends shall be made with a bender that is not capable of reducing the size of the conduit while being bent, and shall leave no marks or scars on the conduit.
- Where a conduit bank changes plane while changing direction it is acceptable to use factory 90-degree elbows for the largest conduit in the bank. All conduits smaller than the largest conduit shall use the same radius as the largest conduit.
- Where a conduit bank stays in the same plane and changes direction, all conduits shall have the same radius center point/concentric bends (exception: where the bank of conduits is less than five the conduits can have the same radius provided there are no concentric bends in the area).
- Where a conduit bank offsets from one plane to another plane all bends shall match in bend angle, distance between bends and placement of bends.
- Where a conduit bank offsets on the same plane, the center of the bend shall line up on all adjacent bends while the distance between conduits is maintained the same throughout.

3.1.8 CONDUIT ROUTING

Do not run raceways across walkways. Avoid obstruction of passageways with raceways. Group raceways in same area together . . . Do not place raceways over valves or couplings in other piping systems. Refer conflicts, with these requirements, to the Engineer for instructions before further work is done.

3.1.9 CONDUITS AND EQUIPMENT PADS

Where conduits pass under equipment pads and where conduits rise up through the equipment pad or rise up close to the equipment pad, the back-fill material shall be compacted in six-inch lifts. The back-fill shall extend not less than 6 inches beyond the pad edge and will fall away from the pad at not more than a 45-degree angle.

Equipment pads shall include pads where transformers, motors, cabinets, or any electrical equipment not covered elsewhere is mounted.

At motor control centers (MCC's), control panels, and bubbler panels, stub the conduit up at most 1-inch above the top of the equipment pad. Install insulated grounding bushings and grounding connections on all stubbed up conduits.

3.1.10 RACEWAYS IN CONCRETE

Locate raceways concealed in poured concrete so that the minimum concrete covering is not less than 1-1/2 inches. Provide support during pouring of concrete to ensure that raceways remain in position, equally spaced and at the same height.

Duct bank alignments shown on Drawings are diagrammatic. Actual alignments shall contain no sharp bends and shall be installed with long radius bends. All underground rigid steel conduit shall be protected by one of the following ways:

- Use PVC coated rigid steel conduit.
- 10 MIL half lapped tape.
- Concrete encased at least 2 inches on all sides.

No conduit shall be embedded in the walls of tanks or basins below the high water elevation, except when absolutely necessary and where specifically shown on the Drawings. Raceways installed under floor slabs shall lie completely under the slab with no part of the horizontal run of the raceway embedded within the slab.

Limit the number of directional changes of conduit to a total of not more than 270 cumulative degrees in any run between pull-boxes. Conduit runs shall be limited to 400 feet maximum, less 100 feet for each 90-degree change in direction.

Exposed conduit shall be run on supports spaced not more than 10 feet apart and shall be constructed with runs perpendicular and parallel to walls, structural members, or intersections of vertical planes and ceiling. No conduit shall approach closer than 6 inches to any object operating at 30 degrees C. above ambient. All conduits shall enter structures at right angles.

3.1.11 CONDUITS PENETRATING WALLS AND STRUCTURES

Seal the interior of all raceways entering structures at the first box or outlet with oakum, suitable plastic expandable compound, or silicon foam to prevent the entrance into or exit from the structure of gases, liquids, or rodents.

Dry pack with non-shrink grout around raceways that penetrate concrete walls or floors above ground, or use one of the methods specified for underground penetrations.

Where an underground raceway enters a structure through a non-waterproofed wall or floor, install a sleeve made of Schedule 40, 316 stainless steel pipe. Fill the space between the conduit and sleeve with a suitable plastic expandable compound, or an oakum and lead joint, on each side of the wall or floor in such a manner as to prevent

entrance of moisture. A watertight galvanized cast iron wall entrance sealing device, having a watertight sealing gland assembly (O.Z./Gedney FSK or FSC, or equal) may be used in lieu of the sleeve. The Rox system is acceptable for all water and gas tight penetrations for conduits and/or SO-Type cords.

3.1.12 INSTALLATION REQUIREMENTS FOR UNDERGROUND RACEWAYS TRENCHING REQUIREMENTS

Coordinate installation of underground raceways (direct buried) with other outside and building construction work.

Do not back-fill underground raceways until they have been inspected by the Engineer or his representative.

Warning Tapes: Bury warning tapes approximately 18 inches above all underground conduit runs.

Where existing roadways, sidewalks, curbing, etc. are encountered, remove those sections as needed during construction and replace with new sections after back filling so as to match original conditions.

Excavations shall be carefully made to avoid unknown underground utilities or utilities which are in a location different from that expected or shown on the Drawings.

Grade trenches and place select material to provide uniform trench bottom for raceway support.

3.1.13 UNDERGROUND CONDUIT RUNS

Separate parallel runs of two or more raceways in a single trench. The trench shall be filled at least half way up the conduit with pea gravel or cement to give the conduit proper support.

3.1.14 WIREWAYS FOR FIBER OPTIC CABLE

Wireways used for utilized for fiber optic cable shall be installed in the following manner:

- For conduits that are underground all deflections greater that 30 degrees within a 10-foot span shall be in rigid galvanized conduit, and the radius for all deflections shall be no less than 36 inches.
- Where the conduit run is less than 20 feet, standard radius 90 degree sweeping elbows can be used.
- Fiber optic cable shall not pass through any condulets that incorporate a 90-degree change of direction. Example: LB LL LR X TB.

- Conduits shall enter any cabinet in a manner that will allow for a logical and professional installation of the fiber optic cable in that cabinet.
- Where fiber is installed other than underground or outdoors, it shall be installed in "lay in wireway". Wherever possible, lay the fiber cables in. **Do not pull** in unless there is no other way to install it.

3.1.15 THREADED JOINTS OF CONDUITS

Make all connections in threaded conduit watertight as practical. Conduits and threaded hubs shall have **no less** than five (5) threads engaged. Long threads known as "running threads" shall not be used. Erickson couplings or unions shall be used only in places where continuous conduit runs cannot be made satisfactorily. Use approved, highly conductive jointing compound on all joints; Thomas & Betts, General Electric, or equal.

All threaded joints are to be made with Copper Kote or equal[24]

3.1.16 CONDUIT CONSTRUCTION

Do not use union type fittings underground. Conduit connections shall maintain the integrity of the enclosure NEMA rating. After installation, plug or cap all raceway ends with a method suitable for sealing the conduit until the time for pulling in conductors.

For all raceways that contain less than 50 percent of the NEC-allowed fill of individual conductors, install a nylon pull cord with the conductors. Empty and functionally usable raceways shall be used whenever possible. All spare raceways shall be provided with non-degradable pull strings. Install raceways concealed except where indicated otherwise on the plans or as directed by the City's Project Engineer. Install concealed, embedded, and buried raceways so that they emerge at right angles to the surface and have none of the curved portion of the bend exposed.

Conduits and threaded hubs shall have **no less** than five (5) threads engaged. Long threads known as "running threads" shall not be used. Regular cutting oil is suitable for threading steel conduit.

Conduit connections to weatherproof enclosures shall be made with watertight hubs or as recommended by the manufacturer.

3.1.17 PREPARATION FOR PULLING IN CONDUCTORS

Take care to prevent the lodging of plaster, concrete, dirt, or trash in raceways, boxes, fittings, and equipment during the course of construction. Make raceways entirely free of obstructions or replace them. Ream all raceways, remove burrs, and clean raceway interior before installing conductors or pull wires.

[24] Rev.2003

3.1.18 CONDUIT MOUNTING EQUIPMENT

All Kindorf or uni-strut steel type conduit mounting channel shall have cut ends painted with cold galvanizing compound or corrosion resistant paint, etc. use fiberglass Kindorf channels where strength permits.

Support multiple raceways adjacent to each other by ceiling trapeze. Support individual raceways by wall brackets (one-hole malleable iron pipe straps), strap hangers, or ceiling trapeze fastened by expansion shields on concrete and machine screws or welded, threaded studs on steel work.

Do not use nails anywhere or wooden plugs inserted in concrete as a base for raceway or box fastenings. Do not weld raceways or pipe straps to steel structures. Do not use wire in lieu of straps or hangers.

3.1.19 PVC CONDUIT

Solvent weld PVC conduit joints with solvent recommended by the conduit manufacturer. Follow manufacturer's solvent welding instructions to provide watertight joints. Where conduit changes from underground direct burial to exposed, extend the PVC coated rigid steel conduit 6 inches above finished grade.

3.1.19.1 THREADING PVC COATED RIGID

Use strap-type wrenches for PVC coated rigid steel conduit. The use of chain or pipe wrenches is not permitted. Where field cut threads are to be made on PVC coated rigid steel conduit, use only machines or dies that have a three point jaw, that have been cleaned of any and all material that might have accumulated and are in like-new condition. Do not use hand dies with a chain vise.

3.1.19.2 PVC COATED RIGID STEEL CONDUIT

Install in strict accordance with the manufacture’s instructions. Use strap type wrenches. Pipe wrenches are not acceptable. PVC boot shall cover all threads. Leave no metallic threads uncovered. Use touch-up compound as recommended by the manufacturer to cover gouges and bare metal after installation.

3.1.20 RIGID PVC NON-METALLIC CONDUIT

Use acceptable heating methods for forming rigid PVC non-metallic conduit for deflections less than 30 degrees. Bends over 30 degrees shall not be allowed.

Where bellied conduits are used. Bevel the unbolted end of the joint before joining. Solvent weld joints with solvent recommended by the conduit manufacturer. Follow manufacturer's instructions and provide watertight joints.

3.1.21 BACKFILL INSTALLATION ABOVE CONDUIT ZONE OF DIRECT BURIAL CONDUIT

Install underground raceways with 30 inches of cover (36 inches required for PGE service entrance conduit). Cover may be reduced to 2 feet or less **only** where indicated on the Drawings.

3.2 CONDUCTOR INSTALLATION

Install conductors and control cables as shown on the Drawings. Do not install DC conductors or antenna transmission conductors and AC conductors of 30 volts or greater in the same conduit.

3.2.1 CONDUCTORS IN ENCLOSURES

In panels, boxes or enclosures, route the three conductors mentioned above separately. Arrange wiring in cabinets, panels, terminal boxes, and motor control centers neatly cut to proper length. Remove surplus wire. Bridle and secure control wiring in an acceptable manner for connection to terminals. Identify all circuits entering motor control center or other control cabinets in accordance with the conductor identification system specified (see Section 16010.4).

Connect all conductors including spare conductors to dedicated terminal block terminals (one terminal point for each conductor). When ty-rap type cable ties are used to bundle or secure cables, wire, etc., the ends shall be cut off flush with the proper tool to ensure that no sharp edges protrude.

Conductor slack shall be provided at junctions and in pull-boxes. Conductor slack shall be sufficient to allow cable or conductors to be routed along the walls of the box.

PULLING CONDUCTORS INTO RACEWAYS

Before pulling any conductor into a raceway, the installation of the raceway shall be completed so that when the conductor is pulled in no damage will result to the conductor or its insulation. Pulling wire and cable into conduit shall be completed without damaging or causing undue stress on the wire or cable insulation.

Conductors shall be free of sandy or gritty material during pulling. If wires are laid on ground during pulling, wires shall be wiped free of sandy or gritty material prior to entry of wires into conduit, and prior to application of any pulling compound.

Do not exceed cable or conductor manufacturer's recommendations for maximum pulling tensions and minimum bending radii. Where pulling compound (American Polywater Corp, or equal) is used, use only UL listed compound compatible with the wire insulation, cable outer jacket, and raceway involved. Grease and petroleum derivatives are not acceptable and shall not be used.

Provide conductors and cables with no splices except as indicated or accepted in writing by the Engineer.

CONDUCTORS CONNECTED BY OTHERS
For conductors that will be connected by others, provide sufficient length of wire to enable termination at any point in the enclosure plus two feet.

3.3 BOXES

3.3.1 JUNCTION BOXES

No junction boxes shall be mounted in a wet-well unless approved in writing by the Engineer.

Connect junction boxes to the equipment grounding system with the 3/8-inch machine screws. Completely remove all paint, dirt, or other Service Coverings at grounding conductor connection points so that good metal to metal contact is made, then refinish for corrosion protection.

Locations indicated on prints for mounting outlet boxes are approximate. Study the Drawings in relation to spaces and equipment surrounding each outlet. When necessary, with the written approval of the engineer, relocate outlets to avoid interference with mechanical equipment or structural features. Locate all light switches on lock side of doors. Locate all light fixture outlets in a symmetrical pattern according to the room layout, unless otherwise indicated.

3.3.2 MOUNTING

Make all boxes accessible. Utilize stainless steel mounting hardware in areas subject to corrosion. Where a box supports a fixture or fixtures, provide proper means of attachment with adequate strength. Mount all boxes plumb and level. Install boxes in a secure, substantial manner supported, independently of conduit, by attachment to the building structure or a structural member. Fasten boxes directly with bolts and expansion shields on concrete or brick. Threaded studs driven in by a powder charge are **not** acceptable in lieu of expansion shields. Mount the centerline of boxes at 48” above finish floor unless otherwise indicated. Boxes mounted within a wall built of concrete masonry units (CMU) shall align the CMU joint with the top or bottom of the box and shall be consistent through out the project.

3.3.3 PANEL AND ENCLOSURE INSTALLATION

Regulator drain valves, when included in the panel, shall not be located above open conductors or electrical devices.

All control panels, enclosures, etc., being placed above ground level shall be protected from the weather by location within a building or under an extended roof that is large enough to provide weather protection for the panel and maintenance personnel working at the panel.

3.3.4 GROUND FAULT INTERRUPTERS

Test all ground fault interrupter (GFI) receptacles for proper connection and operation with an instrument that measures actual trip current in milliamps. Replace any units that do not function properly at the rated current.