

Section 16120

CONDUCTORS AND CABLING

PART 1 - GENERAL

1.1 THE REQUIREMENT

- A. The CONTRACTOR shall furnish all tools, equipment, material, and supplies and shall perform all labor required to complete the work as indicated on the Drawings and specified herein.
- B. The CONTRACTOR shall furnish and install power (low and medium voltage) cables, control and signal cables as described herein and as indicated on the Contract Documents.

1.2 REFERENCE SPECIFICATIONS, CODES AND STANDARDS

- A. All work specified herein shall conform to or exceed the applicable requirements of the referenced portions of the following publications to the extent that the provisions thereof are not in conflict with other provisions of these specifications.
- B. Comply with the latest editions of the following codes and standards.

1. Codes and Standards:

NEC	National Fire Protection Association (NFPA) –70 National Electrical Code (NEC), latest adopted edition.
CCR	Title 8, Industrial Relations, Subchapter 5, Electrical Safety Orders, California Code of Regulations, National Electrical Code

2. Commercial Standards:

ANSI/UL 467	Grounding and Bonding Equipment, Safety Standard For.
ICEA S-95-658/NEMA WC70	Nonshielded 0-2 kV Cables
ICEA S-96-659/NEMA WC71	Nonshielded 2001-5 kV Cables
ICEA S-93-639/NEMA WC74	Shielded Power Cable 5-46 kV
ICEA S-94-649	Concentric Neutral Cables Rated 5-46 kV
ICEA S-97-682	Utility Shielded Power Cable Rated 5-46 kV
ICEA S-105-692	600 V Single Layer Thermoset Insulated Utility Underground Distribution Cable
ICEA S-81-570	Direct Burial, 600 Volt, Ruggedized Insulation

ANSI/UL 62	Flexible Cord and Fixture Wire.
ANSI/UL 510	Insulating Tape.
ANSI/UL 1277	Electric Power and Control Tray Cables with Optical Fiber Members.
ASTM B8	Standard Specifications from Concentric Lay Standard Copper Conductors, Hard, Medium-Hard or Soft.
IEEE 48	Standard Test Procedures and Requirements for High Voltage Alternating Current Cable Terminations.
NEMA WC-55	Instrumentation Cables and Thermocouple Wire
NEMA WC-57	Control Cables

C. All Conductors furnished by the CONTRACTOR shall be listed by and shall bear the label of Underwriters' Laboratories, Incorporated, (UL).

D. The construction and installation of all electrical equipment and materials shall comply with all provisions of the CAL-OSHA Safety Orders Title 8 CCR, as applicable, State Building Standards, and applicable local codes and regulations.

1.3 CONTRACTOR SUBMITTALS

A. Submittals shall be made in accordance with the Section 16010 Electrical General Provisions.

B. CONTRACTOR shall submit the following items.

1. Catalog cuts and other brochures depicting conductor characteristics
2. Manufacturer' certified test records and factory test procedures
3. Manufacturer' recommended splicing, testing, and installation procedures and practices
4. Field testing records in accordance with Section 16080, Electrical Testing

1.4 QUALITY ASSURANCE

A. All test equipment shall be certified within the prior year.

1.5 CONDUCTOR IDENTIFICATION SYSTEM:

A. Provide a complete power, control and signal conductor and cable identification system so that, after installation, conductors and cables shall be easily traced from origin to destination. See Section 16075, Electrical Identification Nameplates and Warning Signs and Standard Drawing S-465 for requirements.

1. Identify power, control, and signal conductors at each termination and in all accessible locations such as maintenance holes, handholes, panels, switchboards, pull boxes, terminal boxes, etc.

B. Conductor and Cable Color Coding:

1. Color coding of multi-conductor control and instrumentation cable is specified in the individual cable type specification.
2. For power conductors, provide all single conductors and individual conductors of multi-conductor power cables with integral insulation pigmentation of the designated colors, except conductors larger than No. 6 AWG may be provided with color coding by applying a heat shrink tube of the appropriate color.
3. Phase A, B, C implies the direction of positive phase rotation.
4. Use the following colors:

System	Conductor	Color
All Systems 120/240 Volts, 1-Phase, 3-Wire	Equipment Grounding	Green
	Grounded Neutral	White
	One Hot Leg	Black
	Other Hot Leg	Red
208Y/120 Volts, 3-Phase, 4-Wire	Grounded Neutral	White
	Phase A	Red
	Phase B	Black
	Phase C	Blue
480Y/277 Volts, 3-Phase, 4-Wire	Grounded Neutral	White
	Phase A	Red
	Phase B	Black
	Phase C	Blue
2,400 Volt		
4,160 Volt		

System	Conductor	Color
12,470 Volt	Grounded Neutral	White
	Phase A	Red
	Phase B	Black
	Phase C	Blue

- C. For all high voltage cable and all 600 volt cable sized AWG #2 and larger, CONTRACTOR shall furnish cable manufactured no more than one year prior to installation.

PART 2 - PRODUCTS

2.1 GENERAL

- A. The use of a manufacturer's name and model or catalog number is for the purpose of establishing the standard of quality and general configuration desired only. Equal products of other manufacturers will be considered in accordance with the General Requirements.
- B. Subject to compliance with requirements, manufacturers offering products that may be incorporated in the work include, but are not limited to, American Insulated Wire Corp., Cable Corp., The Okonite Co., Pirelli Cable Corp., Carol Cable Co. Inc. or Southwire Company.
- C. Cables run in cable tray shall be UL listed for that application. All cable installed in cable tray shall also be rated UV resistant.
- D. Cables shall be suitable for the temperature, conditions and location where installed.
- E. Unless otherwise indicated, provide stranded conductors, except provide solid conductors where No. 10 AWG and No. 12 AWG are designated for branch circuit power wiring in lighting and receptacle circuits.
- F. Use only copper conductors.
- G. All medium voltage power cables shall be UL listed and labeled in accordance with UL Standard 1072, "Medium Voltage Power Cables".
- H. All cables shall be installed in unbroken, unspliced, continuous runs. Cables may be spliced only with the specific written approval of the ENGINEER and when splicing materials specifically approved by the ENGINEER for the specific application are used.

2.2 CONDUCTORS

- A. Power Conductors 600 Volts and Below:
1. Provide Type THHN/THWN insulation for control & instrument cables. Provide conductors with Type XHHW-2 insulation for power cables.

2. Where flexible cords and cables are specified, provide Type SO, 600-volt, with the number and size of copper conductors indicated.
 3. Conductors for applications of 600 volts and below shall be rated for 600 volts unless otherwise specified.
 4. The name of the manufacturer, insulation type, voltage rating and wire size shall be clearly and permanently imprinted throughout the length of each conductor. All conductors and cables supplied shall bear the UL label.
- B. Conductors above 600 Volts:
1. 2kV Conductors:
 - a. Provide 2kV rated conductors for power feed from variable frequency drives to RSS pumps.
 - b. Provide Type RHW-2 conductors with ethylene propylene (EP) chlorosulfonated polyethylene (CSPE) with stranded copper conductor per ASTM B-8 and meeting the requirements of ICEA S-68-516, NEMA WC 8, and UL Standard 44.
 - c. Cable marking shall include manufacturer's name, insulating material, conductor size, voltage class and UL mark.
 2. 15 kV Conductors:
 - a. Unless indicated otherwise, provide 37 strand copper conductors with ethylene-propylene polymer (EPR) insulation, extruded semiconducting strand and insulation shields, copper drain wires, and a polyvinyl chloride or neoprene jacket.
 - b. Provide shielded single conductors with 133 percent insulation level, that meet applicable portions of ICEA S-68-516 and NEMA WC 8, and AEIC CS 5 and CS 6, Ionization Level Requirements. Provide conductors UL listed MV-105.
 - c. Cable marking shall include manufacturer's name, insulating material, conductor size, voltage class and UL mark.
- C. High-Voltage Splice and Termination Kits:
1. Make all high voltage conductor splices with permanent premolded EPDM type submersible splicing kits rated 15 kV, 125 kV BIL with current rating same as cable.
 - a. Use indoor terminations of the factory premolded EPDM type.
 - b. Use outdoor terminations in switchgear, on dip poles, and in transformer cabinets of the factory premolded and skirted EPDM type or preassembled porcelain slip-on type.
 - c. For all terminations provide proper shield termination and grounding. Provide all necessary mounting hardware, covers, and connectors.

- d. Splices and termination kits shall be coordinated with the cable manufacturer. CONTRACTOR shall submit a certified letter from the cable manufacturer stating their concurrence with the type of splice to be performed.
 - e. Termination kits shall be UL listed.
2. Provide terminators rated in accordance with IEEE No. 48, Pothead Standards. Use splices and terminations manufactured by 3M, Joslyn, Elastimold, or equal.
- D. Conductor Arc and Fireproofing Materials: Use Scotch Brand 77 or Plymouth Plyarc 30 arc and fireproofing tape, or equal; Scotch Brand 69 or Plymouth Plyglass glass cloth electrical tape, or equal. Tape shall be a minimum of 3 inch half-lapped and shall extend at least 6 inches into raceways.
- E. 15 kV Underground Connection System:

- 1. Provide a premolded EPDM type connection system as indicated, junction modules, bushing inserts, parking stands, grounding wells, bushings, protective caps, standoff insulators and other necessary accessories suitable for use with subsurface or pad-mounted installations, submersible to 10 feet of water, and meeting the following ratings:

Voltage Rating	15.2/26.3 kV
Impulse Voltage	125 kV BIL
Withstand Voltage	40 kV, 60-Hz, 1 minute; 78 kV, dc, 15 minutes
Corona Voltage Level	19 kV extinction
Dimensions	IEEE (ANSI) 386
Fault Close	65,000 Amp rms symmetrical
Current Rating	600-amp rms continuous, nonswitching where shown

- 2. Elbow Connectors: Arrange elbow connectors for hook stick operation [and having test points.] [Where connection is being made to an existing junction module, supply an elbow connector by the same manufacturer as the junction module.]
- 3. Junction: Provide junctions for the number of points indicated and complete with PVC coated steel or fiberglass brackets for round or flat wall mounting as shown and angled as shown. Supply mounting bracket having parking stands suitable for standoff plugs and portable feed-through modules.
- 4. Protective Caps: Provide protective caps hook stick operated, insulated type, fully shielded for sealing energized bushings and having an electrostatic ground wire. Provide protective caps on all unused bushings of junction modules.
- 5. Manufacturers: Use systems manufactured by Joslyn, Elastimold, RTE or equal.

F. Multi-Conductor Cable:

1. Provide cables as specified under the type number in this Section. Conduits shown on the Drawings and in the Circuit/Raceway Schedule have been sized to accommodate the outside diameter for each type. For this reason, use cable with diameters equal to or less than the diameters specified.
 - a. Type 3 (600-Volt No. 16 AWG Twisted, Shielded Pair Instrumentation Cable, Type TC) (UL 62 & 1277):
 - (1) General: Single pair instrumentation cable designed for noise rejection for process control, computer, or data log applications. Suitable for installation in cable trays, conduit, or other approved raceways. Maximum cable temperature rating shall be 90 degrees C dry locations, 75 degrees C wet locations.
 - (2) Individual Conductors: Bare soft annealed copper, Class B, 7-strand concentric per ASTM B 8; 20 AWG, 7-strand tinned copper drain wire.
 - (3) Insulation and Jacket: Each conductor shall be 15-mil nominal PVC and 4-mil nylon insulation. Pair conductors shall be pigmented black and red. Jacket shall be flame-retardant and sunlight- and oil-resistant PVC with 45 mils nominal thickness. Shield shall be 1.35-mil aluminum/mylar overlapped to provide 100 percent coverage.
 - (4) Dimension: 0.31 inch nominal OD.
 - (5) Manufacturers: The Okonite Company, Alpha Wire Corporation, Manhattan, Belden or equal.
 - b. Type 4 (600-Volt No. 16 Twisted, Shielded Triad Instrumentation Cable, Type TC) (UL 62 & 1277):
 - (1) General: Single triad instrumentation cable designed for noise rejection for process control, computer, or data log applications. Suitable for installation in cable tray, conduit, or other approved raceways. Maximum cable temperature rating shall be 90 degrees C dry locations, 75 degrees C wet locations.
 - (2) Conductors: Bare soft annealed copper, Class B, 7-strand concentric per ASTM B 8; 20 AWG, 7-strand, tinned copper drain wire.
 - (3) Insulation and Jacket: Each conductor shall be 15-mil nominal PVC and 4-mil nylon insulation. Triad conductors shall be pigmented black, red and blue. Jacket shall be flame-retardant and sunlight- and oil-resistant PVC with 45 mils nominal thickness. Shield shall be 1.35-mil aluminum/mylar, overlapped to provide 100 percent coverage.
 - (4) Dimension: 0.32 inch nominal OD.
 - (5) Manufacturers: The Okonite Company, Alpha Wire Corporation, Manhattan, Belden or equal.

c. Type 5 (600-Volt No. 18 AWG, Multi-twisted Shielded Pairs with a Common Overall Shield Instrumentation Cable, Type TC)(UL 62 & 1277):

(1) General: Twisted, shielded pairs of instrument cables, grouped in a single cable, designed for use as instrumentation, process control, and computer cable. Suitable for installation in cable tray, conduit, or other approved raceways. Maximum cable temperature rating shall be 90 degrees C dry locations, 75 degrees C wet locations.

(2) Conductors: Bare soft annealed copper, Class B, 7-strand, concentric per ASTM B 8. Tinned copper drain wires. Pair drain wire size AWG 20, group drain wire size AWG 18.

(3) Insulation and Jacket: Each conductor 15-mil PVC and 4-mil nylon insulation. Pair conductors pigmented black and red with red conductor numerically printed for group identification. Outer jacket shall be flame-retardant and sunlight- and oil-resistant PVC with nominal thickness as shown in table. Individual pair shield shall be 1.35-mil aluminum/mylar. Group shield shall be 2.35-mil aluminum/mylar, overlapped for 100 percent coverage.

(4) Dimensions as noted in table below:

Number of Pairs	Maximum Outside Dimension (inches)	Nominal Jacket Thickness (mils)
4	0.50	45
8	0.68	60
12	0.82	60
16	0.95	80
20	1.05	80
24	1.16	80
36	1.33	80
50	1.56	80

(5) Manufacturers: The Okonite Company, Alpha Wire Corporation, Manhattan, Belden or equal.

2. Signal and Control Circuit Wiring:

a. Wire type and sizes: Conductor shall be flexible stranded copper machine tool wire; these shall be UL listed Type MTW/TEW and shall be rated 600-volts. Wires for instrument signal circuits and alarm input circuits shall be No. 14 AWG. All other wires, including shielded cables, shall be No. 16 AWG minimum. The minimum wire size shall be #18 when wire is used to connect terminal blocks to Modicon input or output modules.

All >50V wiring shall be run separately from <50V wiring. Control panel layout shall divide the panel into two sides with wiring and devices that operate above 50V on one side, below 50V on the other.

- b. PLC Communications Coaxial Cable: Provide RG-6 PLC Communications Coaxial Cable where required. The cable shall be flexible, 5/16-inch in diameter, with bonded aluminum quad shield. Center conductor shall be 18 AWG copper coated steel. Dielectric coating shall be foam polyethylene. Jacket shall be flame retardant PVC. Maximum attenuation at 1.544 MHz shall be 0.48 dB/100 feet. Impedance shall be 75 ohms and capacitance shall be 16.2 pF per foot. Minimum bend radius shall be 2 inches. Maximum pulling tension shall be 45 pounds. All necessary taps and connectors shall be provided.
- c. PLC Quantum Input/Output Module Wiring: Use 140 XTS 012 xx (High power system cable rated at 2 amp per point) for all signals. Use pigtail configuration when pre-wiring MCC sections to MCC remote I/O mounted in the MCC.
- d. Wire Insulation Colors: Conductors shall be identified by color-coded insulation. Conductors supplying 120-volts AC power on the load side of a disconnecting switch shall have black insulation for the ungrounded conductor and white insulation for the neutral. Wire marking shall comply with the next paragraph. The color of the insulation of the conductors shall be as follows, except as indicated otherwise in the Contract Documents.

	<u>120 VAC Power</u>		<u>120 VAC Control</u>
Hot	Match Phase Colors	PLC Output	Red
Neutral	White	PLC Input	Orange
Ground	Green		
	<u>24 VDC Power</u>		<u>24 VDC Control</u>
Positive (+)	Blue, mark (+)	PLC Output	Pink
Negative (-)	Blue, mark (-)	PLC Input	Purple
	<u>0-5 VDC Control</u>		<u>4-20 mA Control</u>
Positive (+)	Brown, mark (+)	Positive (+)	Red, White, or Clear
Negative (-)	Brown, mark (-)	Negative (-)	Black
	<u>Pulse Control</u>		<u>OTHER</u>
Positive (+)	Tan, mark (+)	Any service not listed above	Yellow
Negative (-)	Tan, mark (-)		

- e. Control Panel Internal Wire Marking: Each signal, control, alarm, and indicating circuit conductor internal to the control panel that is electrically continuous shall be designated by a single unique number which shall be shown on all shop drawings. These numbers shall be marked on all conductors at every terminal using white numbered wire markers which shall be plastic-coated cloth, Brady Type b-500, or equal or shall be permanently marked heat-shrink plastic loosely shrunk to allow label to be rotated.

- G. Conductor and Cable Tags: Refer to Section 16075 Electrical Identification Nameplates and Warning Signs and Standard Drawing S-465 for tagging information.
- H. Equipment Grounding Conductors:
 - 1. Provide soft-drawn copper conductors, not smaller than #12 AWG and as indicated or as required by NEC, for equipment grounding.
 - 2. Provide conductors with green insulation of the same type as all other circuit wires.
- I. Direct Buried Grounding Conductors: Provide bare stranded copper conductors, size as indicated, for the ground system grid at transformers, switchgear and where indicated.

2.3 CABLEBUS

- A. **Refer to SPECIFICATIONS, CABLE BUS, SECTION 16342 for Cablebus specification**~~Provide a CableBus System suitable for indoor and outdoor installation with voltage rating, current rating, and routing as shown on the Contract Drawings and meeting the requirements of Specification 16342.~~
- B. ~~The CableBus system shall be UL listed, meet the requirements of the NEC, and provided complete with supporting brackets and stainless steel hardware.~~
- C. ~~The cables used in the CableBus system shall be XHHW-2 and meet all the requirements specified in section 2.2.~~
- D. ~~Provide rain shields for terminations at transformers located outdoors and weatherproof sleeves when penetrating exterior building wall as required.~~

PART 3 - EXECUTION

3.1 GENERAL

- A. Do not exceed cable manufacturer's recommendations for maximum pulling tensions and minimum bending radii. Where pulling compound is used, use only UL listed compound compatible with the cable outer jacket and with the raceway involved.
- B. Tighten all screws and terminal bolts using torque type wrenches and/or drivers to tighten to the inch-pound requirements of the NEC and UL.
- C. Single conductors and cables in maintenance holes, handholes, vaults, cable trays, and other indicated locations shall be wrapped together by arc and fireproofing tapes, and shall be bundled throughout their exposed length with nylon, self-locking, releasable, cable ties placed at intervals not exceeding 12 inches on centers.
- D. Wires and cables in each voltage classification shall be installed in separate raceways and shall be completely isolated at the cable and wire terminations.
- E. No vehicles shall be used to pull conductors.
- F. A means of monitoring cable tension shall be provided at all pulls. (I.e. dynamometer)

- G. Cables shall be secured to cable trays at intervals not exceeding 4½ feet horizontally and 2 feet vertically. Cables shall be installed without splices.
- H. Cables of given voltage rating shall be grouped together. Individual circuits shall be bundled with phases A, B, and C together to minimize the effects of electromagnetic fields. Cables installed in-groups shall be grouped by lashing with manufactured plastic lashing ties spaced approximately 3 feet apart. Each circuit group shall be labeled to identify the circuit or control group by the designations given on the Contract Documents. Instrumentation cables shall be run in separate trays not containing power, control, and lighting cables. Control cables shall be barrier-separated from power cables. In addition, Class 2 and Class 3 instrumentation cables shall not be run in the same tray with Class 1 instrumentation circuits unless the different circuits are separated by a barrier. Class 1, 2 and 3 circuits are defined in Article 725 of the National Electrical Code.

3.2 CONDUCTOR 600 VOLTS AND BELOW

- A. Provide conductor sizes indicated on Drawings.
- B. Wire nuts may be used on solid conductors of 120-volt and 277-volt lighting and 120-volt receptacle circuits only. Place no more than one conductor in any single-barrel pressure connection. Use crimp connectors with tools by same manufacturer and/or UL listed for connectors of all stranded conductors.
- C. Soldered mechanical joints insulated with tape will not be acceptable. Do not use split bolt connectors if the wire sizes differ by 3 or more AWG sizes.
- D. Vinyl plastic insulating tape for wire and cable splices and terminations shall be flame retardant, 7-mil thick minimum, rated for 90 degrees C minimum meeting the requirements of UL 510.
- E. Provide terminals and connectors acceptable for the type of material used.
- F. Arrange wiring in cabinets, panels, and motor control centers neatly cut to proper length, remove surplus wire, and bridle and secure in an acceptable manner. Identify all circuits entering motor control centers or other control cabinets in accordance with the conductor identification system specified in Section 16075 Electrical Identification Nameplates and Warning Signs.
- G. Terminate control and instrumentation wiring with methods consistent with terminals provided, and in accordance with terminal manufacturer's instructions. Where terminals provided will accept such lugs, terminate all control and instrumentation wiring (except solid thermocouple leads) with insulated, locking-fork compression lugs, Thomas & Betts Sta-Kon, or equal.
- H. For terminals designed to accept only bare wire compression terminations, use only stranded wire, and terminate only one wire per terminal. Tighten all terminal screws with torque screwdriver to recommended torque values.
- I. Attach compression lugs with a tool specifically designed for that purpose which provides a complete, controlled crimp where the tool will not release until the crimp is complete. Use of plier type crimpers is not acceptable.
- J. Cap spare conductors and conductors not terminated with UL listed end caps.

- K. 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.
- L. For conductors that will be connected by others, provide at least 6 feet spare conductor in freestanding panels and at least 2 feet spare in other assemblies. Provide more spare conductor in any particular assembly where it is obvious that more conductor will be needed to reach the termination point.
- M. CONTRACTOR shall provide cable pulling tension calculations to the ENGINEER for review and approval before pulling cables sized 4/0 AWG and larger.
- N. Cable Terminations: Cable terminations shall comply with Class 1 of IEEE Standard 48. The insulation class shall be equivalent to that of the cable upon which they are installed. Terminations for shielded cables shall include a mechanical (nonsolder) shield-grounding strap. All materials (except lugs) necessary to make three terminations shall be included as a part of the termination kit. This shall include cable preparation materials. The seal shall be silicon rubber tape, cold-shrink rubber sleeve, or heat-shrink plastic sleeve as recommended by the kit manufacturer. Termination kits shall be performance tested for compliance with IEEE Standard 48 and shall be of the following types:
 - 1. Modular-type, furnished as a kit, with stress relief tube, multiple molded silicon rubber insulator modules, shield ground strap, and compression-type connectors.
 - 2. Heat-shrinkable type with heat-shrinkable inner stress control and outer nontracking tubes, multiple molded nontracking skirt modules, and compression-type connectors.
- O. The CONTRACTOR shall use cable installers who are experienced in the specific work of cable terminating for the specific types of cable and cable accessories specified in this Section.

3.3 CONDUCTORS ABOVE 600 VOLTS

- A. Splices will not be permitted unless specifically indicated or approved by the ENGINEER.
- B. Make all joints and terminations with high voltage splice and termination kits specified herein and in accordance with splice or termination manufacturer's instructions. Once started, install splices or terminations as a continuous operation.
- C. Identify all circuits in accordance with the conductor identification system specified at load centers, maintenance holes, splices, terminations, etc.
- D. Provide terminals or connectors acceptable for the type of conductor material used.
- E. Give 2 working days notice to the ENGINEER prior to the making of joints or terminations.
- F. Cable splices shall be made by qualified cable splicers in accordance with the recommendations of the manufacturer. CONTRACTOR shall furnish documentation detailing the qualifications of each cable splicer to be working on the job.

- G. CONTRACTOR shall provide cable pulling tension calculations prior to pulling any medium or high voltage cable.

3.4 CABLES

- A. Do not splice without permission of the ENGINEER. Locate splices, when permitted, only in readily accessible cabinets or junction boxes using terminal strips. Splices will not be permitted unless deemed necessary by approved pulling tension calculations.
- B. Where connections of cables installed under this Section are to be made under Division Instrumentation and Controls, leave pigtails of adequate length for neat bundled type connections.
- C. Instrumentation, computer, and control cables run under infinite access floors in control rooms may be installed under the floor without protection. Run individual wires, pairs, or triads in flex conduit under the floor or grouped into bundles at least one inch in diameter.
- D. Maintaining the integrity of shielding of instrumentation cables is essential to the operation of the control systems. Take special care in cable installation to ensure that grounds do not occur because of damage to the jacket over the shield.
- E. Cables entering maintenance holes, handholes or vaults shall be sealed using an expanding foam product approved for the purpose.

3.5 CONDUCTOR ARC AND FIREPROOFING TAPES

- A. ~~Use arc and fireproofing tapes on all 600-volt single conductors and cables in all maintenance holes, handholes, vaults, cable trays, and other indicated locations.~~
- B. Use arc and fireproofing tapes on all 15 kV cables throughout their entire exposed length in all maintenance holes, handholes, vaults, cable trays, and other indicated locations.
- C. Wrap together as a single cable all conductors entering from each conduit.
- D. Follow tape manufacturer's installation instructions. Secure the arc and fireproofing tape at frequent intervals with bands of the specified glass cloth electrical tape. Make each band of at least two wraps of tape directly over each other.
- E. Wrap together as far as possible, conductors carrying phases A, B, and C of the same feeder. Do not wrap together conductors carrying only two of the three phases.
- F. The cables shall be trained as closely as possible to their final positions.
- G. The cables shall be cleaned of all oil, grease, and cable pulling compounds using suitable solvents and cleaners non-injurious to cable and then wiped completely dry.
- H. Any projecting surfaces such as fittings, ground connectors or bonding connections shall be covered with an insulating compound to present a smooth continuous surface for taping.

- I. Fireproofing tapes shall be submitted as shop drawings for approval. Tapes shall be 3-inch width half-lapped and extend a minimum of 6-inches into the raceway. Use glass tape at three-foot intervals to hold tape in place.

3.6 CABLEBUS

- A. Install cablebus in strict accordance with manufacturer's recommendations and the requirements of the NEC. Do not space cablebus supports more than 10 feet apart. Provide cablebus that is UL listed for support and spacing used.
- B. Coordination between supplier of cablebus, supplier of switchgears and transformers that connects to cablebus, and electrical CONTRACTOR is essential to properly interface these systems. Provide equipment submittals that include specific information related to cablebus-equipment interfacing.

3.7 UNDERGROUND DIRECT BURIAL CABLE

- A. Comply with requirements for Installation of Underground Direct Burial Raceways in Section 16130, "Raceway Systems and Pullboxes", including warning tapes above the cables. Such cable shall not be used in permanent installations.

3.8 FIELD TESTS

- A. Field test shall be performed on conductors in accordance with Section 16080 Electrical Testing.

3.9 UNDERGROUND WIRE AND CABLE INSTALLATION

- A. Wire and Cable Installation

Before pulling wire or cable in underground conduit, the conduit shall be mandreled with a painted wooden mandrel 2½ inches long having a diameter of ½ inch smaller than the inside diameter of the conduit.

Conductors shall be installed using a nylon pulling rope. A nylon pulling rope shall be left in each spare underground conduit for future installations.

The pulling compound for all types of wire and cables, except lead-covered cables and thermocouple wire, shall be a waterbased gel lubricant, American Polywater Corp. "Polywater Lubricant J", or approved equal. The cable manufacturer shall be consulted for acceptable pulling compounds. The pulling compound for lead-covered cables shall be cup grease. Thermocouple wire shall be pulled in dry.

Care shall be taken to avoid sharply binding or kinking conductors, damaging insulation, or stressing cable or wire beyond manufacturer's recommendations during pulling. Maximum calculated cable pulling tensions and sidewall pressures shall not be exceeded during cable pulling.

3.10 TERMINAL BLOCKS

- A. Terminal Blocks: Terminal blocks shall be of the size required for conductors installed thereon and a minimum of 20 percent spares shall be provided in each terminal box. Terminal blocks shall be Buchanan, Square D Company, or equal.

1. Control conductors shall be attached to screw-type terminal strips using tinned, insulated, locking-spade lugs.
2. Terminal blocks installed in the field shall have the individual terminals as shown on the elementary diagrams or per the project numbering system established on the Contract Documents.

3.11 TERMINATIONS AND SPLICES

- A. Terminations and Splices: Splicing cables in conduits is prohibited. Splicing of power and control cables is prohibited, except where specifically approved by the ENGINEER. Where required, lighting and 120 V receptacle circuits using solid #12 AWG conductors may be spliced in conduit fittings using twist-on-type connections. A tubular crimp-type splice shall be used for stranded conductors. Conductors shall be spliced in enclosures or fittings approved for the purpose. The number of splices shall be kept to a minimum.
1. Splicing shall join conductors mechanically and electrically to provide a complete circuit prior to installation or insulation. Splices in wet locations and all splices below grade shall be waterproof, heat-shrink type as manufactured by Elastimold, Raychem, or equal.
 2. Splices at motor junction boxes shall be accomplished by joining of motor lead wire to feeder cable with compression-type lugs. The lugs shall be bolted together with washers, and lockwashers. The lugs shall then be insulated using a cold roll-type motor pigtail splice kit as manufactured by 3M, Raychem, or equal.
 3. All terminations for medium voltage cable shall be made using termination kits.
 4. The number of taps and splices shall be held to a minimum. Boxes containing splices shall be sized in accordance with NEC and in no case shall the number of conductors exceed that allowed in NEC. For control circuits, splicing of conductors is not allowed except that devices that have pigtail wiring may be spliced in an approved enclosure. If splicing is required, the conductors shall be connected at approved terminals in an approved enclosure. Barriers shall be provided to separate various classes of control and/or power circuits in enclosures where terminations are made.

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