

DIVISION 16

ELECTRICAL

160100 GENERAL

It is the intent of this part of the Contract Documents to cover all work and materials necessary for erecting complete, ready for continuous use, a tested and working electrical system, substantially as indicated on the Plans and as hereinafter specified. The work specified in this Division includes materials, testing, and installation of electrical system and equipment.

160101 GENERAL PROVISIONS

Minimum sizes of equipment, electric devices, etc., are indicated but it is not intended to show every offset and fitting, nor every structural or mechanical difficulty that will be encountered during the installation of the work.

All work indicated on the Plans is approximately to scale, but actual dimensions and detailed drawings should be followed as closely as field conditions permit. Field verification of scale dimensions on Plans is directed since actual locations, distances, levels, etc. will be governed by field conditions.

Discrepancies indicated on different Plans, between Plans and actual field conditions, or between Plans and Contract Documents shall be promptly brought to the attention of the Engineer for a decision.

The alignment of equipment and conduit shall be varied due to architectural changes, or to avoid work of other trades, without extra expense to the Owner.

The Contractor shall furnish and install all parts and pieces necessary to the installation of equipment in accordance with the best practice of the trade and in conformance with the requirements of these Contract Documents.

All items not specifically mentioned in these Contract Documents or noted on the Plans or accepted shop drawings, but which are obviously necessary to make a complete working installation, shall be deemed to be included herein.

Typical electrical details indicated on the Drawings shall apply to all locations whether or not they are specifically referenced on any drawings.

The Contractor shall lay out and install electrical conduit prior to placing floors and walls. He shall furnish and install all sleeves and openings through floors and walls required for passage of all conduits. Sleeves shall be rigidly supported and suitably packed or sealed to prevent ingress of wet concrete.

The Contractor shall furnish and install all inserts and hangers required to support conduits and other electrical equipment. If the inserts, hangers, sleeves, etc. are improperly placed or installed, the Contractor shall do all necessary work, at his own expense, to rectify the errors.

All electrical equipment shall be capable of operating successfully at full-rated load, without failure, at an ambient air temperature of 40 degrees C, and specifically rated for an altitude of 5000 feet.

The Contractor shall submit shop drawings, data and details to the Engineer on all controls, fixtures, wiring, electrical equipment, conduit, etc. for review and acceptance prior to use of any components in the work.

The Contractor shall provide for delivery, unloading, transportation and storage of all equipment under this Contract until such time as installation is required. To insure adequate protection of all electrical and instrumentation equipment and panels, all such equipment shall be stored in a suitable, air conditioned enclosure designed to protect this equipment from temperatures above 90 degrees F. The Owner shall assume no liability for either the storage facilities or equipment stored therein. The Contractor shall be responsible for maintaining the storage facilities and equipment stored therein and shall make provision for all utilities required. Continuous access shall be provided to the Owner for all equipment so stored.

160102 WORK INCLUDED

- A. Furnishing, installation, connections, and testing of control and power panels and equipment.
- B. Electrical connections of all equipment furnished under this and other Divisions of the Contract, and requiring electric power and/or control.

160103 REGULATIONS AND CODES

Electrical work, including connection to electrical equipment integral with mechanical equipment, shall be performed in accordance with the latest published regulations of the National Electrical Code (NEC), National Electrical Safety Code (NESC), State and local codes, and according to the latest Institute of Electrical and Electronic Engineers (IEEE); American National Standards Institute (ANSI); American Society for Testing and Materials (ASTM); Insulated Cable Engineers Association (ICEA); National Electrical Manufacturers Association (NEMA) Standards; National Electrical Contractors Association (NECA) Standard of Installation; and the latest published regulations of the Federal Occupational Safety and Health Act (OSHA). When applicable, the material used in the performance of the electrical work shall be approved by the Underwriters' Laboratories, Inc. (UL) for the class of service for which they are intended.

160104 SEISMIC REQUIREMENTS

The Contractor is informed herein that all electrical equipment installed in this project shall be securely anchored, tied, restrained, or attached to the structures in such a manner that such equipment shall remain in place and function when subject to seismic forces. The Contractor shall be responsible for assuring the Owner that all subcontractors and suppliers furnish and install equipment and its anchorage in a manner that shall conform to these requirements. Shop drawings for the following equipment shall be provided to show anchorage provisions which comply with these seismic requirements.

- A. Control panels and devices.

160105 TEMPORARY POWER

The Contractor shall furnish, install and maintain all temporary power and lighting systems needed for construction. This temporary system shall include weatherproof panel(s) for the Contractor's main breakers and distribution system. Ground fault interrupting equipment shall be installed. All connections shall be watertight with wiring done with Type SO portable cable. After construction is completed, the Contractor shall remove all temporary power equipment and devices.

160106 CUTTING AND REPAIRING

Where it becomes necessary to cut into existing concrete for the purpose of making electrical installations, core drills shall be used for making circular holes. Other demolition methods for cutting or removing shall be reviewed by the Engineer prior to starting the work.

The Contractor shall repair all damage caused thereby and restore damaged areas to original condition.

160107 CORROSION PROTECTION

Wherever dissimilar metals, except conduit and conduit fittings, come in contact, the Contractor shall isolate these metals as required with neoprene washers, 9-mil polyethylene tape, or gaskets. Where fastening conduit, electro plated, or equivalent fasteners and stainless steel bolts shall be used.

Factory finishes damaged and/or rusting shall be restored to original new condition.

All electrical panels, switchgear, motor control centers, etc. shall be shipped in sealed dust and moistureproof plastic sheet enclosures and the seal maintained until units are installed. Said units shall be in new condition, no dirt, dust, water, grease, rust, damaged parts, components, etc. All relay, starter, circuit breaker, switches, etc., contacts, insulators, mechanisms, and buses shall be free of dust, dirt, oil, moisture, metal shavings, etc. before testing and energizing.

All support channels, used in conjunction with the electrical work, shall be galvanized steel unless specifically specified or indicated on the drawings.

Once equipment is installed, it shall be protected at all times with plastic sheet covers until the area is secure from dirt, dust, workers, paint spray, water, etc. Heat shall be provided to eliminate condensation.

160108 COORDINATION OF THE ELECTRICAL EQUIPMENT RATING

The Contractor shall verify all actual equipment and motor full-load and locked-rotor current ratings. The necessary minimum equipment, wire, and conduit sizes are indicated on the Plans. If the Contractor furnishes equipment of different ratings, the Contractor shall coordinate the actual current rating of equipment furnished with the branch circuit conductor size, the overcurrent protection, the controller size, the motor starter, and the branch circuit overcurrent protection. The branch circuit conductors shall have a carrying capacity of not less than 125 percent of the actual full-load current rating. The size of the branch circuit conductors shall be such that the voltage drop from the overcurrent protection devices up to the equipment shall not be greater than 2 percent when the equipment is running at full-load and rated voltage.

The motor running overcurrent protection devices shall be rated or selected to trip at no more than 125 percent of the motor full-load current rating for motors marked to have a temperature rise not over 40 degrees C or motors marked with a service factor not less than 1.15 and at no more than 115 percent for all other types of motors. The motor controller size shall be coordinated to the current rating and horsepower size of the installed motor.

The motor-branch-circuit overcurrent protection device shall withstand the locked-rotor current of the motor without tripping. This device shall also protect the motor-branch-circuit conductors and the motor control apparatus against overcurrent due to short-circuits or grounds. The motor control circuits shall have overcurrent protection of the type indicated on the Plans.

160109 TEST

The electrical work shall be free from improper grounds and from short circuits. The correctness of the wiring shall be verified first by visual comparison of the conductor connections with connection diagrams. Individual circuit continuity checks shall next be made by using electrical circuit testers. Last, the correctness of the wiring shall be verified by the actual electrical operation of the electrical and mechanical devices. Any deviation from the wiring indicated on the Plans or accepted drawings shall be corrected and indicated on the Record Drawings. The Contractor shall meter test all power and control wiring for all circuits and record results to ensure that actual tests are made and all circuits are free from improper grounds or shorts. The recorded results shall be submitted to the Owner as a record document.

Electrical tests shall be made on all medium voltage and low voltage equipment and shall consist of the following but not limited to:

- Low voltage motor control center and distribution equipment
- Switchgear, motor controls including all protective meters and relaying
- DC hypotential tests
- Switchgear ground and resistance to ground
- Medium and low voltage transformers

160110 CONFORMS TO RECORD DOCUMENTS DRAWINGS

Prior to completion of the Contract, the Contractor shall furnish the Engineer with a set of electrical plans marked with any changes, deviations or additions to any part of the electrical work.

Each conductor shall be identified as required by the Contract Documents. This identification shall be indicated on the record documents drawings to enable rapid and accurate circuit tracing by maintenance personnel.

160111 SINGLE LINE DIAGRAMS

Single line diagrams, as indicated on the Plans, show circuit voltages, (5xx is 4160V, 4xx is 480V, 3xx is 277V, 2xx is 208V, 1xx is 120V circuits), wire and conduit sizes, circuit protection rating, and other pertinent data. Where conflicts exist on the Plans the single line diagrams shall take precedence. Grounding conductors are not necessarily indicated. See grounding requirements specified elsewhere herein.

160112 CIRCUIT IDENTIFICATION

The 3-phase wires shall be identified at the switchgear, panelboards and motor control centers as Phases A, B, and C.

Color coding of general purpose conductor and cable should be in accordance with the following:

<u>Application</u>	<u>Conductors</u>	<u>Color</u>
3 Phase, 12,470 V	Phase A	3 black strips
	Phase B	3 red strips
	Phase C	3 blue strips
3 Phase, 5 KV Power (4,160 V)	Phase A	2 black strips
	Phase B	2 red strips
	Phase C	2 blue strips
3 Phase, 480 V, 208 Y/120 V Power or 240 V	Phase A	Brown
	Phase B	Orange
	Phase C	Yellow
	Neutral	White
Control	All	Violet
All Systems	Neutral	White or Gray
	Ground	Green

In addition to color coding all conductors, each conductor shall be identified in each pull box, manhole, panelboard, cable tray, or termination with circuit identification markers. This identification is applicable to all power, control, alarm, and instrumentation conductors and these markings shall be recorded on the Record Documents. Markers shall be slip-on PVC sleeve type as manufactured by Brady, Seaton, or equal.

Markers for other cabling shall be B-292 vinyl as manufactured by Brady, Seaton, or equal.

160113 NAMEPLATES

The Contractor shall furnish and install nameplates which shall be black laminoid with white letters. The nameplates shall be fastened to the various devices with round head stainless steel screws. Each disconnect means for service, feeder, branch, or equipment conductors shall have nameplates indicating its purpose. All field mounted devices, transmitters, instruments, control stations etc. shall have identification nameplates.

All motor control centers, switchgear, control panels, light switches, enclosures and pull boxes shall have nameplates which shall consist of equipment name, function and applicable circuit designation.

160114 AUTOMATIC EQUIPMENT WARNING SIGNS

Permanent warning signs shall be mounted at all mechanical equipment which may be started automatically or from remote locations. Signs shall be in accordance with OSHA regulations and shall be suitable for exterior use. The warning signs shall be fastened with round head stainless steel screws or bolts, located and mounted in a manner acceptable to the Engineer.

Warning signs shall be 10 inches high by 14 inches wide, colored yellow and black, on not less than 18 gauge vitreous enameling steel. Sign shall read:

DANGER
THIS EQUIPMENT STARTS
AUTOMATICALLY
BY REMOTE CONTROL

160115 HIGH VOLTAGE WARNING SIGNS

Permanent and conspicuous warning signs shall be mounted on all equipment, doorways to equipment rooms, pull boxes, manholes, where the voltage exceeds 600 volts.

Signs shall be in accordance with OSHA regulation, and shall be suitable for exterior use. The warning signals shall be fastened with round head brass screws or bolts, located and mounted in a manner acceptable to the Engineer.

Signs shall be 10 inches high by 14 inches wide, colored red and white, on not less than 18 gauge vitreous enameling steel. Sign shall read:

DANGER
HIGH VOLTAGE
KEEP OUT

Exposed medium voltage circuit raceways shall be labeled at 50 foot intervals with 7 inch letters stating voltage. For example: 12,470 Volts - Labels shall be vinyl plastic made by Brady; Seaton; or equal.

160116 CONDUCTOR FASTENERS

Glue-on type conductor fasteners shall not be used in any panels, panelboards, switchboards, switchgear, motor control centers, or other enclosures containing electrical devices and/or conductors. Snap on or screw on type shall be used. Provide backplate for non glue-on type of fasteners.

160200 GENERAL MATERIALS AND METHODS

160201 GENERAL

All materials, equipment, and parts comprising any unit or part thereof specified or indicated on the Plans shall be new and unused, of current manufacture, and of highest grade consistent to the state of the art. Damaged materials, equipment and parts are not considered to be new and unused and will not be accepted.

Field verification of scale dimensions on Plans is directed since actual locations, distances, and levels will be governed by actual field conditions. The Contractor shall also review architectural, structural, yard, mechanical and other Plans, and the accepted electrical and mechanical shop drawings, and shall adjust his work to conform to all conditions indicated thereon.

160202 RACEWAYS

Raceways include rigid metal conduit, rigid nonmetallic conduit, or any other channel for holding wires, cables, or bus bars that is designed for, and used solely for, this purpose.

160202.10 CONDUIT

160202.11 GENERAL

All conduit shall be rigid steel unless specifically indicated otherwise on the Plans. All wiring, except as otherwise noted, shall be in conduit. Conduit size shall not be less than the National Electrical Code (NEC) size required for the conductors therein and shall not be smaller than 3/4-inch. No underground conduit shall be less than 1 inch.

Conduit runs are schematic only, and shall be modified as required to suit field conditions, subject to review and acceptance by the Engineer.

Conduit shall run continuously between outlets and shall be provided with junction boxes where connections are made, except in special pull boxes indicated on the Plans.

Conduits entering or exiting concrete shall be PVC coated or equivalent.

Conduit runs shall be straight and true; elbows, offsets, and bends shall be uniform and symmetrical. Changes in direction shall be made with long radius bends or with fittings of the conduit type. Conduit type fittings shall be Crouse-Hinds, Appleton, or equal with wedge nut covers.

Conduit runs in buildings and structures shall be exposed except as specifically noted or accepted by the Engineer.

Conduit runs shall not interfere with the proper and safe operation of equipment and shall not block or interfere with ingress or egress, including equipment removal hatches.

Exposed conduits shall be securely fastened with regulation clamps or straps. All exposed conduit shall be run on the walls and ceiling only and shall be parallel to the planes of the walls or ceiling. No diagonal runs will be permitted. Flexible conduit shall be used only for short lengths required to facilitate connections between rigid conduit and motors or control equipment. The maximum length of flexible conduit shall be 5 feet. Where flexible conduit is used, it shall be grounding type, weatherproof and watertight as manufactured by American Brass Company, General Electric, or equal. All conduits located outdoors or in wet locations shall be weathertight.

Conduit runs on water-bearing walls shall be supported 1 inch away from the wall on an accepted channel. When channel galvanizing or other coating is cut or otherwise damaged, it shall be field coated to original condition. No conduit shall be run in water-bearing walls, unless specifically designated otherwise.

Underground conduit runs shall be concrete encased, as detailed on the Plans, unless otherwise noted.

All conduit shall be thoroughly reamed after the threads have been cut to remove burrs. All joints shall be made with acceptable sealing compound and shall be watertight. Bushings or conduit fittings shall be used at all conduit terminals. The total of all bends in any run between pull boxes or junction boxes shall not exceed 360 degrees. Pull boxes shall be installed at points acceptable to the Engineer. Conduits brought into pull boxes, conduits, and other openings shall be capped until used to prevent the entrance of moisture. All spare conduits shall be capped and shall contain a suitable plastic (non-corrosive) pulling wire.

Joints shall be set up tight. Hangers and fastenings shall be secure and of a type appropriate in design and dimensions for the particular application.

After installation of complete conduit runs 2 inches and larger, conduits shall be snaked with a conduit cleaner equipped with a cylindrical mandrel of a diameter not less than 85 percent of the nominal diameter of the conduit. Conduits through which the mandrel will not pass shall not be incorporated as part of the contract.

Conduit runs shall be cleaned and internally sized (obstruction tested) so that no foreign objects or obstructions remain in the conduit prior to pulling in conductors.

Couplings, connectors, and fittings shall be threaded and shall be certified types specifically designed and manufactured for the purpose. They shall be installed expertly to provide a firm mechanical assembly and electrical conductivity throughout.

All medium voltage underground conduit shall be PVC coated rigid galvanized steel.

Expansion fittings shall be installed across all expansion joints and at other locations where necessary to compensate for thermal expansion and contraction. Expansion fittings shall be OZ Type AX with jumper for exposed locations and Type DX at structural expansion joints, Spring City, or equal.

Shop drawings shall be submitted as requested by the Engineer for review and acceptance showing routing, conduit size, and number and size of wires in each conduit before installation of conduit.

160202.12 RIGID STEEL

Conduit and couplings shall be hot-dipped galvanized with zinc coated threads and outer coating of zinc bichromate as manufactured by Triangle PWC, Inc., Allied Tube and Conduit Corporation, or equal.

Steel conduit shall not be buried in earth without concrete encasement except in special cases where PVC coating is indicated on the Plans.

160202.14 PVC COATED STEEL

PVC coated conduit and fittings and associated pull boxes shall be installed where shown on the Plans or elsewhere specified and shall conform to NEMA RN-1, Current Edition.

The zinc surface of the conduit shall remain intact and undisturbed on both the inside and the outside of the conduit throughout the preparation and application processing. A Polyvinyl Chloride (PVC) coating shall be bonded to the galvanized outer surface of the conduit. The bond between the PVC coating and the conduit surface shall be greater than the tensile strength of the plastic. The thickness of the PVC coating shall be a minimum of 0.040-inch (40 mil).

A loose coupling shall be furnished with each length of conduit. A PVC coating shall be bonded to the outer surface of the coupling and a PVC sleeve equal to the outside diameter of the uncoated conduit shall extend beyond both ends of the coupling approximately one pipe diameter or 1-1/2 inches, whichever is smaller. The wall thickness of the coating on the coupling and the sleeve shall be a minimum of 0.055-inch (55 mil).

A PVC coating shall be bonded to the outer surface of all conduit bodies and fittings and a PVC sleeve shall extend from all hubs. The wall thickness of the coating on conduit bodies and fittings and the sleeve walls shall be identical to those on couplings in length and thickness. The covers on all conduit bodies shall be coated on both sides and shall be designed to be completely interchangeable. The inside of conduit bodies shall remain undisturbed in the processing and shall retain the manufacturer's cadmium plate-aluminum paint finish.

Stainless steel screws shall be furnished and used to attach the cover to the conduit body. All coated material shall be installed and patched according to the manufacturer's recommended installation and patching instructions.

PVC coated conduit and fittings shall be as manufactured by Kor Kap Corporation, Occidental Coating Company, or equal.

160202.16 RIGID NONMETALLIC - PVC

Where specifically indicated on the Plans, or elsewhere specified, conduit may be high density Schedule 80, 90 degrees C, heavy-duty PVC. The conduit shall be manufactured from virgin polyvinyl chloride compound which meets ASTM standards. Smoke emissions shall be limited to less than 6 grams per 100 grams of material tested. Encasement shall be reinforced as indicated on the Plans. Conduit supports shall be installed at 2-1/2 foot intervals. PVC conduit shall be manufactured by Carlon, Triangle Conduit and Cable, or equal.

160202.20 CONDUIT SCHEDULE

<u>Location</u>	<u>Conduit</u>
Utility power conduits underground	PVC Sch 80
Utility power conduits exposed	Galvanized rigid steel
Conduits exposed	Galvanized rigid steel
Conduits entering concrete	Galvanized rigid steel
	Tapped wrapped or PVC coated
Conduits in concrete	PVC Sch 40
Conduits below ground, not in duct bank	PVC Sch 80
Conduits below ground in concrete duct bank	PVC Sch 40

160202.30 METAL PULL BOXES

160202.31 GENERAL

Furnish and install pull boxes as indicated on the Plans and specified herein.

Installation of pull boxes shall be such that access to the pull boxes is not restricted by obstructions such as pipes, valves, ladders, etc. Exact locations and sizes shall be submitted to the Engineer for review and acceptance prior to fabrication and installation.

Additional pull boxes shall be installed as required to meet cable manufacturer's pulling tension requirements.

Covers shall be secured with 3/16 stainless steel screws or bolts with coated threads.

160202.32 CONSTRUCTION

Pull boxes shall be compatible with the type of conduit systems on which they are used. Pull boxes shall be fabricated from 1/2-gauge (minimum) steel or aluminum and shall be completely weatherproof with gasketed removable covers. Weatherproof conduit hubs shall be furnished for all conduit connections to pull boxes.

160202.33 FINISH

All metal surfaces shall be phosphatized and primed with a rust-resistant paint. Finish shall be two coats of "Safety Red" enamel paint.

160202.35 SIZING

Pull boxes shall be sized according to code and shall be sized to provide room for the future conduits and cables indicated on the Plans.

160203 CONDUCTORS

160203.01 GENERAL

All wiring shall be as indicated on the Plans. Wires shall be newly manufactured (not more than 12 months old) and shall be soft drawn copper with not less than 97 percent conductivity. The wire and cable shall have size, grade of insulation, voltage, and manufacturer's name permanently marked on the outer covering at not more than 2-foot intervals. All wires shall conform to the latest Standards of the ASTM and ICEA and shall be tested for their full length by these Standards. Insulation thickness shall be not less than that specified by the National Electrical Code.

Wire sizes shall be American Wire Gauge sizes with Class B stranded construction. No. 12 and No. 10 AWG may be solid conductor.

No. 2 AWG and smaller shall be factory color coded with a separate color for each phase and neutral, which shall be used consistently throughout the system. Larger cables shall be coded by the use of colored tape.

As far as practicable, all circuits shall be continuous from origin to termination without splices in intermediate pull boxes. Sufficient slack shall be left at the termination to make proper connections. In no case shall a splice be pulled into the conduit.

160203.02 PULLING LUBRICANT

All cables shall be properly coated with pulling compound recommended by the cable manufacturer before being pulled into conduits so as to prevent mechanical damage to the cables during installation.

Other lubricants to be substituted must be accompanied by a statement from the cable manufacturer as to its acceptable use with the cable being installed.

160203.07 15 KV SERVICE SUBSTATION PRIMARY CABLE

UP&L will supply and install the primary cable from 4100 South to the transformer pad. The Contractor shall excavate and install the required segments of conduits from 4100 South to the booster station transformer pad. UP&L will install the primary cable in the excavated trench and conduits under 4100 South and the railroad tracks.

All grounding requirements at the service transformer and at the service pull box shall be done by the Contractor at no additional cost to the Owner.

160203.20 600-VOLT CLASS CABLE

Individual or multiple conductor cables for power, control, and alarm circuits of 480 volts or less shall be insulated for not less than 600 volts and shall have Type THWN insulation. Cable tray conductors shall have Type TC insulation. Where wire size is not indicated, they shall be of the size required by the NEC, except that no wire external to panels and motor control centers shall be less than No. 12 AWG, unless specifically noted on the Plans. Panel control wiring shall not be less than No. 14 AWG. Wire and cable shall be as manufactured by Okonite Company, Anaconda Wire and Cable Company, or equal.

The pulling tension and side-wall pressures, as recommended by the cable manufacturer, shall not be exceeded.

160203.21 TERMINATIONS AND SPLICES (600-VOLT AND LESS)

Terminations shall be terminal board type with set-screw pressure connectors. Splicing shall join conductors mechanically and electrically to provide a complete circuit prior to installation of insulation. Conductors, including grounding conductors, of different sizes shall be spliced and then soldered or welded. Splices in wet locations and all splices below grade shall be waterproof heat shrink type as manufactured by Elastimold, Thomas-Betts, or equal.

160203.30 INSTRUMENTATION CLASS CABLE

Instrument cable shall have the number of twisted pairs indicated on the Plans and shall be insulated for not less than 600 volts. Unless otherwise indicated, conductor size shall be No. 18 AWG minimum.

The jacket shall be flame retardant Flamenal or Okoseal, 90 degrees C temperature rating. The cable shield shall be a minimum of 2.3-mil aluminum or copper tape overlapped to provide 100 percent coverage and a tinned copper drain wire.

The conductors shall be bare soft annealed copper, Class B, 7-strand minimum concentric lay with Okoseal or Vulkene, 15 mils nominal thickness, nylon jacket, 4 mils nominal thickness, 90 degrees C temperature rating. One conductor within each pair shall be numerically identified.

Pairs shall be assembled with a nominal 2-inch lay and shall then be group shielded with a minimum of 1.3-mil aluminum or copper tape overlapped to provide 100 percent coverage. All group shields shall be completely isolated from each other.

Instrumentation cables shall be installed in separate raceways. This includes through manholes. Instrumentation cable shall be continuous between instruments or between field devices and instrument enclosures. There shall be no intermediate splices or terminal boards.

The instrumentation cable shall be Type TC as manufactured by Okonite, Okoseal-N Type SP-OS, Belden equivalent or equal.

160204 GROUNDING

The grounding systems shall consist of concrete encased ground conductors and/or ground rods. Each duct bank shall contain a concrete encased system ground conductor. The system ground conductors shall run continuously in duct banks, through manholes, handholes, and other raceway boxes. The system ground shall be connected to the structure grounding systems to provide a continuous ground system. Each metallic raceway, panel, switchboard, and other metallic devices associated with the electrical and instrumentation systems shall be bonded to this grounding system.

All equipment cases, devices, etc. shall be grounded. Ground rods shall be driven or concrete encased conductors installed before a building or structure is built and ground conductors brought through the

concrete to accessible points for grounding equipment. These systems shall be installed at each structure where switchgear, motor control centers, switchboards, panelboards, etc. are installed.

Where ground conductors are not sized, the NEC shall govern. Driven ground rods shall be copperweld, or equal, 5/8-inch in diameter and not less than 10 feet in length.

All connections of ground cable to rods or to cable shall be thermoweld connections. Maximum allowable ground resistance shall be 3 ohms.

Tests shall be conducted by the Contractor and witnessed by the Engineer to determine the ground resistance for the entire system and at each building where there is switchgear, motor control, etc.

It is the intent of these Contract Documents that a grounding conductor for all device and equipment grounds shall be run as a separate conductor in the conduit from the equipment to the motor control center or system ground. All wireways, enclosures, etc. shall be properly bonded and grounded, and grounding conductors shall be run for all circuits. See drawings for additional grounding requirements.

160205 OUTLET, SWITCH, PULL AND JUNCTION BOXES

160205.01 GENERAL

Unless otherwise specified or indicated on the Plans, device boxes, condulets and junction boxes shall be heavy-duty cast and shall be compatible with the location and conduit system being used, rigid steel or rigid copper free aluminum and shall be as manufactured by Crouse-Hinds, Appleton, or equal, with stainless steel cover screws and with cover gaskets. Device boxes shall be FD type.

160205.10 FASTENERS

Fasteners used with wiring devices shall be aluminum or stainless steel and all screws, nuts, bolts, etc. shall be stainless steel.

160205.20 CONCRETE PULL BOXES

The Contractor shall furnish and install precast concrete pull boxes in the locations indicated on the Plans and as required.

The pull boxes shall be installed on 12 inches of compacted gravel and shall be installed in such a manner that the cover of the pull box will be flush with finished grade.

The pull boxes shall be designed for traffic conditions, and the pull box and cover shall be designed for heavy traffic bridge loading. The pull boxes shall be a minimum of 3 feet by 2 feet by 30 inches deep with 3/4-inch diameter pulling irons located at each end. The pull boxes shall be constructed of reinforced Class A concrete.

The pull boxes shall be Quickset, Utility Vault Company, or equal, with covers. The covers shall be engraved "ELECTRICAL."

160206 LIGHTING SWITCHES

160206.01 GENERAL

Snap switches shall have the number of poles as indicated on the Plans, shall be specification grade, rated at 20-ampere, and shall be as manufactured by Hubbell, General Electric, or equal. Special switches, covers, etc. shall be as specified herein or indicated on the Plans. All light switches shall be mounted at 42 inches above finished floor unless otherwise indicated on the Drawings.

160206.10 INDOOR

Stainless steel cover plates shall be utilized.

160206.20 OUTDOOR AND CORROSION RESISTANT

Enclosures shall be weatherproof.

160207 RECEPTACLES

160207.01 GENERAL

Duplex receptacles shall be 2-pole, 3-wire grounded, 120 volts, industrial, rated at 20 amperes, and shall be as manufactured by Hubbell, General Electric, or equal. Special receptacles, covers, etc. shall be as specified herein or as indicated on the Plans. All receptacles shall be mounted at 36 inches above finished floor unless otherwise noted on the Drawings.

160207.10 INDOOR

Stainless steel cover plates shall be utilized.

160207.20 OUTDOOR AND CORROSION RESISTANT

Enclosures shall be weatherproof with yellow "fiberglass" lift cover plates or accepted equal.

160207.30 GROUND FAULT INTERRUPTER RECEPTACLES (GFI)

GFI outlets shall be rated at 20 amperes at 125 volts AC as manufactured by Leviton, Bryant, or equal. All outdoor receptacles and receptacles mounted below grade, and in vaults shall be GFI type.

160207.50 240-VOLT RECEPTACLES

The 240-volt receptacles shall be of the ampere rating as indicated on the Plans, however, the minimum rating shall be 20 amperes at 250 volts AC and shall be as manufactured by Leviton, Bryant, or equal.

160208 PUSH-BUTTON STATIONS

160208.01 GENERAL

Push buttons, selector switches, and pilot lights (screw-on type) shall be heavy-duty, oiltight manufactured by Square D Company; General Electric Company; or equal. Control stations shall be in NEMA 4X enclosures (corrosion resistant, compression molded fiberglass) for outdoor and corrosive resistant (NEMA 4X) areas as designated on the Drawing and NEMA 12 for indoor installations. Lenses shall be clear not opaque. NEMA 4X enclosures and pushbuttons shall be Crouse-Hinds, N Series, Allen-Bradley 800 H Series, or equal.

"Start-Lockout-Stop" push-button stations shall be installed adjacent to every motor unless specifically indicated otherwise. Lockout mechanism shall be made of metal.

For MCC or control panel-mounted or stand-alone pushbutton stations, the pushbuttons shall be heavy duty oil tight, rugged construction with chromeplated lockrings and guards. All pilot lights shall be transformer push-to-test LED type.

160209 TRANSFORMERS - DRY TYPE

160209.10 DISTRIBUTION TRANSFORMERS - LOW VOLTAGE LIGHTING AND POWER

Transformers shall be of the premium high efficiency quiet type and shall be installed where indicated on the Plans. The primary winding of the transformers shall have two 2-1/2 percent taps above and below normal. All windings shall be copper.

The transformers shall have a BIL of 10 KV with a temperature class of 185 degrees C for transformers up to 25 KVA and a temperature class of 220 degrees C for transformers rated at 30 KVA and larger.

The sound level shall not exceed 44 dba measured at 5 feet from the transformer after installation. Core and coil assemblies 30 KVA and larger shall be mounted on rubber vibration isolators designed specifically to reduce 120 Hertz sound and multiple harmonics.

Transformer standards shall be submitted to the Engineer prior to purchase and installation.

Transformers shall be of the types manufactured by General Electric Company, Westinghouse Corp., or equal.

160209.20 ISOLATION TRANSFORMERS

Isolation transformers shall be provided for all solid state devices and elsewhere where indicated. Regulation shall be ± 3 percent for an input range of ± 10 percent. Common mode noise rejection shall be better than 120 db with transverse mode noise rejection better than 60 db. Voltage spike attenuation shall be better than 250:1.

Isolation transformers shall be as manufactured by Square D, Westinghouse, or equal.

160210 RELAYS

160210.10 CONTROL RELAYS

Control relays shall be General Electric, Westinghouse, Square D Company, or equal, industrial 600-volt, 10-ampere type with contact arrangement and operating coils of the proper voltage as required by the control circuit sequence. Each relay shall have a minimum of four reversible pole contacts. The coils shall be sealed by pressure molding.

160210.11 INTRINSICALLY SAFE RELAYS

Intrinsically safe relays shall allow the use of any type of remote pilot device located in Class 1 hazardous areas by providing a pilot circuit incapable of releasing sufficient electrical energy to ignite gases and vapors classified in Groups A, B, C, and D.

The unit shall have an output relay with double pole, double throw contacts rated at least 16 amperes at 120 volts AC, resistive load, and 24 volts DC. They shall operate on the AC supply voltage indicated on the Plans.

They shall be Cutler-Hammer, BW Series, or equal.

160211 TIMERS

160211.01 GENERAL

Timers which require pins or other removable trip devices shall be provided with at least one pin or trip device for each possible time setting.

160211.10 RESET TIMERS AND REPEAT CYCLE TIMERS

Timers of this type shall be heavy-duty industrial timers as manufactured by Eagle, Paragon, or equal.

160211.20 TWENTY-FOUR HOUR TIMERS

Timers of this type shall be heavy-duty industrial timers as manufactured by Paragon, Tork, or equal.

160211.30 TIMING RELAYS

Timing relays shall be heavy-duty industrial 600-volt, 10-ampere as manufactured by Square D Company, Westinghouse, or equal.

160211.40 AREA LIGHTING CONTROL TIMERS

Timers for use with area lighting circuits shall be of the astronomic dial type and shall have a day-omitting device. These timers shall be General Electric, Paragon, or equal.

160212 ENCLOSURES

160212.01 GENERAL

This specification includes enclosures to house electrical controls, instruments, terminal blocks, etc. If not indicated otherwise they shall be NEMA 12 for indoor and NEMA 4X for outdoor installations.

160212.10 CONSTRUCTION - STEEL

Enclosures shall be from 14-gauge steel with seams that are continuously welded. Doors shall have full length piano hinges with the door removable by pulling the hinge pin. They shall be as manufactured by Hoffman, Fischer & Porter, or equal.

A rolled lip shall be provided around three sides of the door and around all sides of the enclosure opening. The gasket shall be attached with oil-resistant adhesive and held in place with steel retaining strips. Exterior hardware, such as clamps, screws, and hinge pins, shall be of stainless steel for outdoor installations. A hasp and staple shall be provided for padlocking. Each enclosure shall have a print pocket.

160212.11 FINISH - STEEL

Finish shall be white enamel interior, light grey enamel, ANSI 61 exterior, over phosphatized surfaces. Special finishes and colors shall be furnished for wet locations. Plans should be checked for special conditions.

160212.20 CONSTRUCTION - FIBERGLASS NEMA 4X

Enclosures shall consist of base and cover which shall be heavy-duty hot compression molded from fiberglass reinforced polyester compound containing not less than 25 percent fiberglass by weight. Transparent covers, where indicated, shall be polycarbonate. The enclosures shall be provided with cover hinges manufactured from nonmetallic materials. The cover latch system shall be nonmetallic.

The gasket system shall be of neoprene material cemented into a molded labyrinth on the cover.

The enclosures shall be NEMA 4X and shall be as manufactured by Crouse-Hinds, English Electric Corp., or equal.

160213.30 PANELBOARDS

160213.31 GENERAL

Dead-front panelboards, including lighting distribution and control panels, shall be furnished and installed as indicated on the Plans. All bus shall be copper. Mounting and type enclosures shall be as indicated on the Plans. Where not indicated, indoor enclosures shall be NEMA 12 and outdoor enclosures shall be NEMA 4. The minimum interrupting capacity of any device shall be 10,000 amperes.

160213.32 INTERIORS

Protective devices shall be such that they can be replaced without disturbing adjacent units. Wire connectors shall be suitable for wire sizes indicated. Branch circuits shall be numbered as indicated on the Plans and a complete typed circuit schedule shall be furnished under a transparent cover and affixed to the panel. Phase busing shall be full height without reduction. Full size neutral bars shall be included and shall have suitable lug for each outgoing circuit requiring neutral connection. Spaces for future protective devices provided in lighting panels shall be bused for the maximum device that can be fitted into them.

160213.33 ENCLOSURES

Panelboards shall be finished with a primer, rust-resistant phosphate undercoat and two coats of oven-baked enamel with finish color to be accepted by the Engineer. They shall have sufficient size to provide a minimum of 4 inches of gutter space on all sides. Doors shall be such that they:

- A. In making switching devices accessible, shall not uncover any live parts;
- B. Are hinged and have latches that require no tool to operate; and
- C. Can be locked. Lock and two keys shall be furnished.
- D. On door inside pocked to hold typed circuit directory.

160213.34 IDENTIFICATION

Each panelboard shall have, on the outside of the door, a lamicoïd nameplate with 3/4-inch letters as specified elsewhere in these Contract Documents.

Panelboards shall be as manufactured by Westinghouse, General Electric, or equal.

160215 THERMOSTATS

Thermostats shall be heavy-duty thermostats with full load rating of 120-volt, 16-amp, and shall be Honeywell T6051 Series, Rockwell, or equal.

160217 ALARM HORNS, BUZZERS AND BEACON LIGHTS

160218 TERMINAL BLOCKS

Terminal blocks shall be 600 V rated Square D Company, Buchanan, or equal. Terminal blocks shall be of the size required for conductors therein and a minimum of 50 percent spares shall be provided in each terminal box.

160219 DISCONNECT SWITCHES

Disconnect switches shall be heavy-duty safety switches with a quick-make, quick-break operating mechanism, full cover interlock and indicator handle. The disconnect switches shall be furnished with fuses of the size indicated on the Plans. One set of spare fuses shall be furnished for each fused disconnect switch.

Disconnect switches shall be as manufactured by Square D, Westinghouse, or equal.

160220 PHOTO ELECTRIC CELL UNIT

The photo electric cell unit shall be used for automatic control of lighting fixtures as noted on the Plans. The photo electric cell unit shall be in weatherproof enclosure and shall be suitable for 120V AC control circuit with 30A rated contact for switching lighting circuit. The photo electric cell unit shall be as manufactured by General Electric, Paragon equivalent or equal.

160300 ELECTRICAL METERING AND RELAYING

160300.01 GENERAL

Instruments, relays, and other devices for panels shall be flush or semiflush mounted with cases of similar design.

Instruments shall have antiglare glass fronts, antiparallax scales, and white faces with black numerals and markings. Instruments shall be selected with the full-load reading at approximately 75 percent of full scale, unless otherwise specified or accepted. Accuracy of instruments shall be one percent of full scale values. Transformer accuracies shall be suitable for relays and meters.

160300.10 POTENTIAL TRANSFORMERS

Potential transformers shall be indoor, dry type, single phase, 60 Hertz, with 120-volt secondary and rated as required for the equipment furnished. They shall be furnished with current limiting fused disconnects. They shall be equipped with resistors as required to limit the fault current to a value which the fuse is able to interrupt without damage.

Medium voltage potential transformers shall be mounted on a carriage in a separate compartment within the stationary structure. It shall be arranged so that the carriage must be withdrawn to permit access and the withdrawal shall, through a self-aligning, multipole connector with silver to silver contact surfaces, disconnect the primaries and secondaries and automatically connect the primaries to ground potential.

160300.20 CURRENT TRANSFORMERS

Current transformers shall be indoor, dry type insulated for the voltage for which it is used and rated as required for the equipment furnished. They shall have sufficient thermal and mechanical capacity to withstand the maximum momentary current rating of the associated circuit breaker.

161100 CIRCUIT BREAKERS - LOW VOLTAGE

161100.01 GENERAL

All circuit breaker frame and trip ratings shall be as indicated on the Plans, except that they shall be coordinated with the ratings of the equipment actually furnished and shall be modified where necessary to suit this equipment. Circuit breakers to be used in motor control centers shall be as indicated on the Plans. Where no indication of type is given on the Plans, the following shall govern:

Circuit breakers protecting motors rated 7.5-horsepower or less shall be motor circuit protectors, all other circuit breakers shall be molded case circuit breakers.

Circuit breakers shall be as manufactured by Westinghouse, General Electric, or equal.

161100.10 MOLDED-CASE CIRCUIT BREAKERS

Circuit breakers for mounting in motor control centers or for separate mounting shall be of the air-break type, quick-make and quick-break, 600-volt, with number of poles as indicated on the Plans. The minimum frame size shall be 100 amperes.

Each pole of these breakers shall provide inverse time delay and instantaneous circuit protection.

The breakers shall be operated by a handle and shall have a quick-make, quick-break switching mechanism that is mechanically trip free from the handle so that the contacts cannot be held closed against short circuits and abnormal currents. Tripping due to overload or short circuit shall be clearly indicated by the handle automatically assuming a position between the manual ON and OFF positions. All latch surfaces shall be ground and polished. All poles shall be so constructed that they open, close and trip simultaneously.

Breakers must be completely enclosed in a molded case. Noninterchangeable trip breakers shall have their covers sealed; interchangeable trip breakers shall have the trip unit sealed to prevent tampering. Ampere ratings shall be clearly visible. Contacts shall be of nonwelding silver alloy. Arc extinction must be accomplished by means of arc chutes.

The minimum interrupting ratings of the circuit breakers shall be at least equal to the available short circuit at the line terminals.

Circuit breakers shall conform to the applicable requirements of NEMA Standards Publication No. ABL.

Circuit breaker ratings, modifications, etc. shall be as indicated on the Plans.

Molded case circuit breakers shall be ambient compensating that provides inverse time delay overload and instantaneous short circuit protection by means of a thermal magnetic element. Compensation shall be accomplished by a secondary bimetal that will allow the breaker to carry rated current between 25 degrees C and 50 degrees C with tripping characteristics that are approximately the same throughout this temperature range.

On breakers with interchangeable, thermal, adjustable magnetic trip, the accessibility and position of the adjustment knob shall not be changed from those on the standard breaker.

161100.20 MOTOR CIRCUIT PROTECTORS

Electrical circuits shall be protected by motor circuit protectors (MCP) as manufactured by Westinghouse Electric Corporation, General Electric, or equal.

The MCP shall be operated by a handle and shall have a quick-make, quick-break switching mechanism that is mechanically trip free from the handle so that the contacts cannot be held closed against short circuits and abnormal currents. Tripping shall be clearly indicated by the handle automatically assuming a position between the manual ON and OFF positions. All latch surfaces shall be ground and polished. All poles shall be so constructed that they open, close, and trip simultaneously.

MCP's must be completely enclosed in a molded case. MCP's shall have the trip unit sealed to prevent tampering. Ampere ratings shall be clearly visible. Contacts shall be of nonwelding silver alloy. Arc extinction must be accomplished by means of arc chutes.

Each pole of these MCP's shall provide instantaneous short circuit protection by means of a single adjustable magnetic only element. The single adjustment screw shall adjust all poles simultaneously.

Provision shall be furnished in the MCP for locking the maximum achievable trip setting to values less than maximum obtainable trip setting. Each adjustment shall have eight main setting points and mid-setting points following a linear scale so that each point has a significant value within calibration tolerances.

MCP's shall be suitable for use with current limiters, having 100,000 ampere interrupting capacity and a built-in trip indicator, that are fully coordinated with the MCP so that the MCP will open all three phases if the limiter operates. Current limiters shall be so constructed that they can only be replaced by an identical or similar limiter having the same interrupting capacity.

The minimum interrupting ratings of the MCP shall be at least equal to the available short circuit at the line terminals.

MCP ratings, modifications, etc., shall be as indicated on the Plans.

161100.40 MODULAR OVERLOAD RELAYS

Where called for on the Plans, modular overload relays shall be provided with the motor starters. The modular overload relays shall be 3-pole solid state devices set by one plug-in heater and shall protect all three phases of the motor in ambient temperatures ranging from -20 degrees to +70 degrees C.

The jam modules shall plug in the modular overload relays and shall provide for instantaneous trip of the overload relay should the current exceed a preset value at any time after the motor has accelerated. The modules shall be adjustable to any value between 150 percent and 400 percent of the motor full-load current.

The underload modules shall plug in the MOR and shall provide for overload relay trip whenever the current falls below a set value after the motor has accelerated. The modules shall be adjustable between 50 percent and 90 percent of the full load value of the motor full load current.

Each module shall provide individual trip indication and reset for each trip condition, visible without opening the motor control center compartment door. Each module shall provide an auxiliary contact for remote trip indication.

All solid state circuits shall be completely protected from damage arising from line transients and voltage spikes.

They shall be as manufactured by Westinghouse, Square D Company, or equal.

161200 MOTOR CONTROL - LOW VOLTAGE

161200.01 GENERAL

Starters Size 2 and larger shall have arc quenchers on all load breaking contacts. Starters shall be suitable for the horsepower ratings specified, except the Contractor shall verify the motor ratings and coordinate the starter and overload trip ratings with the actual horsepower ratings of the motors installed. Extended overload reset buttons shall be mounted so as to be accessible for operation without opening the door of the enclosure.

Magnetic contactors shall be factory adjusted and shall be chatter free. Magnetic contactors shall have bimetallic type overload relays in each line conductor as indicated on the Plans.

Starters shall be furnished complete with a 120-volt control transformer unless otherwise noted.

Where above normal ambient temperatures are anticipated, circuit breaker trip elements and starter overload trip elements shall be supplied to meet such conditions and shall be acceptable to the Engineer.

Control fuses shall be furnished where indicated in the schematics.

The magnetic contactors shall not be smaller than the size indicated on the Plans. Starters shall be sized to handle motors furnished even if motors should be larger than indicated on the Plans.

The minimum size starter shall be NEMA Size 1.

161200.10 MANUAL STARTERS

Manual starters as indicated on the Plans shall be across-the-line manual motor starters for motors up to one Hp, 600V having the electrical characteristics indicated on the Plans.

Manual starters shall have: Enclosures as indicated on the Plans, handles that clearly indicate the ON, OFF with lockout, and TRIPPED positions, pilot light, and positive, quick-make, quick-break mechanisms.

The manual starters shall be Square D, Westinghouse Electric Corporation, or equal.

161210.20 MAGNETIC STARTERS

161210.21 FULL VOLTAGE

Across-the-line full voltage magnetic starters for up to 600V shall have electrical characteristics indicated on the Plans.

Magnetic starters shall have: NEMA 12 enclosures unless otherwise noted; positive, quick-make, quick-break mechanisms; padlockable enclosure doors; three overload relays ± 15 percent adjustment from nominal heater rating on the overload relay; cover mounted reset button; and at least three reversible contacts in addition to the hold-in contact.

Magnetic starters shall be built in accordance with the latest NEMA Standards and shall be manufactured by Westinghouse Electric Corporation, General Electric, or equal.

166010 VARIABLE FREQUENCY DRIVES

This specification covers the minimum acceptable requirements for the design engineering, manufacturing and supplying of the Variable Frequency Drive System specified.

The equipment and materials supplied shall be new, unused and shall be standard products of an established manufacturer who has produced, and has in operation, the type of equipment being supplied for at least five (5) years.

The equipment will be located in a building at an elevation of approximately 5000 feet above sea level.

The Variable Frequency Drive System shall consist of two units mounted in the MCC as shown on the plans. Each VFD unit shall be in separate compartments. The VFD shall have a minimum MTBF (mean time between failure) rating of 100,000 hours.

166010.10 CODES AND STANDARDS

Equipment and material supplied to meet this specification shall meet the requirements listed in this specification and shall conform to the latest applicable standard of the following:

IEEE – Institute of Electrical and Electronic Engineers (including Harmonic Standard IEEE-519 – 1992)

NEC – National Electrical Code

NEMA – National Electrical Manufacturers Association

The complete package unit being supplied shall be listed and carry the label of at least one of the following:

UL – Underwriters Laboratory

ETL – ETL Testing Laboratories

The manufacturer shall supply a VFD System that shall meet the requirements as specified in this specification.

The manufacturer shall verify compatibility of the proposed VFD system with the pump motors being furnished.

Each unit shall have an engraved label on the door showing the respective pump being powered by the VFD.

The system shall be supplied complete and prewired.

The manufacturer shall supply 10 copies of an Operation and Maintenance manual consisting of catalog sheets showing actual components and parts numbers. Manual shall also show test certificates, warranty and service personnel responsible for warranty.

Manufacturer shall supply a minimum of one day of eight (8) hours of on-site VFD System and start-up service. This 8 hour period does not include the 4 hours required training noted in Section 160210.17.

166010.11 CONSTRUCTION

The Variable Frequency Drive units and components shall be assembled in pull out sections in the MCC as shown on the drawings.

The Variable Frequency Drive inverter shall be altitude compensated and sized for the elevation at which the unit will be installed, as previously listed. The inverter shall operate in an ambient temperature of -10 degree C to 50 degree C and a humidity of 0 to 90 percent noncondensing.

Door mounted operator devices shall be industrial oil tight similar to those found on motor control centers.

All control power for operator devices and customer connections shall be 120 volts. The control power transformer shall be a "Machine Tool" type and have both primary and secondary fusing.

166010.12 STANDARD FEATURES

The following features shall be standard on all VFD units specified:

The VFD unit shall be solid state pulse-wide modulation (PWM) type. The amperage rating shall be equal to or greater than the full load amps of the motor connected to the VFD unit. The VFDs shall employ Isolated Gate Bipolar Transistor (IGBT) technology.

The units shall operate on:

Input Voltage 460 VAC +/- 15%
Input Frequency 60 Hz +/- 5%

The drive shall contain an output frequency clamp such that minimum or maximum output frequency can be set at desired limits.

Rated overload current shall be 150 percent for one minute.

The drive must meet the requirements for Radio Frequency Interference (RFI) above 7 MHz as specified by FCC regulations, part 15, subpart J, Class A devices.

In compliance with IEEE 519, the Total Harmonic Distortion for the drive shall be no greater than 5%. When the THD is above 5% the supplier of the drive shall provide a dc bus choke or line reactors to ensure compliance.

The VFD Unit shall have an adjustable acceleration/deceleration time setting from 1 second to 120 seconds.

The VFD Unit shall maintain a 95% or better displacement power factor on the entire speed range.

The following front mounted operator controls shall be provided as a minimum:

1. Local/Off/Remote Switch
2. Power Light
3. Run Light
4. Fail Light
5. Stop Pushbutton
6. Start Pushbutton
7. Programmer Module with Key Pads Digital Display
8. Elapset Time Meter
9. Kilowatt Meter

The following functions of the programmer module as a minimum shall be:

1. Failure Indication
2. Failure Codes
3. Output Speed
4. Output Voltage
5. Output Frequency
6. Speed Control for Local Operation

The Inverter shall have a minimum of the following protective features:

1. Overcurrent Shut-off
2. Regenerative Overvoltage
3. Electronic Thermal Protector
4. Heatsink Overheat
5. Instantaneous Power Failure
6. Ground Fault

The following termination points shall be provided on terminal strip for field connections:

1. Power Failure Contact to the Surge Anticipator Valve.

2. Remote DCS Contacts as Shown on the Drawings
3. VFD Fault Contacts (N.C.) for Remote Indication
4. Input for Electronic Signal (4-20 mA D>C> control signal)
5. Remote VFD on Indication (N.O.)
6. Communication links with the RTU & PLC.

Auto Restart shall be initiated by means of an automatic time delayed restart after recovering from undervoltage or loss of power. The Inverter shall not automatically restart after overcurrent, overvoltage, overtemperature, or any other damaging conditions but shall require a manual restart.

166010.13 OPTIONS

The following options shall be provided:

The VFD shall be furnished with two VFD failure output contacts.

Output a 4-20 ma DC signal for remote indication of VFD output speed.

The drive shall be supplied with a frequency jump control to avoid operating at a point of resonance with the natural frequency of the machine.

Manual Bypass shall be provided and bypass components shall be mounted inside a common enclosure, fully pre-wired, and ready for installation as a single UL listed device. Bypass shall include the following.

1. Input, output, and bypass contractors, to disconnect power to the drive when the motor is running in the bypass mode.
2. 115 V.A.C. control transformer, with fused primary.
3. Thermal overload relay, to protect the motor while operating in the bypass mode.
4. Circuit breaker/disconnect switch, with a "through-the-door" handle mechanism.
5. Control and safety circuit terminal slip.
6. "Drive-Off-Bypass" selector switch.
7. Pilot lights for "Power On" and "Fault".
8. "Normal/Test" selector switch, to allow testing and adjustment of the drive, while the motor is running in the bypass mode.
9. "Auto/Manual" selector switch, to provide convenient switching between "manual" and "auto" modes.

Manufacturers of VFD equipment shall meet the following requirements:

Manufacturers of VFD Systems must be in the primary business of supplying Variable Frequency Drives and have a minimum of five (5) years of service in that business and must have regional service center with factory spare parts inventory and factory authorized service technician on call 24 hours per day.

After the VFD units are installed, supplier shall take harmonic voltage and current distortion readings and supply actual strip chart recording the same in owner manual. Notify Engineer prior to scheduling test to arrange Engineer witness at his/her option.

VFD units supplied shall be labeled by UL, CSA, or ETL. Note, the entire shall carry the label, not just a component.

The VFD units shall be as manufactured by:

- a) Allen Bradley
- b) Mitsubishi VTP 300F Series
- c) Toshiba
- d) Magnetek
- e) Or equal

And shall meet all of the requirements of this specification.

166010.15 TESTING

Prior to shipping, each unit shall be tested and certified test report shall be supplied with each unit. The engineer shall be advised of testing schedule and at his option witness any or all tests. Standard tests will include:

Visual inspection; consisting of checking unit enclosure, wiring, connections, fasteners, covers and locking mechanism.

Motor run test.

Optional equipment; test optional equipment specified with VFD system.

Special tests; as required and specified.

All protective features.

166010.16 DRAWINGS/MANUALS

Manufacturer shall supply drawings of proposed system for Engineer's review prior to manufacture of the units. Drawings shall include, as a minimum:

- a. General arrangement of each unit showing size and incoming and outgoing conduit.
- b. Schematic
- c. Connection diagram, sufficient to install drive system.

The VFD system shall be supplied with four operations and maintenance manuals which include:

- a. Manufacturer information of equipment being supplied
- b. Connection information
- c. Start-up procedure
- d. Fault reset instruction
- e. Wiring diagrams (power and control)
- f. Parts list
- g. Test results

166010.17 START-UP

Manufacturer shall supply field start-up service by an authorize factory service representative consisting of system check-out, start-up and system run. The manufacturer shall provide warranty and authorized factory trained service technicians located within a 60 mile radius of the plant available for routine service calls during normal business hours. The VFD service technicians shall be full time employees of the VFD supplier, primarily engaged in VFD service work. Start-up sales representative is not acceptable.

166010.18 WARRANTY

The manufacturer shall supply a warranty of parts and labor for 1.5 years after delivery, or one year after acceptance by Owner, whichever occurs first.

166100 RUNNING TIME METERS

Running time meters shall be non-resettable and measure up to 99999.9 hours and shall draw less than 5 watts of 120 V 60 Hz. The digits shall be at least one quarter inch high. They shall be Cramer 635 Series, Simpson equivalent or equal.

*** END OF DIVISION 16 ***

DIVISION 17

INSTRUMENTATION

170000 GENERAL

170000.10 REQUIREMENTS

The Contractor shall furnish and install, ready for use, the complete control/instrumentation systems as indicated on the Plans and in each of these Contract Documents. These documents include descriptions of functional operation and performance, as well as standards, but do not necessarily enumerate detailed specifications for all components and devices which are necessary. However, all components and devices shall be furnished and installed as required to provide complete and operable systems for accomplishing the functions and meeting the performance set forth hereinafter. Each control/instrumentation system specified shall be separate and distinct and shall be the responsibility of a single manufacturer for the design, construction and furnishing of the desired control hardware, mechanical drawings, interconnection drawings, control piping layout drawings, control conduit layout drawings, internal drawings, installation and start-up supervision and/or calibration of the control equipment. The responsible manufacturer as described in the preceding sentence shall hereinafter be referred to as the "primary manufacturer" and shall bear the responsibility for furnishing a fully complete system operating in a satisfactory manner.

In addition to this Division of the Specifications, the Work shall conform to the applicable requirements of the other Divisions of the Contract Documents including the following Divisions:

- Division 1 - Special Conditions
- Division 5 - Metals
- Division 6 - Wood and Plastic
- Division 9 - Finishes
- Division 14 - Mechanical Equipment
- Division 15 - Piping
- Division 16 - Electrical

The control/instrumentation systems shall be furnished and installed by the Contractor complete and ready to operate, including all necessary interconnections and connections to sources of electrical power, air, water, drains and vents, with all required valves, switches and accessories as specified or as recommended for best operation by the manufacturer of the equipment furnished. All necessary mounting panels, stands, hangers and brackets shall be furnished and installed and shall comply with the relevant sections of these Contract Documents. In general, overall system accuracy shall be within plus or minus three percent of the actual process parameter being controlled (flow, temperature, etc.), unless otherwise specified.

Where two or more manufacturers are concerned in furnishing equipment for a single-control/instrumentation system, Contractor shall supply the primary manufacturer with such information and drawings from other manufacturers as are needed to fit their equipment into the control or instrumentation system or panels. All equipment with interconnects shall be shown together on one coordinated drawing. All equipment system design proposed to be furnished shall be coordinated and submittals for the equipment shall be bound in book or booklet form before the equipment will be evaluated for acceptance.

The Contractor shall include in his bid allowance for factory-trained service personnel, other than sales representatives, to supervise installation of and to adjust all the control and instrumentation equipment until this equipment has been field-tested by the Contractor and the results of these tests have been reviewed by the Engineer. In addition, factory bench-test data shall be submitted to show that the manufacturer's proposed equipment has been tested in the specified arrangement and found to achieve specified accuracy. The Contractor shall also include in his bid for training of personnel in the operation and maintenance of the furnished control systems. Training shall include at least eight four hour sessions for two designated employees. Training shall include hands-on instructions and equipment operations.

The following drawings shall be submitted to and returned reviewed before fabrication is started:

- A. Layout drawings of system showing wiring, piping, valves, switches, and control units in schematic form. This includes individual loop drawings and total integrated system drawings.
- B. Shop drawings of panels or enclosures showing size, arrangement, color, and nameplates.
- C. Bill of material and catalog data on all equipment, wiring, conduit, tubing, and such other accessories as are needed to properly operate the control/instrumentation system.
- D. Wiring diagrams of all electrical work including conduits and piping diagrams of pneumatic/hydraulic systems.

Upon acceptance, Contractor shall submit three sets of "as-built" drawings of the control/instrumentation systems. Also, instruction manuals, installation, operation and maintenance instructions shall be submitted in triplicate for each item, instrument, etc., prior to installation.

The Contractor and suppliers are cautioned regarding the review and compliance with the total Contract Documents. Typical examples are control relays, timers, enclosures, and nameplates. These particular items are sometimes furnished and installed by an instrument supplier; however, they are specified in DIVISION 16 of these Contract Documents.

All work covered under this Division shall comply with the Instrument Society of America (ISA) Standards and Practices for Instrumentation.

170000.15 WORK INCLUDED

- A. Furnish and install new instrumentation specified under this Division.
- B. Install and/or connect instrumentation furnished under other Division.
- C. Testing of instrumentation and control system.

170000.20 CONTROL AND INSTRUMENTATION DEVICES

Control mechanisms shall be standard devices constructed of corrosion-resistant materials, enclosed in a dustproof case and mounted as specified in the individual application. Instruments to be mounted outdoors

or in basements shall be in weatherproof cases. Corrosion resistant cases shall be furnished where indicated. Cases shall be finished in manufacturer's standard colors except as otherwise specified. All instrument wires or cables shall be enclosed and not exposed or within reach of the public.

Each meter, indicator, totalizer, controller, recorder or other device shall have an identifying engraved lamicoïd nameplate. This includes all primary elements, such as flow meters. The nameplate shall be mounted on the case so that it will identify the equipment as specified on the drawings. Brass or stainless steel mounting screws shall be used. The nameplate shall be typical for all transmitters, pressure gauges, control stations, valves, actuators, etc.

Engineering unit shall be provided for all scales (0 to 100% shall not be acceptable). For 2 wire transmitters specified, the receiving end shall be provided with a DC power supply with 120V input as required.

Each receiver and each transmitter shall have an individual cutout, switch and/or fuse to disconnect the receiver from all sources of electricity, including both power and signal sources.

Straightening vanes or other required accessories shall be furnished and installed if necessary to meet the accuracy requirements in these Contract Documents.

17000.24 DEVICE AND SIGNAL IDENTIFICATION

All field mounted devices, such as meters, gauges, pumps, valves, controllers, and other equipment, shall be identified with a permanently affixed, embossed stainless steel tag. Characters shall be at least 3/8 inch high and markings shall include a tag number, device or equipment name, and circuit number (where applicable). Tags shall be attached to devices with stainless steel tie wires. The tags shall be compatible with tag description listing for record documents drawings as noted on the Plans.

At all devices, terminal blocks, splices, etc. all wiring and terminals shall be identified with circuit identification markers as described in Section 160112 of these Specifications. This identification shall include a signal tag number and polarity (where applicable). All instrumentation cables shall be tagged at both ends and at any intermediate pullboxes or manholes in which the instrumentation cables are routed through. Tagging requirements shall also apply to all internal and external wiring of all instruments, and control panels.

17000.25 TESTING

All control/instrumentation shall be factory tested and calibrated. Factory test/calibration records shall be submitted to show that the equipment has achieved the specified performance and accuracy. The Contractor shall field test and calibrate all control/instrumentation in accordance with the manufacturer's instructions. Field test/calibration data sheets shall be submitted to show that the equipment has achieved the specified performance and accuracy. Test equipment shall have an accuracy three times better than that of the device under test. Analog devices shall be tested at five point over the full range.

The Contractor shall conduct loop/system acceptance tests proving loop/system integrity and accuracy. Acceptance tests shall be witnessed by the City engineer and data sheets shall be submitted. Unless otherwise specified or listed as an exception in the bed, overall loop/system accuracy (not repeatability, not resolution) shall be within ± 3 percent of the measured/controlled process variable. Where equipment or

systems fails to meet the manufacturer's specified performance and accuracy, the Contractor shall provide the services of the manufacturer's field service engineer.

170000.27 TRAINING

The Contractor shall also include in his bid for training of personnel in operation and maintenance of the furnished control systems. Training shall comprise sessions 32 hours for general instrumentation and control systems. A submittal detailing the proposed training program shall be subject to review by the City.

170000.30 INTERCOMPONENT WIRING AND TUBING

Intercomponent wiring shall be run in conduit. Minimum permissible signal wiring insulation voltage is 600 volts, with the exception of special cable as required by the manufacturer and accepted by the Engineer.

Pneumatic systems control tubing and fittings internally used for panels fabrication and externally used for interconnection of components shall be (1/4-inch OD) stainless steel. All tubing and fittings shall be designed and installed for a minimum of 150 psi.

170001.10 INSTRUMENTATION CLASS CABLE

Instrument cable shall have the number of twisted pairs indicated on the Plans and shall be insulated for not less than 600 volts. Unless otherwise indicated, conductor size shall be No. 18 AWG minimum.

The jacket shall be flame retardant Flamenal or Okoseal, 90 degrees C temperature rating. The cable shield shall be a minimum of 2.3 mil aluminum or copper tape overlapped to provide 100 percent coverage and a tinned copper drain wire.

The conductors shall be bare soft annealed copper, Class B, 7-strand minimum concentric lay with Okoseal or Vulkene, 15-mil nominal thickness, nylon jacket, 4-mil nominal thickness, 90-degree-C temperature rating. One conductor within each pair shall be numerically identified.

Pairs shall be assembled with a nominal 2-inch lay and shall then be group shielded with a minimum of 1.3-mil aluminum or copper tape overlapped to provide 100 percent coverage. All group shields shall be completely isolated from each other.

Instrumentation cables shall be installed in separate raceways. This includes through manholes. Instrumentation cable shall be continuous between instruments or between field devices and instrument enclosures. There shall be no intermediate splices or terminal boards.

The instrumentation cable shall be Type TC as manufactured by Okonite, Okoseal - N SP-OS, Belden equivalent, or equal.

170002.10 TERMINATIONS AND SPLICES (600 VOLT AND LESS)

Terminations shall be terminal board type with set-screw pressure connectors. Splicing shall join conductors mechanically and electrically to provide a complete circuit prior to installation of insulation. Conductors, including grounding conductors, of different sizes shall be spliced and then soldered or welded. Splices in

wet locations and all splices below grade shall be waterproof heat shrink type as manufactured by Elastimold, Thomas-Betts, or equal.

170003.10 CONDUIT

Conduit shall be as shown on the Plans and as specified in DIVISION 16.

170010 PRIMARY ELEMENTS

170010.10 GENERAL

Primary elements shall be complete and ready for operation. Elements consisting of more than one unit, such as sensor, signal converter, and transmitter, shall include all conductors and conduit furnished and installed to interconnect each component.

170011.21 SOLID STATE RELAYS

The solid state relays shall be of the silicone controlled rectifier type. The self-contained unit shall be for use in controlling liquids having a low specific resistance.

The relays shall be dual voltage, 120/240 volts AC, with silver cadmium oxide contacts rated at 10 amperes at 120 or 240 volts AC, or 28 volts DC. The load contacts shall be two double pole double throw, plus a single pole double throw holding contact. If more contacts are required, an auxiliary relay specified elsewhere shall be provided.

The relays shall be as manufactured by B/W, Warrick Company, or equal.

170011.22 INTRINSICALLY SAFE RELAYS

The intrinsically safe relay shall be Factory Mutual approved for use in Class 1, Divisions 1 and 2, Groups A, B, C, and D hazardous locations. It shall be equipped with a variable resistance potentiometer that permits field adjustment of sensitivity.

The relays shall be dual voltage 120/240 volt AC with contacts rated at 25 amperes at 120 or 240 volts AC or 24 volts DC. The contacts shall be double pole double throw. If more contacts are required, an auxiliary relay specified elsewhere shall be provided.

The relays shall be as manufactured by B/W, Warrick Company, or equal.

170012.10 MAGNETIC FLOW SENSORS

Magnetic flow sensors shall be installed as required, complete with associated instrumentation, interfaces, cabling, and, as a minimum, shall consist of the following:

170012.12 SIGNAL CONVERTERS

The signal converter assemblies shall be mounted in NEMA 4X enclosures as indicated on the Plans. They shall have a 4-20 mA DC and pulse output to be used to totalize, indicate, and control.

Cable and conduit between flow meters and signal converters shall be furnished and installed. The size and type of cable and conduit shall be in accordance with the meter manufacturer's recommendations.

The signal converters shall be Fischer & Porter, Foxboro, or equal.

170200 SIGNAL CONVERTERS

170201.10 PRESSURE-TO-CURRENT TRANSDUCER

The pressure-to-current transducer shall produce a 4-20 mA DC output signal with a 3-15 psig input. Its accuracy shall be plus or minus 0.5 percent of span or better and its operating temperature range shall be from minus 20 degrees F to 180 degrees F. Its body shall be die-cast aluminum, with fully gasketed cover. Its wetted parts shall be stainless steel. It shall be of the two-wire design requiring no power supply in the field.

The pressure-to-current transducer shall be Fischer & Porter Type EP, Taylor, or equal.

170201.20 CURRENT-TO-CURRENT CONVERTER

Current-to-current converters shall provide electrical isolation between the input and output. Current-to-current converters shall be supplied where shown and wherever the circuit impedance exceeds the capability of a transmitter. The converter shall receive a 4-20 mA DC analog current input signal and produce an identical 4-20 mA DC output signal into a 0-1,000 ohm load. Accuracy shall be plus or minus 0.25 percent of span. The converter shall be provided with NEMA 12 enclosure suitable for back of panel mounting.

170306.10 SQUARE ROOT EXTRACTORS

Electronic square root extractors shall be provided as required. They shall be suitable to accept an input of 4-20 mA DC and shall be powered by 120 volts AC, 60 Hertz. They shall produce an output of 4-20 mA DC into a load of up to 500 ohms. Their calibrated accuracy shall be plus or minus 0.5 percent between 10 percent and 100 percent of full scale and plus or minus 0.2 percent full scale between 0 and 10 percent of full scale.

The connections shall be brought to a barrier type terminal board and the housing shall be a steel case with slide-out chassis.

They shall be Fischer & Porter, Foxboro, or equal.

170307.10 TOTALIZERS (GENERAL)

Totalizers shall be seven or more digit type, reading directly in the units required without the use of a multiplier, except for the addition of ciphers. If ciphers must be added, this shall be so indicated on a permanent lamicoid nameplate that is visible from the outside.

They shall be Fischer & Porter, Foxboro, or equal.

170307.11 TOTALIZERS (INTEGRATORS)

Electronic totalizers (integrators) shall be furnished and installed as required. They shall be suitable to accept an input of 4-20 mA DC and shall be powered by 120 volts AC, 60 Hertz. They shall be linear or square root type, as called for on the Plans or elsewhere in these Contract Documents. Their count rate shall be adjustable from 200 to 25,000 counts per hour and their output shall be displayed on an electro-mechanical counter. Their calibrated accuracy shall be as follows:

Linear plus or minus 0.5 percent of rate when operating above 10 percent full scale.

Square Root plus or minus 0.5 percent of rate when operating above 25 percent full scale.

The connections shall be brought to a barrier type terminal board and the housing shall be a steel case with slide-out chassis.

170307.12 TOTALIZERS (PULSE COUNTERS)

Totalizers (pulse count type) shall be of the same overall construction as the totalizers (integrators).

170312.10 ELECTRONIC 4-20 MA INDICATORS

Electronic indicators shall be provided as required for 4-20 mA process variable. Their input impedance shall be 5 ohms maximum, their accuracy plus or minus 2 percent and power requirements 120 volts AC, plus or minus 10 percent, 60 Hertz.

They shall be supplied with appropriate range and units of measurement to indicate actual conditions. Zero to 100 percent or 4-20 mA DC is not acceptable. A front mounted screw for zero adjust shall be provided.

Panel mounted indicators shall be flush mounted and other indicators shall be in NEMA 4 enclosures with the indicating dial fully exposed.

They shall be Fischer & Porter, Foxboro, or equal.

170312.11 DIGITAL ELECTRONIC 4-20MA DC INDICATORS

Digital indicators shall be provided as required for 4-20 mA DC input signal. They shall have 5 ohms impedance maximum with plus or minus 2 percent accuracy. Power input shall be 120 volt. They shall have five segment planner LED minimum or as required by process variable indication. They shall be Doric Scientific, Electro Industry, or equal.

170313.10 DIFFERENTIAL PRESSURE INDICATORS

Where the flow signal is not to be transmitted or totalized, and only a local flow indication is called for, a differential pressure gauge of the proper range to give a full-scale indication at maximum flow shall be supplied. The scale shall be of the square root type and calibrated in actual units of flow. Gauges shall be Dwyer, Ameter, or equal.

170314.10 SET POINT RELAYS

The set point relays shall be solid state device and shall provide a contact closure or opening output from a 4-20 mA current input upon reaching a preselected set point. The set point shall be continuously adjustable over the entire span. The dead band shall also be adjustable from at least 1 percent to 20 percent. The output relay shall be DPDT with contacts rated 5 amps at 120 volts AC resistive load. The output contacts shall be isolated. Power requirements shall be 120 volts AC, 60 Hertz.

The unit shall be housed in a general purpose, dead front, type housing.

The set point relays shall be AGM, Fischer & Porter Type 55PA, Foxboro 63 Series, or equal.

170405.10 CONTROL PANELS

Control panel(s), unless otherwise indicated, shall be vertical rack type with full length hinged doors to open as shown on the Plans. The panel dimensions shall be as indicated on the Plans and as required for the equipment furnished. Sufficient working space shall be provided around all installed equipment. The panels shall be formed of not less than 10-gauge cold-rolled steel. The framework shall be made of not less than 2-inch by 2-inch by 3/16-inch thick steel angle.

The control panels shall be furnished, designed, shop painted, assembled and wired, shop tested, field tested, and placed in satisfactory operation by the supplier and major manufacturer of the instrumentation equipment.

The panels shall be complete with instruments, meters, switches, controls, indicating lights, wires, wireways, grounding, nameplates, and all other accessories and appurtenances required for complete panels. The controls and components to be included on the panels are as shown.

The following drawings of each panel shall be supplied by the panel manufacturer for acceptance before fabrication:

- A. Panel front view showing equipment arrangement and dimensional information.
- B. Panel floor plan and side view showing dimensions, doors, and equipment layout inside the panel.
- C. Drawing showing structural details.
- D. Diagrams showing all external devices connected to the panel.
- E. Wiring diagrams.

F. Panel bill of material with detailed description of components.

Instruments shall be securely braced and secured by a supporting framework such that a minimum load is put on the panel face.

Joints shall be welded and ground smooth. All hardware shall be noncorrodible metal. All anchor bolts, nuts, and washers required for secure anchorage to steel channel bases shall be provided. Panel enclosures shall be shipped with nameplates mounted, and all equipment mounted and wired.

The exterior of the panels shall be selected by the Engineer and the interior shall be white. Both finishes shall be applied over bonderizing.

The fabrication of the enclosures shall be subject to the Engineer's acceptance. Proposed panel layouts are, in general, shown on the Plans; however, these shall be modified as required to facilitate equipment furnished. Enclosures shall be NEMA 1 gasketed or as indicated on the Plans.

All punching, reaming, cutting, and other fabricating work shall be done before the finish is applied. All electrical connections shall terminate at terminal strips, which shall be labeled with appropriate identifying data. All terminal strips shall be provided with a minimum of 25 percent spare terminals. Panels shall be delivered with all instruments and controls installed and completely wired and piped. Panels shall be shipped with complete wiring and piping diagrams and instructions to identify instrumentation inside the panel, as well as internal wiring and piping diagrams.

Each device requiring power or neutral connection shall be arranged so that when the wires are removed from any unit, no other shall be interfered with.

All electrical wiring within the panels shall be color coded, bundled, and bound with plastic strip lock straps and terminated on numbered terminal strips. All external connections shall be properly identified by function and number in accordance with ISA standards. Power to the panel shall be 120 volts, 60 Hertz, single phase. The panel shall be provided with a 20A 125V receptacle, a fluorescent fixture provided with wire guard and a switch.

If the instruments are series wired, only one receiver in the loop shall be grounded while the others shall accept a floating input. Also, current-to-current converters shall be provided as required for load boosting in order to accommodate the appropriate number of instruments. If the instruments are parallel wired, all receivers shall be referenced to the same common.

All signal connections for outgoing 4-20 mA DC signals shall be equipped with adequate signal retransmission devices. For parallel wired systems, voltage-to-current transducers shall be provided and shall be referenced to the same common as all other receiving instruments. For series wired systems, fully isolated current-to-current transducers shall be provided to maintain loop continuity and eliminate grounding problems.

All lights, instruments, push buttons, and other equipment mounted in or on the panels shall have engraved identification and function nameplates. The nameplates shall be black lamicoïd plastic with white letters and shall be fastened with round head brass screws. Equipment mounted inside the panels shall be labeled with identification which correlates with Plan identification.

***** END OF DIVISION 17 *****